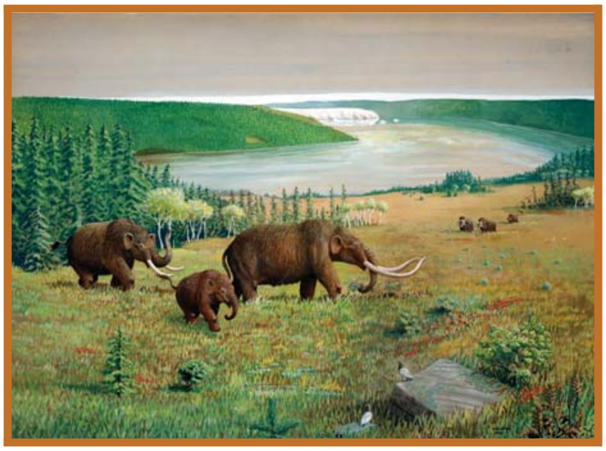

Mastodon Paleobiology, Taphonomy, and Paleoenvironment in the Late Pleistocene of New York State: Studies on the Hyde Park, Chemung, and North Java Sites

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WOOD MACROFOSSILS AND DENDROCHRONOLOGY OF THREE MASTODON SITES IN UPSTATE NEW YORK

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ABSTRACT

Arboreal macrofossils including wood, bark, twigs, and cones were found in three mastodon excavations located in Hyde Park, near Watkins Glen, and in North Java, New York. The oldest wood macrofossils at each site are spruce [*Picea* A. Dietrich (1824)]; their radiocarbon ages reflect the southeast to northwest retreat of the ice sheet and subsequent migration of spruce across New York State (12,548 ± 38 ^{14}C yr BP, Hyde Park; 12,365 ± 75 ^{14}C yr BP, Chemung/Watkins Glen; and 12,254 ± 44 ^{14}C yr BP, North Java). The dates are from 500 to 1,500 years earlier than their respective sites' mastodon and mammoth bone dates, and no wood other than digested twigs date contemporaneously with the bones. The tree-ring sequences of two single samples from the Hyde Park and Chemung sites plus two floating tree-ring chronologies from the North Java site cover over seven centuries of the Late Glacial period prior to the Younger Dryas, with the twigs extending into the Younger Dryas. The longest chronology is 427 yr in length and consists of 13 samples from eight trees. Two single samples of pine date to the Early Holocene and reflect the transition from a boreal to temperate climate regime. An increased variability in atmospheric radiocarbon content during the Late Glacial into the early Holocene is apparent in the variability over time of the radiocarbon dates used to wiggle-match each sequence to the IntCal04 and Cariaco Basin calibration curves. Possible effects of this variability on regional climate and tree-ring growth are discussed.

INTRODUCTION

In addition to bones, arboreal and other macrofossils were found in abundance during the excavations of three mastodon sites in New York State. The arboreal macrofossils represent the trees growing directly at each site in the late Pleistocene through Holocene Epochs, and the periods represented by the macrofossils indicate favorable climatic and environmental conditions for preservation. Twigs, branches, boles, and roots were found in addition to cones, needles, leaves, and bark. Samples of all sizes of macrofossils were collected and used to identify the species present at the sites over time. Wood samples with more than 50 rings were measured for dendrochronological analysis; a few were selected for radiocarbon dating. The results were analyzed to interpret the immediate environment and climate represented by the different assemblages of taxa and their tree-ring record at different time intervals. This paper concentrates on the macrofossils from the Late Glacial period at the end of the Pleistocene; the radiocarbon-dated dendrochronological samples are all from prior to the Younger Dryas. There is also a brief description of the macrofossils from the Holocene, reported in more detail by Griggs (2006); their analysis is still underway.

Chapter 5, in *Mastodon Paleobiology, Taphonomy, and Paleoenvironment in the Late Pleistocene of New York State: Studies on the Hyde Park, Chemung, and North Java Sites*, edited by Warren D. Allmon and Peter L. Nester, *Palaeontographica Americana*, 2008, (61): 49-61.

Tree-ring analysis of Late Glacial wood in eastern and central North America is currently limited to samples from around the Great Lakes (Panyushkina & Leavitt, 2004; Kaiser, 1994) and the samples analyzed in this study. For the Two Creeks Interstadial in the Great Lakes region (also prior to the Younger Dryas), wood was collected from tree stumps on what had been part of the ancestral lakebed. The lower lake level was probably due to the first drainage of the Great Lakes system to the northeast, around 12,000 ^{14}C yr BP; a higher level returned at the end of the Two Creeks Interstadial, killing the trees (Kaiser, 1994; Hansel *et al.*, 1985). In New York State, the three sites consist of one oxbow pond in a small floodplain of a tributary to the Hudson River and two kettle ponds, one on the Valley Heads moraine and the other on a kame east of ancestral Lake Erie.

The calibration of any Late Glacial radiocarbon age is dependent on the ongoing research that has improved the accuracy of the radiocarbon calibration for dates prior to 10,400 ^{14}C yr BP (Friedrich *et al.*, 2001; Hughen *et al.*, 2000, 2004a; Kromer *et al.*, 2004; Reimer *et al.*, 2004). In 1999, the calibration of radiocarbon dates older than 12,000 ^{14}C yr BP resulted in a calibrated date with a one-sigma error that was ten times greater than the ^{14}C error. This was due to the lack of terrestrial-based values for any age before 10,400 yr BP in the IntCal98 calibration curve. In 2000, the Cariaco calibration curve, based on marine foraminiferans found in varves in the Cariaco Basin, provided more calibrated dates older than

Table 1. The radiocarbon dates for wood samples from the three mastodon sites. CHE = Chemung; HDP = Hyde Park; NJV = North Java. The radiocarbon laboratories are the Heidelberg Laboratory (HD) and Beta Analytic, Inc. (Beta). All the radiocarbon dates are beta-decay dates. The reference numbers in the first column refer to the segments shown in the horizontal lines in Text-figs 4A-D. The "Begins" and "Ends" are the range of rings of the segment relative to the number of rings in that sample. "1" is the first ring measured, "2" is the second, and so on. Ring measurements always start from the first complete inner ring and go outward. (*Table continues on facing page*)

