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External Characteristics of Old Trees in the Eastern Deciduous Forest

Neil Pederson[1]

Department of Biological Sciences
Eastern Kentucky University
521 Lancaster Ave.
Richmond, KY 40475

[1] Corresponding author:
adk@ldeo.columbia.edu

[2] Current address:
Tree Ring Lab, Lamont-Doherty Earth
Observatory of Columbia University
P.O. Box 1000, 61 Route 9W
Palisades, NY 10964

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ABSTRACT: Because old trees contain centuries of environmental history, investigators are increasingly turning to dendrochronology to create context for current environmental change. While a suite of characteristics to identify old trees has been developed, most of these characteristics are for conifers or trees growing in low-density forests. Given that the diverse Eastern Deciduous Forest (EDF) is dominated by a species-rich, angiosperm-dominated woody flora, old-growth forests are scarce in the EDF, and research permits in natural areas often limit the number of trees that can be sampled, having a suite of characteristics that identify old trees for a wider range of species increases the likelihood of efficiently creating longer depths of ecological history. The common indicators of old (> 250 year old) EDF angiosperms are presented to aid in the recovery and preservation of these living sources of information. Six common external characteristics of old angiosperm trees include: (1) smooth or "balding" bark; (2) low stem taper; (3) high stem sinuosity; (4) crowns comprised of few, large-diameter, twisting limbs; (5) low crown volume; and (6) a low ratio of leaf area to trunk volume. The existence of old trees in the landscape can also be related to life-history traits or land-use histories. Both professionals and lay folk can be trained to identify these traits and environmental conditions. While these characteristics and settings generally signal the potential for old trees, there is no guarantee that they represent old ages. However, these characteristics should aid in the discovery of old trees throughout the EDF.

Index terms: angiosperm trees, Eastern Deciduous Forest, forest history, old-growth forests, tree-ring analysis

INTRODUCTION

As investigators try to understand the long-term context of recent environmental change, many are turning to tree-ring analysis as a tool for understanding the range of variation in climatic and disturbance history. Old trees are vital to the revelation of environmental history because of their capacity to store information in their annual growth rings, morphology, wounds, and scars (Douglass 1920; Sheppard and Cook 1988; Fritts and Swetnam 1989). Old trees are also of great cultural value because of their aesthetic and spiritual qualities (Leverett 1996; Perlman 1996). Because of the limited area of old-growth forest in the eastern United States (Davis 1996), limited number of exceptionally old trees within an old-growth forest, and limits routinely placed on sampling trees in natural areas, the ability to readily identify old trees increases the likelihood of creating longer, well-replicated reconstructions of environmental history. Eastern North America is a highly fragmented region that is continuing to undergo rapid change under the threat of invasive species and pests, urban development, and climate change. In fact, recent land-use analysis suggests that forest loss has resumed after decades of forest recovery (Drummond and Loveland 2010). Therefore, identification of old trees should help preserve these rare, living, and culturally-valuable individuals.

Past work has identified a suite of external characteristics that can be used to readily identify older trees across a range of genera. These external features include spiral grain in a tree's trunk, thin or balding bark, loss of apical dominance, crown dieback, and crowns with a few, large limbs, among others (Swetnam and Brown 1992; Stahle and Chaney 1994; Kaufmann 1996; Stahle 1996; Huckaby et al. 2003). Most of these diagnostic features were identified from conifers or trees growing in relatively low-density forests. Given that there are more than 300 tree species in the dense Eastern Deciduous Forest (EDF), of which at least 75% percent are angiosperms (Burns and Honkala 1990; U.S. Department of Agriculture, Forest Service 2009), there is a need to discover and describe external characteristics of potentially old trees in this biome.

The primary purpose of this paper is to describe the common external indicators of trees > 250-years old in closed-canopied forests typical of the EDF and to hypothesize on the potential mechanisms of these features. Observations described here expand on previously-described traits for *Quercus* subgenera *Leucobalanus* (see Stahle and Chaney 1994; Stahle 1996) with the inclusion of additional characteristics and observations of other *Quercus* species and other genera, including *Acer, Betula, Carya, Liriodendron, Magnolia*, and *Nyssa*. Admittedly, many of the characteristics already documented for conifers and trees in the western portion of the EDF apply to species in this paper. However, finer points and specific examples presented here should aid in the identification of old trees throughout the EDF.