Ref No.	Lab and Analysis No	Site-Sample No.	Genus	Material Dated	First ring	Last ring	^{14}C Age	$\Delta^{13}C$
Chemung (CHE)								
C1	Hd-20780	NY-CHE-17	*Picea*	Root	11	20	12,269 ± 66	-27.10
C2	Hd-20795	NY-CHE-17	*Picea*	Root	41	60	12,365 ± 75	-27.60
	Beta-176929	NY-CHE	*Mammuthus*	Bone			10,890 ± 50	NA
	Beta-176930	NY-CHE	*Mammut*	Bone			10,840 ± 60	NA
	Hd-26603	NY-CHE-11N	*Picea/Larix*	Twigs			10,758 ± 25	-25.64
	Hd-21416	NY-CHE-3A	*Pinus*	Bole	84	103	8,028 ± 60	-24.23
	Hd-21418	NY-CHE-21	*Tsuga*	Branch	25	44	7,388 ± 51	-25.38
	Hd-21413	NY-CHE-19	*Ulmus*	Bole	1	20	6,729 ± 40	-25.96
	Hd-21420	NY-CHE-18	*Quercus*	Bole	68	77	5,993 ± 56	-26.78
	Hd-20752	NY-CHE-1	*Quercus*	Bole	81	90	1,929 ± 30	-26.34
	Hd-20754	NY-CHE-1	*Quercus*	Bole	268	277	1,726 ± 24	-24.83
	Hd-21396	NY-CHE-24	*Tsuga*	Branch	21	40	1,059 ± 24	-25.02
	Hd-21414	NY-CHE-20	*Tsuga*	Branch	61	95	635 ± 28	-26.07
Hyde Park (HDP)								
H1	Hd-22687	NY-HDP-1	*Picea*	Bole	1	20	12,416 ± 33	-24.91
H2	Beta-168585	NY-HDP-1	*Picea*	Bole	36	45	12,230 ± 80	-24.60
H3	Hd-22395	NY-HDP-1	*Picea*	Bole	71	105	12,548 ± 38	-24.98
H4	Hd-22583	NY-HDP-1	*Picea*	Bole	76	85	12,416 ± 31	-25.15
H5	Hd-22595	NY-HDP-1	*Picea*	Bole	86	110	12,396 ± 53	-24.92
	Beta-141061	NY-HDP	*Mammut*	Bone			11,480 ± 50	NA
North Java (NJV)								
NI1	Hd-22780	NY-NJV-39	*Picea*	Bole	100	138	12,254 ± 60	-25.94
NI2	Hd-22596	NY-NJV-G24	*Larix*	Bole	52	61	12,064 ± 44	-24.23
NI3	Hd-22585	NY-NJV-19	*Picea*	Bole	41	50	12,092 ± 32	-25.09
NI4	Hd-24121	NY-NJV-19	*Picea*	Bole	51	60	12,049 ± 27	-25.15
NI5	Hd-24123	NY-NJV-G24	*Larix*	Bole	82	106	11,966 ± 25	-23.87
NI6	Hd-24122	NY-NJV-19	*Picea*	Bole	61	70	12,056 ± 29	-25.33
NI7	Beta-168586	NY-NJV-G21	*Picea*	Bole	11	40	11,970 ± 80	-25.40
NI8	Hd-25622	NY-NJV-19	*Picea*	Bole	96	110	11,969 ± 30	-25.20
NI9	Hd-23065	NY-NJV-G21	*Picea*	Bole	21	30	11,902 ± 51	-25.81
NI10	Hd-24119	NY-NJV-G21	*Picea*	Bole	41	60	11,969 ± 19	-25.75

NI11	Hd-22597	NY-NJV-G21	*Picea*	Bole	71	115	12,046 ± 74	-25.38
NI12	Hd-22782	NY-NJV-F17	*Picea*	Bole	2	30	12,030 ± 45	-24.15
	Beta-176928	NY-NJV	*Mammut*	Bone			11,630 ± 60	NA
NII1	Hd-22598	NY-NJV-F15	*Picea*	Bole	51	60	11,328 ± 61	-25.49
NII2	Hd-22586	NY-NJV-F15	*Picea*	Bole	71	80	11,296 ± 44	-24.87
	Hd-22775	NY-NJV-F36	*Pinus*	Bole	pith	9	9,509 ± 29	-26.73
	Hd-22772	NY-NJV-F36	*Pinus*	Bole	110	119	9,367 ± 23	-24.15

10,400 ^{14}C yr BP, and was adjusted for the differences between terrestrial and marine ^{14}C with the 420-yr reservoir value established for the Holocene (Hughen *et al.*, 2000, 2004a, b). For the Late Glacial and into the first millennium of the Early Holocene, it has been shown that there was significantly more variability in atmospheric and oceanic radiocarbon content, caused by production changes and fluctuations in the upwelling of ^{14}C-depleted bottom water (Friedrich *et al.*, 2001; Kromer, 2004; Muscheler *et al.*, 2004; Text-fig. 3). The large fluctuations in the upwelling were probably caused by variations in the water mass structure of the North Atlantic (Broecker, 1998; Björck *et al.*, 1996, 1998; Hughen *et al.*, 2004a; Reimer *et al.*, 2004). Our radiocarbon dates are reported here in radiocarbon age because the research is still in progress, but the current calibrated values, relative to AD 1950, are indicated in the figures. Holocene dates are given in both radiocarbon and calibrated years.

METHODS

Genus and Species Identification

For the identification of genus and species, the keys by Harlow *et al.* (1979) and Core *et al.* (1979) were used. Species of spruce, pine, and oak (*Picea*, *Pinus*, and *Quercus* spp.) are difficult to identify without their respective bark, needles, leaves, cones, or seeds. Inferences were made in a few cases from associated material and the pollen records from around the region (Webb *et al.,* 1993). Samples are housed at the Tree-Ring Laboratory at Cornell University, Ithaca, New York.

Dendrochronology

The samples of wood with adequate ring count were each prepared by cutting a cross section, then surfacing the section with a razor blade. Ring widths were measured twice, compared, and for differences of greater than 3% of the lower value, the widths were remeasured for reconciliation. Sample measurements were detrended by fitting an appropriate curve to the time series and dividing each measurement by the value of the curve in the corresponding year (Cook & Kairiukstis, 1990; Griggs, 2006; Text-fig. 4.2). Samples of the same taxon were crossdated by visually and statistically matching the patterns in two or more detrended time series with the CORINA software (Fritts, 1976; Cook & Kairiukstis, 1990; software available at http://dendro.cornell.edu/corina/).

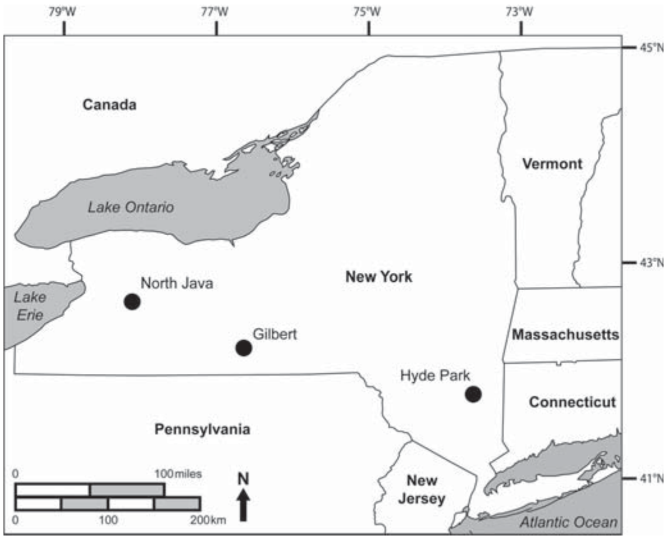
For each site, when two samples' time series crossdated securely, they were combined into a taxon-specific site chronology. This process was repeated with all of the samples from one site. Segments of certain samples included in the chronologies were selected for radiocarbon dating. Samples that did not securely crossdate with other samples were categorized as singletons, and were not radiocarbon-dated except for a few samples that were of importance in terms of taxon, stratigraphy, or context.

Radiocarbon dating

As noted above, samples were selected for radiocarbon dating if they were part of floating chronologies, or if they were found in a key stratigraphic level or in association with bone or other artifacts. Sections of the chosen samples were divided into decade-long segments. With a processed weight of five grams of carbon required for an accurate beta-decay radiocarbon date, generally an initial weight of 25-50 g of wood was necessary for spruce and pine (*Pinus*); for the hemlock [*Tsuga canadensis* (Linnaeus, 1753) Carrière (1855)] and angiosperm taxa, 15-25 g was adequate. The low ratio of processed to initial weight was due to the samples' moisture content, a result of their *in situ* settings, and minor degradation over time. The weight of the decadal segments in about half of the samples was of enough bulk for good dates, but for the segments of smaller samples or for periods of narrow ring widths, adjacent segments had to be combined. The lengths of the dated segments ranged from 10-45 rings (Table 1).

More than one segment per sample was radiocarbon dated to better determine their place in time. The radiocarbon ages of multiple segments from any tree-ring time series are dated by wiggle-matching, *i. e.*, using the known number of rings both in the segments and between segments to fit the radiocarbon ages onto the calibration curve by matching their patterns. The wiggle-match generally gives a better fit to a calibration curve than the calibration of single dates, which results in a smaller standard error value.

The radiocarbon ages were calibrated with the IntCal98 and IntCal04 radiocarbon calibration curves (Stuiver *et al.*,



Text-fig. 1. The locations of the three mastodon sites across New York State.

1998; Reimer *et al.*, 2004); the Late Glacial samples were also calibrated with the Cariaco Basin marine radiocarbon curve (Hughen *et al.*, 2000, 2004).

THE THREE SITES AND THEIR MACROFOSSILS

The mastodon and mammoth bones were found when the owners of each site excavated their ponds for expansion and a deeper basin (see Text-fig. 1 for locations). The Chemung mastodon (PRI 8829) and mammoth (PRI 8830) bones were found in John and Elaine Gilbert's pond in Chemung County, south of Watkins Glen. It is a kettle pond, the result of a very large chunk of glacial ice left buried in the ground as the glacier retreated. The Hyde Park mastodon (PRI 49820) was found in Larry and Cheryl Lozier's pond in Hyde Park, Dutchess County. This pond originated as an oxbow of a paleomeander of nearby Fall Kill. The North Java mastodon (PRI 49618) was found in Bob Moffett's pond in North Java, Wyoming County. Moffett's pond is most likely also a kettle pond formed in a kame. Each of the sites was excavated with a different strategy.

THE CHEMUNG SITE (CHE)

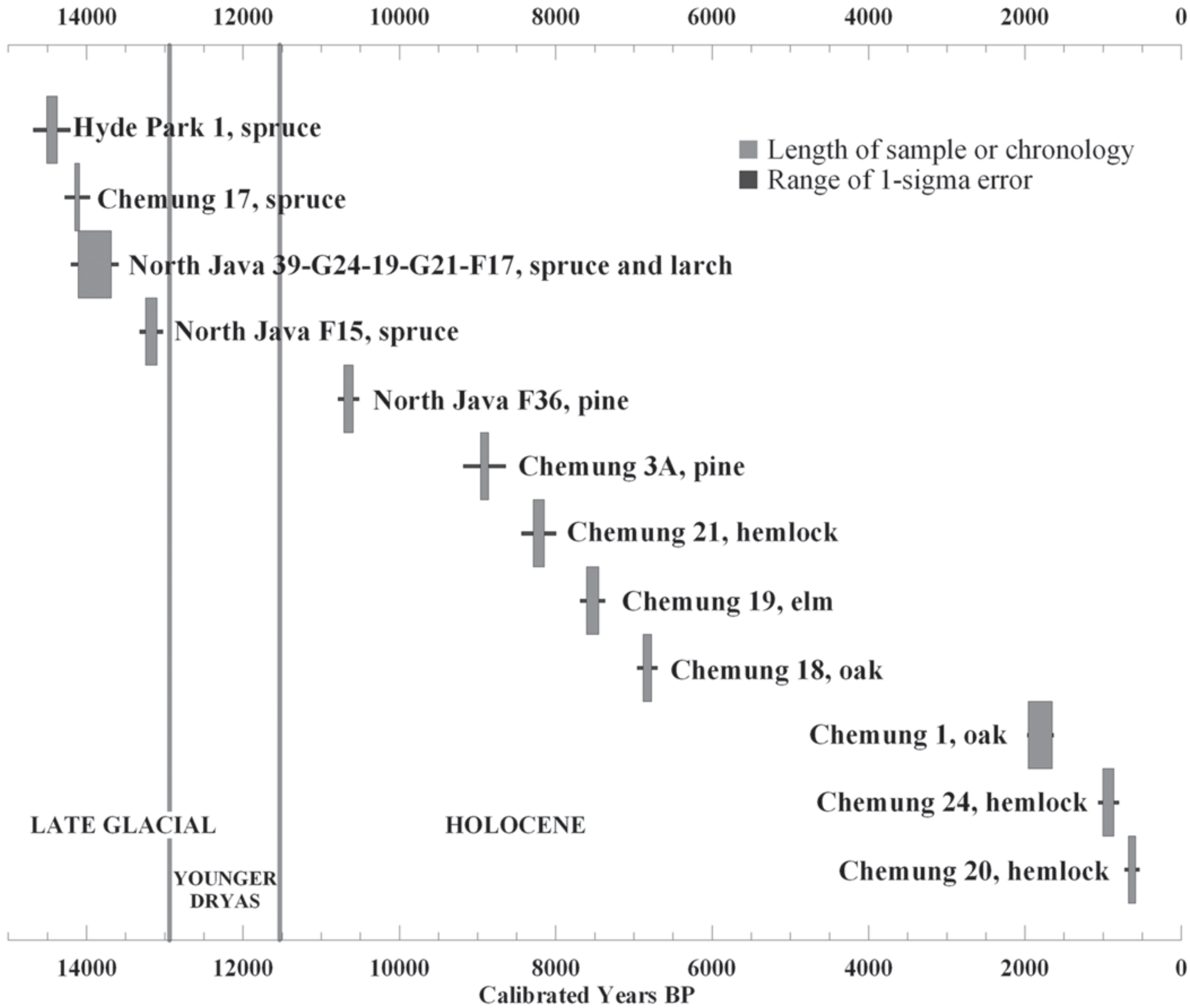
This site was a shallow anoxic pond surrounded by an acidic bog. Once the first mastodon bone was found and the pond drained, the stratigraphic layers were visible and excavated separately. There was a top layer of anoxic pond sediments, including peat, organic detritus, gravel, and silt; then a 1-2 m layer of "mastodon matrix" – unusually well-preserved green organic detritus of mastodon dung plus bone and gravel, similar in texture to a wallow. Beneath that layer, there was an irregular and thin layer of glacial cobbles, and under that, glacial clay.