A secondary goal of this paper is to describe ecological conditions, especially in managed forests, where the likelihood of old trees is greater than in 'typical' second-growth forests. While old-growth forests and sites prone to drought in the eastern deciduous forest are likely to have older trees (see Cook and Jacoby 1977; Stahle and Chaney 1994; Therrell and Stahle 1998), there are particular ecological settings or regional land-use histories that result in a higher than expected number of old trees. Case studies are presented to expand on a trait that appears specific to *Liriodendron tulipifera* (L.) and a specific example of an interaction of site and abundance of old trees near New York City. To underscore the utility of the observations put forth in this paper, two examples of successful technology transfer of these observations are described.

Database of Observation

Since 1999 and with the assistance of many volunteers, I have developed a tree-ring network composed of 82 sites, 47 tree species, and 3331 trees over a region extending from southern Maine through northern New York State, south to central Georgia, and west from the Coastal Plain through western Kentucky, central Tennessee, and northern Alabama. Through trial and error, the development of this collection led to the observations presented here. A little more than 60% of these samples have been fully cross-dated:176, 300 to 399 yr old; 27, 400 to 499 yr old; and nine trees > 500 yrs old have been precisely aged based upon the rings present in each core using standard dendrochronological techniques (Stokes and Smiley 1968). Age of trees reported here are minimum ages (minimum age = year of coring - year of the last partial ring from the inner portion of a tree's oldest core sample + one). No extrapolations have been made for the number of missing rings from hollow trees, samples without pith, or the number of years to reach coring height. Extrapolations were not attempted because: (1) derivation of ages from age-diameter relationships is fraught with potential error (e.g., Harper 1977) and (2) large errors in the estimation of 'true' tree age have been detected for fast growing, shade intolerants (e.g., *Pinus taeda* (L.); Pederson 1994), and more shade tolerant species (e.g., *A. rubrum* (L.); Baker 2003). Narrow initial ring widths in *P. taeda* caused the largest errors in age estimation (Pederson 1994). Therefore, total tree age presented here, based upon the age at a tree's root collar, could be anywhere from just a few years to more than 50 or 100 years older than reported.

Finally, it should be noted that *old* is used in a relative sense. An old *A. rubrum* or *B. lenta* (L.) is not 'old' compared an old *N. sylvatica* (Marsh.). I put forth that these traits are fairly universal and could likely apply to old *Populus deltoides* (Bartr. ex Marsh.) or *P. tremuloides* (Michx.) trees, where old might mean 100 to 150 yrs. Also, old trees for purposes here and in my research is placed at 250 yrs. This age predates a good portion of European settlement outside of the major river valleys and Coastal Plain physiographic provenance. More importantly, trees this old predate almost all meteorological records in the EDF and observation of forest dynamics allowing for greater likelihood of capturing large, infrequent disturbances and climatic events. Nomenclature follows Jones (2005).

External Indicators of Old Trees

Six external characteristics of potentially old angiosperm trees are presented here. These characteristics are found in the stems and crowns of trees and include: (1) smooth bark; (2) low stem taper; (3) high stem sinuosity; (4) crowns comprised of few, thick, twisting limbs; (5) low crown volume; and (6) a low ratio of leaf area to trunk volume. Admittedly, characteristics (4) and (5) are often correlated: a crown with low volume often has only a few, twisting limbs. The greater the number of these characteristics in one tree, the greater the likelihood the tree is old.

Bark Characteristics of Old Trees

It has long been observed that bark morphology changes with age (Wahlenberg 1946). Older trees generally have a "balding" pattern on their lower bole (Swetnam and Brown 1992; Stahle 1996; Hardin et al. 2000; Huckaby 2003). However, there is an important consideration that needs to be made for some in the EDF. Some species have great bark pattern variability, which requires careful interpretation when interpreting age from bark. For example, *Q. alba* (L.) bark ranges from tightly ridged to peeling and flaky bark in young trees to patchy and balding bark to entirely smooth lower boles in older trees (Figure 1 a-d; for an extensive presentation on bark variation in a species, see Symonds 1958). Also, while balding or smooth bark on a *Magnolia acuminata* (L.) can be an indicator of greater age, an important characteristic for identification of this tree is the occurrence of oval areas of smooth bark on young trees. Therefore, while balding on the lower bole appears to be a somewhat universal pattern of age, each species has its own unique pattern of bark variation at greater ages (Figure 2 a-f). The general pattern of increased balding with age has also been observed in species not presented in this paper, including *A. sacharrum* (Marsh.), *A. rubrum, B. lenta, B. allegheniensis* (Britton), and *M. acuminata*, among others. Bark characteristics, being at eye-level, are good initial indicators of tree age.