The amount of well-preserved arboreal macrofossils was noted immediately during excavation. Seven logs to approximately 0.5 m in diameter and at least 3 m in length were found in the anoxic layer, with some directly above the mastodon-matrix level and thus from contemporaneous to post-mastodon dates. Sections of each log were cut by chain saw for dendrochronological analysis and for radiocarbon dates of the stratigraphic layer. These were the largest logs recovered at this site. Within the mastodon-matrix level, the wood segments were less then 0.25 m in diameter and always less than 1 m in length: most were of branches less than 0.1 m in diameter. A total of 42 samples was specifically collected for dendrochronology and hundreds more for species identification. Of the 42 tree-ring samples, eight were selected for radiocarbon dating, their selection depending on species, stratigraphic level, and relationship to the mastodon bones at the site. The dated samples include: an oak (*Quercus*, CHE-1) found in the anoxic level on top of the matrix; one oak (CHE-18) and one elm (*Ulmus*, CHE-19) segment plus three hemlock (*Tsuga canadensis*, CHE-20, 21, and 24) segments found within the matrix; one pine (*Pinus*, CHE-3A) found directly with mastodon bones; a handful of spruce or tamarack twigs (*Picea*/*Larix laricina* (Du Roi, 1771) K. Koch (1873), CHE-11Nov99) that had been digested by the mastodon and found in the matrix layer; and one spruce root (*Picea* spp., CHE-17) found at the top of the glacial clay. Two pieces of bone were also sent for dating, one mastodon and the other mammoth, discussed elsewhere in this volume (Shoshani & Marchant, 2008; Hodgson *et al.*, 2008). Results are listed in Table 1 and shown in Text-fig. 2.

The radiocarbon-dated spruce sample (CHE-17) is one of only two samples of spruce recovered from this site that contains over 50 rings. Two segments of this sample radiocarbon-dated to 12,269 ± 66 and 12,365 ± 75 ^{14}C yr BP (Hd-20780 and 20795; Table 1) and the sample was wiggle-matched and fit to the calibration curves (Text-fig. 3). The spruce cones found in the matrix are all of *Picea glauca* (Moench, 1785) Voss (1907), which implies that the two samples are also *P. glauca*.

The pine sample, CHE-3A, radiocarbon-dates to the Early Holocene (8,028 ± 60 ^{14}C yr BP). This sample, a branch, was found directly with bones at the site. The larger pine logs above the mastodon matrix have not been radiocarbon-dated, but the radiocarbon-dated branch could have broken off from one of them.

All the other radiocarbon dates of Chemung wood samples, as well as the small size of the segments in the mastodon matrix, indicate intrusion of much later-deposited materials into that level throughout the Holocene. Such samples include



Text-fig. 2. The calibrated radiocarbon dates, sequence lengths, and error bars of the radiocarbon-dated wood samples and chronologies from the three mastodon sites.

hemlock branch segments (CHE-20, 21, and 24), an oak bole (CHE-18), and the bole of an elm (CHE-19) that was found in the matrix but extended down into the glacial clay with its branch collar upside down. They were not expected to date contemporaneously with the mastodon due to the established migration patterns of each taxon from pollen studies around the region. Their location in the matrix and glacial clay made their radiocarbon dating important to establish possible periods of deposition as well as intrusion and nonintrusion of the upper-level sediments into the matrix and clay during the Holocene, long after the mastodons disappeared.

Hundreds of smaller samples were also collected for generic and species identifications (Table 2). The count of 19 taxa found at this site is remarkable and is probably due to both the lengths of the deposition intervals represented by the radiocarbon dates and location of the site within major migration routes for many taxa (Webb *et al.*, 1993). Most of the taxa still naturally occupy the region with the exception of the spruce, white birch, and jack pine (Harlow *et al.,* 1979).

Indirect evidence of fauna from the arboreal samples includes thousands of twigs digested by the mastodons; their taxa were identified and are discussed below. Beaver-tooth gnawing marks are evident on several branches, and muskrat bones were also found in the matrix. The tunneling of both might have added to the bioturbation of the layers at any time since deglaciation; this activity might have been limited to periods of a wetter climate.

The colors of the organic matter in the mastodon matrix

Table 2. Tree taxa found at each mastodon site from east to west. An 'X' indicates the presence of the taxa and a number indicates how many dendrochronological samples of the taxa were collected. They are split into periods according to their ^{14}C dates and the pollen analyses of sites in New York and Pennsylvania (Davis, 1993; Miller, 1973, 1988).