Bole Indicators of Old Trees

The next external characteristic that aids in the identification of old trees is stem taper. Stem taper, the difference in diameter at the base of a tree to just below the base of its crown, appears to be positively correlated with tree age (note: I have not quantified stem taper, only recognized it as a fairly consistent identifier of old trees). Trees with low taper are often older than neighboring trees of the same species with greater taper. Again, this is a trait commonly observed in old conifers and *Q.* subgenus *Leucobalanus* in the western portion of the EDF (Swetnam and Brown 1992; Kaufmann 1996; Stahle 1996; Huckaby et al. 2003). This same taper indicator holds for many

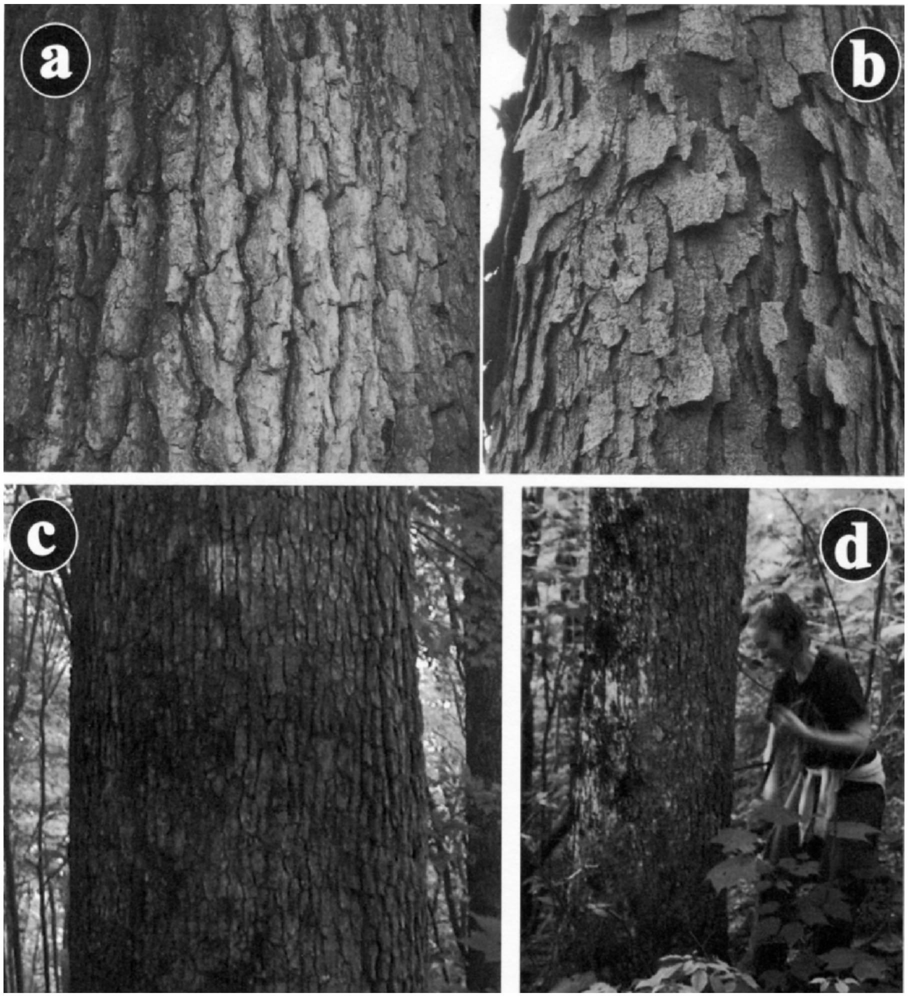

Figure 1. Examples of variation bark patterns in young versus old trees. Here, *Quercus alba* at different ages: a) and b) show the ridged and flaky characteristics of trees ≤ 150 yrs old and c) and d) show the variations of low ridging and balding of old or slow growing trees ≥ 250 yrs old.

other species in the eastern portion of the EDF (Figure 3a). Despite the formation of wider annual radial increments at the base of live crown versus lower on the bole (Farrar 1961; Assman 1970; Fritts 1976), the basal section of a tree is wider simply because it is older. As the apical tip ascends to the canopy, the upper portion of a young stem will continue to be narrower despite differential in radial increments moving up the stem. When trees approach maximum height for a microsite, the formation of wider rings in the upper bole begin to reduce bole taper. Identification of low stem taper on the bole of a tree often leads to identification of an old tree.

A second bole characteristic that is fairly common in old EDF trees is a highly sinuous stem. Like a snake climbing a tree, stems of old angiosperms often 'snake' side-to-side, moving from the trunk to the base of its crown, resulting in high stem sinuosity. Specifically, sinuosity is defined as the amount of waviness between stem nodes (Campbell 1965). Trees in the *Quercus* subgenus *Leucobalanus* greater than 300 years often have this morphology (Figure 3b; see also Figure 5c). Unexpectedly, the relation between stem sinuosity and greater age seems to be true of trees with lower shade tolerance (shown further in the *Liriodendron tulipifera* case study). Although others have noted twisted trunks and spiral grain in old *Q. stellata* (Wangenh.) and *Juniperus virginiana* (L.) (Stahle and Chaney 1994; Stahle 1996), sinuosity might be a different trait. High sinuosity is a common external indicator of old trees across species. A few of the oldest individuals near or at the maximum known age for the species share this trait (Eastern OLDLIST 2010).

Most research on stem sinuosity has been conducted on conifers (Campbell 1965; Timel 1986; Spicer et al. 2000; Baker et al. 2005; Gartner and Johnson 2006; Krause and Plourde 2008; Espinoza 2009). Research indicates that stem sinuosity can be the result of suppression, leader damage, growth rates, nutrient levels, or genetics. Long internodes has been associated with sinuosity (Spicer et al. 2000), although recent work calls that finding into question (Gartner and Johnson 2006). From an energetics perspective, stem sinuosity in old angiosperm trees could reflect a decadal to perhaps multi-decadal type of phototropism. More often than not, the oldest *Q. alba, Q. montana* (Willd.), *N. sylvatica*, etc., grew in deep shade or highly competitive environments when young (Figure 4). Research on trees of the genera *Alphonsea, Polyalthia*, and *Saccopetalum* in Thailand indicate that many in these genera have sinuous stems and experienced suppression in the past (Baker et al. 2005). Hypothetically, the surviving portions of each tree's crown intercepted light in sunflecks. As the crowns of neighboring trees changed through time (as a result of branch-clipping storms, branch, or tree mortality), areas with more light influenced growth patterns in these subordinate trees. In response, the allocation of photosynthates to crown and supporting stem growth in subordinate trees tracks available light. Over decades, the changing spatial patterns of light availability are preserved in the morphology of tree boles. This is an area of research that needs more study in the EDF.

Finally, a common misconception is that trees with large diameters are old. While this can be the case, it is striking how the oldest, well-documented trees tend to gravitate around an average diameter for the species or site. Figure 3 in Black et al. (2008) shows that the older trees across four genera were not the largest trees and were, in fact, within the average range for diameter. Similarly, many tree species have an asymptotic relationship between