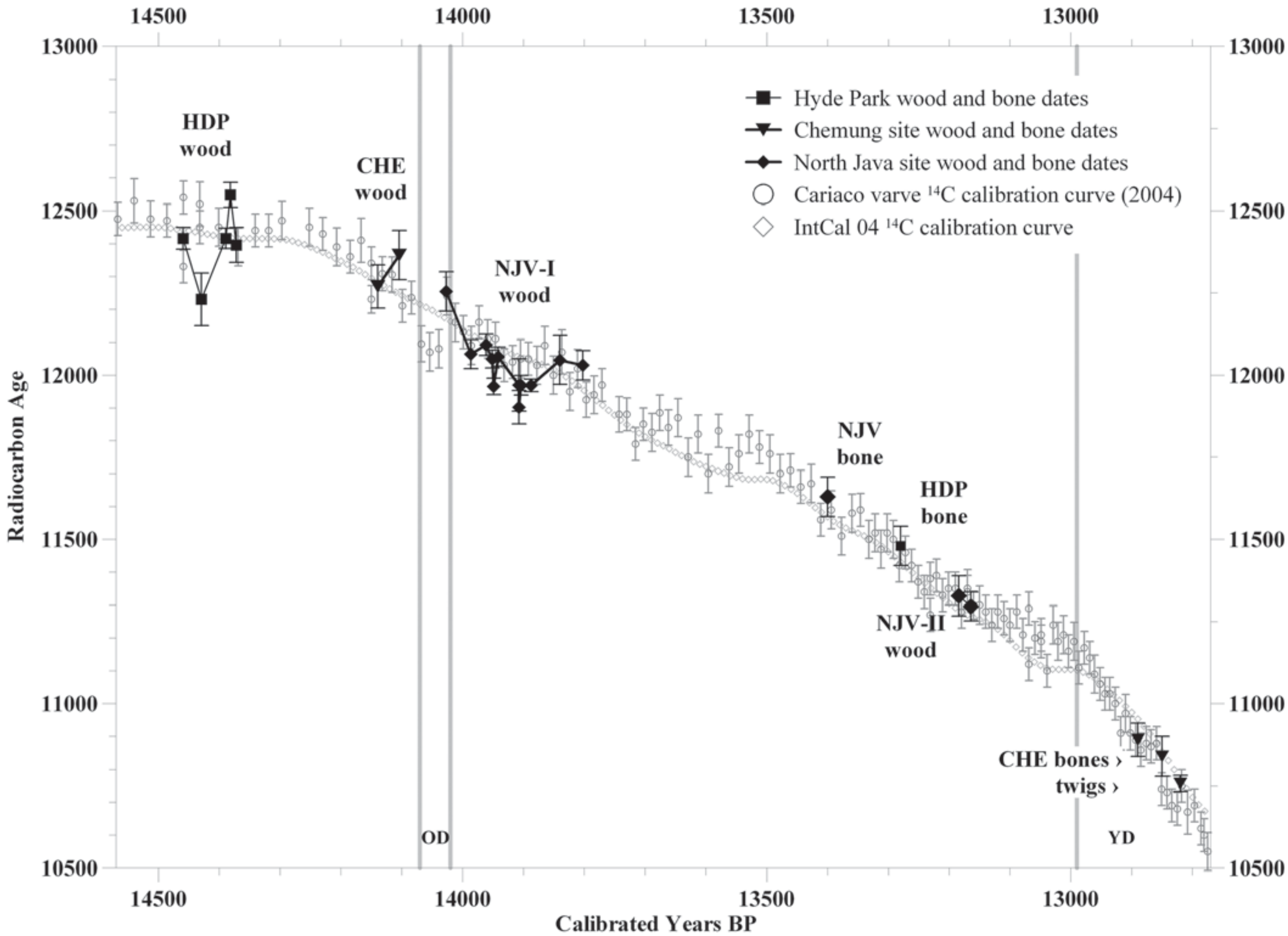
Arboreal Taxa	Common names	Hyde Park	Chemung	North Java
Late Glacial period, *ca.* 14,500-11,000 Cal yr BP				
Picea spp.	Spruces	1	4	30
P. glauca (Moench, 1785) Voss (1907) (cones)	White spruce	X	X	X
Betula spp.	Birches	X	X	
B. papyrifera Marshall (1785) (bark)	Paper birch		X	
Abies balsamea Miller (1768)	Balsam fir	X	2	1
Populus spp.	Poplars	X	X	X
Salix spp.	Willows	X	X	X
Larix laricina (Du Roi, 1771) K. Koch (1873)	Tamarack / Larch		2	3
Alnus spp.	Alders	X	X	
Mainly from the early Holocene, following the Younger Dryas up to *ca.* 8,500 Cal yr BP				
Pinus sp.	Pine spp.	X	4	
P. banksiana Lambert (1803)	Jack pine		1	1
P. resinosa Aiton, 1789	Red pine		1	
Holocene and Recent, from *ca.* 8,500 Cal yr BP to present				
Tsuga canadensis (Linnaeus, 1753) Carrière (1855)	Eastern hemlock	X	14	44
Fraxinus spp.				27
Fraxinus nigra Marshall (1785)	Black ash		1	
Ulmus americana Linnaeus (1753)	American elm	X	6	32
Quercus sp.	Oaks	1	4	1
Thuja occidentalis Linnaeus (1753)	Northern white cedar		2	3
Prunus sp.	Cherries		1	
Acer rubrum Linnaeus (1753)	Red maple		X	
Juglans nigra Linnaeus (1753)	Black walnut		X	
Fagus grandifolia Ehrhart (1788)	Beech			6
Castanea dentata (Marshall, 1785) Borkhausen (1803)	American chestnut		X	1

during excavation, including the wood, twigs, needles, and leaves, were extraordinarily vibrant and lifelike. Unfortunately most of the colors were lost within an hour after the material was exposed to the air. Five-pound (2.3 kg) bags of matrix were sent to anyone interested in searching for small fossils; the recipients were asked to search for small bone, plant, shell, and other remains, then wash and screen for even smaller fragments. The returned material so far includes at least 5 L of twigs, some of which had been digested by mastodons, similar in size and character to those reported by Laub *et al.*, (1994: 136, text-fig. 2). A radiocarbon date of some of the masticated spruce or tamarack twigs from one day's excavation is close to the bone dates and much later than the dates of the spruce root sample (Table 1). The identification of the taxa of nearly 1,000 digested twigs (Table 3) indicates that spruce and/or tamarack were the dominant food source for the mastodons. However, the inclusion of poplar and/or willow (*Populus* and *Salix*, respectively), pine, and fir [*Abies balsamea* Miller (1768)] twigs indicates that the mastodons did not dine exclusively on spruce.

THE HYDE PARK SITE (HDP)

This pond was an oxbow pond formed by a paleomeander of the Fall Kill, now to the east of the site. The stratigraphic layers, discussed in detail by Miller (2008), consisted of *ca.* 0.1 m of fine-grained peat at the top, then 0.6-0.8 cm of peaty marl (the spruce zone), *ca.* 1.0 m of clayey silt, and *ca.* 0.5 m of silty clay with cobbles of increasing sizes down to the glacial clay at the base of the excavated section.

Many arboreal macrofossils were collected from this site in the spruce zone and above, but there are only two (HDP-1 and HDP-2) that contained enough rings for dendrochronology. One sample is a large spruce log (HDP-1), found at the same level as the mastodon. This is the oldest spruce macrofossil



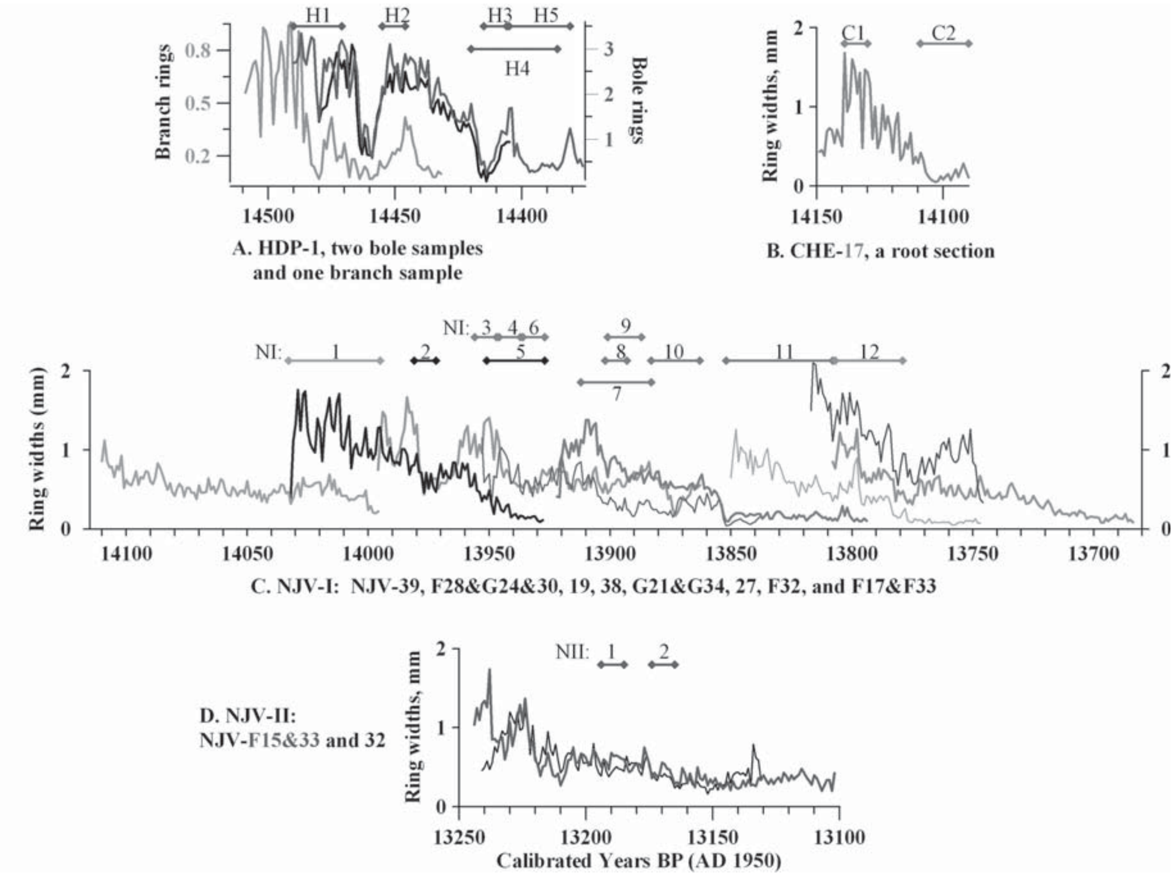
Text-fig. 3. The radiocarbon dates of Late Glacial wood and mastodon bone samples placed on the IntCal04 and Cariaco Basin (Hughen *et al.*, 2004b) calibration curves. The Hyde Park and Chemung samples are single trees; the North Java I and II chronologies include several samples along with the dated segments (see text and Text-figs 4-5). The vertical bars are 1σ error bars; "OD" and "YD" refer to the Older Dryas and Younger Dryas chronozones, respectively.

from the three sites (Table 1), with a diameter of *ca.* 0.5 m (a radius of 0.187 m plus an estimated 0.06 m to the pith) and was *ca.* 8 m in length. The wood has an average ring increment of over 1 mm in width, the widest of ring widths in all the sites' spruce samples. The relatively wide ring widths and size of the log indicate an open tundra/woodland setting or riverbank environment with little or no competition, as well as favorable soil, drainage, and climate (Schweingruber, 1996). The smooth exterior of the log and branches worn down close to their branch collars but not entirely worn off are indicators of some transportation to the site and/or weathering by the paleo-Fall Kill, before the meander became the oxbow (Miller, 2008). Three other collected samples of spruce, all with fewer than 50 rings, are not branches of HDP-1 because they are too large in diameter. They do contain comparable tree-ring widths to HDP-1. Similar to the Chemung site, spruce cones of only white spruce were found (Table 2) with some directly below the log, implying that this spruce log is also *Picea glauca.* A piece of mastodon bone was also dated from this site (Text-fig. 2; Table 1).

The other Hyde Park sample with a high ring count is oak (HDP-2), from a level above the mastodon and spruce. This sample has yet to be radiocarbon dated. Other tree macrofossils include numerous white spruce cones and small wood segments from various other species (Table 2). This site's arboreal species diversity is the least of the three sites, due to the open forest environment in the Late Pleistocene and the pond's alluvial floodplain setting causing the lack of deposition in the Holocene (Miller, 2008).

The North Java Site (NJV)

This pond was excavated before the Paleontological Research Institution was contacted, so the wood collected was part of a recovery from excavated sediments deposited around the



Text-fig. 4. Ring-width measurements of the samples of the Late Glacial from the three mastodon sites. A. The Hyde Park spruce sample. B. The Chemung root sample. C. The 11-sample North Java chronology (NJV-I). D. The three-sample North Java chronology (NJV-II). The horizontal lines with reference numbers at the top of each graph represent the radiocarbon-dated segments. The reference numbers correspond to the numbers in the left column of Table 1.

pond. The probable kettle pond is located on a kame and is extremely alkalinic due to a limestone source for the deposit (John Chiment, pers. comm., 2001; Calkin & McAndrews, 1980). This site is unique due to the pond's location nearly at the top of a kame (a pile of glacial till deposited at the margin of an ice sheet on the side of bedrock, sorted by streamflow) with an underground water source. There is little relief in the surrounding topography.

One-hundred and fifty-three samples were collected for dendrochronology. They include 34 samples of boreal species (Webb *et al.*, 1993), mainly of spruce with a few tamarack (Table 2). As noted above, two floating chronologies have been constructed, mainly of spruce, and both date prior to the Younger Dryas (Text-figs 2-3). The earliest chronology is 427 yr in length and could include the Older Dryas, an event the onset of which is indicated by an abrupt change in the amount of radiocarbon contained in the marine record (Text-fig. 3; Table 1). The second spruce chronology dates much later, toward the onset of the Younger Dryas (Text-fig. 3; Table 1). The date of the North Java bone sample indicates that this site's mastodon lived sometime after the first assemblage of preserved trees, but before the second group (Text-fig. 3).

The pine sample (NJV-F36) was taken from this site's only wood macrofossil that was seen *in situ* during collection. The log was dug out while widening the pond. It contains 116

Table 3. The taxa of digested twigs found in the mastodon matrix at the Chemung site. The distinction between spruce (*Picea*) and tamarack (*Larix*) and between poplar (*Populus*) and willow (*Salix*) in twigs is very difficult, therefore they are listed together.

Taxa	Number of twigs	Percentage
Picea or *Larix* sp.	758	77.9
Populus or *Salix* sp.	88	9.0
Pinus sp.	74	7.6
Abies balsamea	47	4.8
Unidentified	6	0.6
Totals	973	100.0

rings, with two segments radiocarbon-dating at 9367 ± 23 and 9509 ± 29 ^{14}C yr BP. This was the only pine sample found in this excavation, and the only dated sample from all the sites that represents the first millennium of the Early Holocene, the transition between climate regimes.

For the other 119 wood samples, there are approximately equal quantities of hemlock, elm, and ash (*Fraxinus*) and small amounts of other taxa (Table 2). All migrated into this region during the Holocene with the possible exception of the ash, which could have been an earlier migrant into western New York (Webb *et al.*, 1993; Davis, 1993). Of the samples of the three predominant taxa, 17 chronologies of 114-325 yr in length with a total of 2,882 yr have been constructed (Griggs 2006). More radiocarbon dates and dendrochronological research are needed to complete the analysis of the Holocene samples.

THE ARBOREAL SPECIES FOLLOWING DEGLACIATION

The arboreal species gradually migrated into New York following the path of the retreating ice sheet, but each taxon followed a different route (Davis, 1993; Webb *et al.*, 1993; Overpeck *et al.*, 1992). Miller characterized the earliest vegetation at the Hyde Park site as grassland/tundra with the earliest radiocarbon date of nonarboreal macrofossils from that site at 12,880 ± 50 ^{14}C yr BP (AMS, Beta-175557; Miller, 2008), 332 radiocarbon-yr earlier than our earliest spruce date of 12,548 ± 38 ^{14}C yr BP (Hd-22395). The values of the oldest radiocarbon date of arboreal samples at each site (12,548 ± 38 ^{14}C yr BP for Hyde Park to 12,365 ± 75 ^{14}C yr BP for Chemung to 12,254 ± 44 ^{14}C yr BP for North Java; HD-22395, -20795, and -22780, respectively) nicely reflect the southeast to northwest retreat of the Wisconsin ice sheet (Muller & Calkin, 1993).

Stratigraphic association is good at the Chemung site for the spruce (CHE-17) found at the bottom of the matrix, the pine (CHE-3A) found in a shallow depression with the bones, and the large logs found above the matrix of pine, hemlock, and oak. The positions of the smaller Holocene samples in the mastodon matrix were due to settling and bioturbation of the pond sediments. The two tree-ring samples at Hyde Park both have good stratigraphic association. For the North Java site, only the pine (NJV-F36), which was excavated from the bottom of the pond at the time of collection, has stratigraphic definition. The higher number of boreal samples at this site corroborates with a more closed forest that is indicated by the pollen analyses of western New York (Miller, 1973). However, for all the sites, the taxa (Table 2) and their associated radiocarbon dates (Table 1) compare well with the established migration record of each taxon into and across upstate New York following deglaciation. This migration record has been inferred from pollen analyses (Miller, 1988, 2008; Davis, 1993; Webb *et al.*, 1993; Calkin & McAndrews, 1980; Robinson & Burney, 2008). The presence and radiocarbon dates of the boreal-taxa macrofossils in each pond indicate deposition and preservation at all sites over that time – an indicator of a cool, wet environment throughout the Late Glacial.

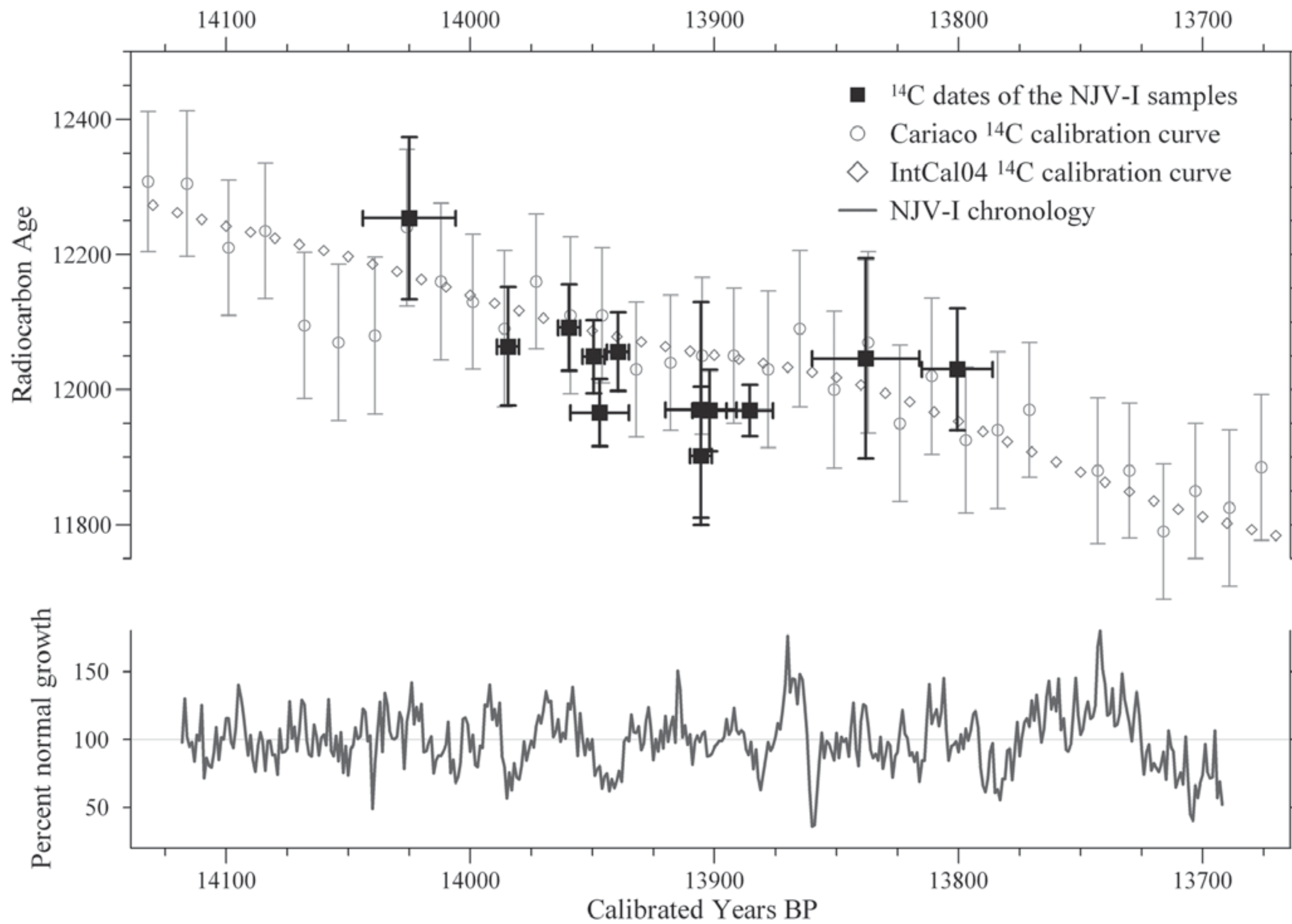
The relatively high numbers of certain Holocene taxa (hemlock and elm at the Chemung site; elm and ash at the North Java site) and the low numbers of other taxa (pine, oak, maple, beech) are most likely due to their preferred habitats and the limited Holocene deposition at Hyde Park. Hemlock and elm and at least one species of ash grow best in wetter conditions, and the less frequent taxa grow best on well-drained, dryer soils (Harlow *et al.*, 1979).

From the samples of all three sites combined, there appears to have been less preservation of arboreal detritus from the Younger Dryas into early Holocene, and in the mid- to late Holocene until the most recent two millennia (Text-fig. 2). Biases in field collection and selection of samples for radiocarbon dating might have caused the gaps in our data, but these intervals of deposition and nondeposition are similar to those seen at the Hiscock site (Miller, 1988). Radiocarbon dates of the North Java spruce and pine samples indicate that the late Pleistocene-early Holocene gap is most likely present; more dates are needed to determine whether there is also a mid-late Holocene gap. Also underway is a project that includes oxygen isotope analyses of modern trees that were recently cored at all three sites to compare with isotope analyses of the samples contained in the radiocarbon-dated chronologies to look for variations in precipitation over time in New York State. All of this research, plus what has been found in other paleoecology studies around the region, will help to prove whether the depositional gaps are real, if they are the result of regional or local climate change, and why they occurred.

THE DENDROCHRONOLOGY OF THE SAMPLES

The Tree-ring Chronologies

Of the 197 wood samples with sufficient ring count for dendrochronological analysis, 163 had been measured by June 2007, and 24 chronologies have been built with more in progress. The chronologies, composed of several samples, dampen the trees' individual responses to their micro-environments and emphasize the response that the trees share in common to the site's geomorphology (*e. g.*, a kettle pond in a small valley with limited drainage) and climate (*e. g.,* precipitation) parameters. A site chronology is necessary for an accurate analysis of a response that reflects local and regional changes in the environment and climate parameters.



Text-fig. 5. (*Top*) The radiocarbon ages from the NJV-I chronology fitted to the IntCal04 and Cariaco Basin (Hughen *et al.*, 2004b) radiocarbon calibration curve. The vertical bars are 2σ error bars and the horizontal bars indicate the rings included in the radiocarbon-dated segments. (*Bottom*) The detrended NJV-I chronology. In both, note the dip in the radiocarbon ages from 14,075-14,050 cal yr BP, the onset of the Older Dryas interval.

The common response also allows a secure crossdate between the site chronology and other chronologies and sample data sets from the same time period (Fritts, 1976; Cook & Kairiukstis, 1990). Chronologies are genus- or species-specific. The accuracy of crossdating between chronologies of different taxa ranges from very good to limited due to the level of similarity in each taxon's primary growth-limiting factor(s). One example is that for oaks, the primary factor is the precipitation of the growing season, and for hemlocks, it is a combination of precipitation plus temperature (Fritts, 1976).

The Late Glacial Samples

The Chemung and Hyde Park sites each have only one spruce sample that was both measured and radiocarbon-dated (Text-figs 4A-B). Both radiocarbon-date to earlier than 12,200 ^{14}C yr BP. The North Java site has a remarkably large number of boreal-taxa macrofossils dating after 12,250 yr, including the Older Dryas event and up to the Younger Dryas. Of the 33 spruce and tamarack samples from that site, one spruce chronology is constructed of 12 samples from 8 trees and is 427 yr long (NJV-I, Text-figs 4C, 5). The ring-width patterns of the individual trees indicate an open environment with little suppression-release patterns. The trees contain moderate amounts of compression cells that are nearly symmetrical around their circumference, which might indicate steady winds but with no persistent direction. The compression does not occur to the extent of the samples from the Two Creek site (Kaiser, 1994). The ring widths of the site's spruce samples are small when compared to spruce that was planted at the North Java site about 50 yr ago. The average late Pleistocene spruce ring width of the inner 50 rings is 0.84 mm as opposed to the modern ring width average of 3.15 mm, an indication of a much cooler climate with the assumption that temperature was the primary limiting growth factor for the spruce (Briffa *et al.*, 1994).

The second North Java chronology was built of three spruce samples from two trees, of 145 yr length (NJV-II, Text-fig. 4D). Radiocarbon dates for two segments of one sample place the chronology toward the end of the Allerød Interstadial, later than this site's mastodon bone date (Text-fig. 3, Table 1). Two shorter spruce chronologies from the North Java site have yet to be dated.

The variability in atmospheric radiocarbon content in the Late Glacial is very evident in the range of the radiocarbon ages of consecutive and even contemporaneous sections from this chronology (Text-figs 4C, 5). Of particular interest is one tree (sample G21) whose radiocarbon ages are either the same or increasing over its lifespan (Table 1), indicating that there could have been a significant fluctuation in the atmospheric radiocarbon content over that period. A significant reduction in ring size at the position of its last radiocarbon date is a possible indicator of abrupt climate change (NI9, Text-fig. 4C). The variability in the radiocarbon ages of the samples in this chronology is certainly similar to the variability in the Cariaco calibration curve (Text-fig. 5).

THE HOLOCENE SAMPLES

The Chemung site has five tree-ring chronologies for the Holocene. These include a 301-yr oak chronology, a 171-yr pine chronology, a 153-yr elm chronology, and two hemlock chronologies, one of 240 yr and one of 237 yr in length. The oak, elm, and the 240-yr hemlock chronologies are radiocarbon-dated as shown by their placement in Text-fig. 2, and dates for the samples from the other chronologies are in progress. The oak sample from Hyde Park has yet to be radiocarbon dated.

The 104 hemlock, elm, and ash samples from North Java have been measured. Forty-four samples are included in 14 chronologies with an average length of 169 yr, and they cover a total of 2,357 yr. Of the 15 samples still to be measured, maple (*Acer* spp.) and beech [*Fagus grandifolia* Ehrhart (1788)] are the major taxa. Radiocarbon dates are needed for samples included in the longer chronologies.

CONCLUSIONS

Upper New York State, after the recession of the last ice sheet and during the reign of the mastodon and mammoth, was a boreal environment with a cool, humid climate regime. The tundra environment that immediately followed glacial recession gradually evolved into open forests dominated by spruce, with poplar, paper birch, tamarack, fir, and pine present. This boreal ecosystem is indicated by the taxa, their radiocarbon dates, and the patterns of relative ring widths in the dendrochronological samples. The radiocarbon dates of the oldest spruce wood at each site are up to 1,500 yr older than the radiocarbon dates of their respective mastodon and mammoth bones, the Chemung site having the largest gap, with the North Java mastodon bone dating about 500 yr after its oldest chronology. The lack of large wood samples with the same dates as the mastodon bones, and the fact that the mastodons' diet consisted mainly of spruce twigs, implies that the arboreal flora was cleared out from at least immediately around each site during their presence.

Despite the limited stratigraphic record of samples at the Chemung site, the radiocarbon dates of the spruce, pine, earliest hemlock, and elm samples are very similar to the dates of their migration into this region, inferred from the regional pollen record (Webb *et al.*, 1993). The paucity of samples from the Younger Dryas through early Holocene, and mid- to late-Holocene could indicate drier periods across this region. Isotope analysis and radiocarbon dates of the Holocene samples from the North Java site will further indicate whether this pattern is real (not due to sample bias), and whether all sites were similarly affected. Late Glacial and Holocene wood samples have also been collected from other sites around northeastern North America, and the results of their taxa, ring widths, isotope analysis, and radiocarbon dates will add to the interpretation. This research is necessary for a better understanding of the amplitude and variability of climate change over time.

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