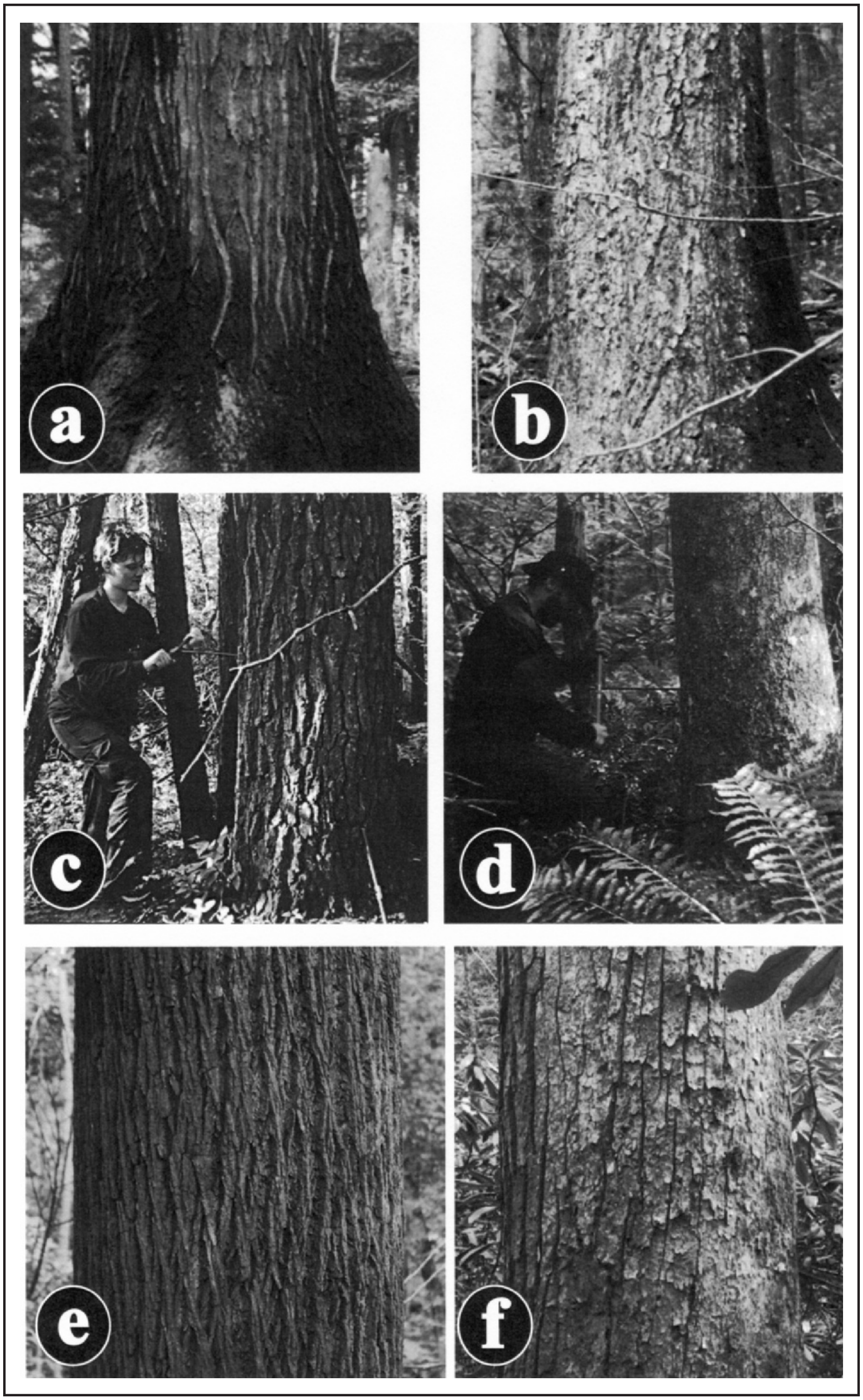

Figure 2. Examples of young versus old trees of three Eastern Deciduous Forest species: *Quercus rubra* at a) 150 yrs and b) 270 yrs, *Nyssa sylvatica* at c) ca. 250 yrs and d) 400+ yrs, and *Liriodendron tulipifera* at e) ca. 80 yrs and f) 500+ yrs.

diameter and age (e.g., Platt et al. 1988; Pederson 1994; Meldahl et al. 1999). These studies generally show that as the relationship between diameter at breast height (dbh) and age increases positively for the first ca. 100 years, the relationship plateaus and becomes poorly correlated at greater ages.

Observations of several 410 to 428 yr old *Q. montana* undercuts the "tree size indicates age" concept. Diameters of the oldest-documented *Q. montana* within three regions of the EDF ranged from only 47.1 cm to 62.8 cm dbh (Figure 5), far shy of the species' diameter capacity of 183 cm dbh (McQuilkin 1990). Larger trees often have larger crowns and, likely, larger roots systems, which make them better competitors and faster-growing trees. The take-home lesson is that while large trees can be old, size does not connote age (e.g., Harper 1977; Baker 2003). Low taper and high sinuosity, especially in combination, appear to be better external indicators of tree age in the EDF and elsewhere.

Crown Indicators

Architecture of tree crowns can also be a good indicator of old age in EDF trees. Thick, large, and "gnarled" branches have long been known as indicators of older trees (Swetnam and Brown 1992; Stahle and Chaney 1994; Kaufmann 1996; Stahle 1996). These crown architecture traits likely reflect a tree that has endured numerous disturbance events. Canopy openings cause trees to increase growth in or towards these new openings, which will result in larger size of the residual branches (Figure 6a).

Another indicator of tree age is crown volume. Trees with a smaller crown volume, whether the result of a shallow crown depth or the presence of a few branches, often have a smaller leaf area. These trees resemble a stalk of celery from the grocery store (i.e., a stout stem with a few leaves; Figure 6b). Trees that resemble celery stalks have often turned out to be older than co-occurring trees.

Trees with small leaf areas convert less solar radiation to usable energy for growth. In addition, trees with lower crown volume are also likely to have relatively smaller roots systems. Hypothetically from an energetics perspective, a combination of lower photosynthetic area and smaller root

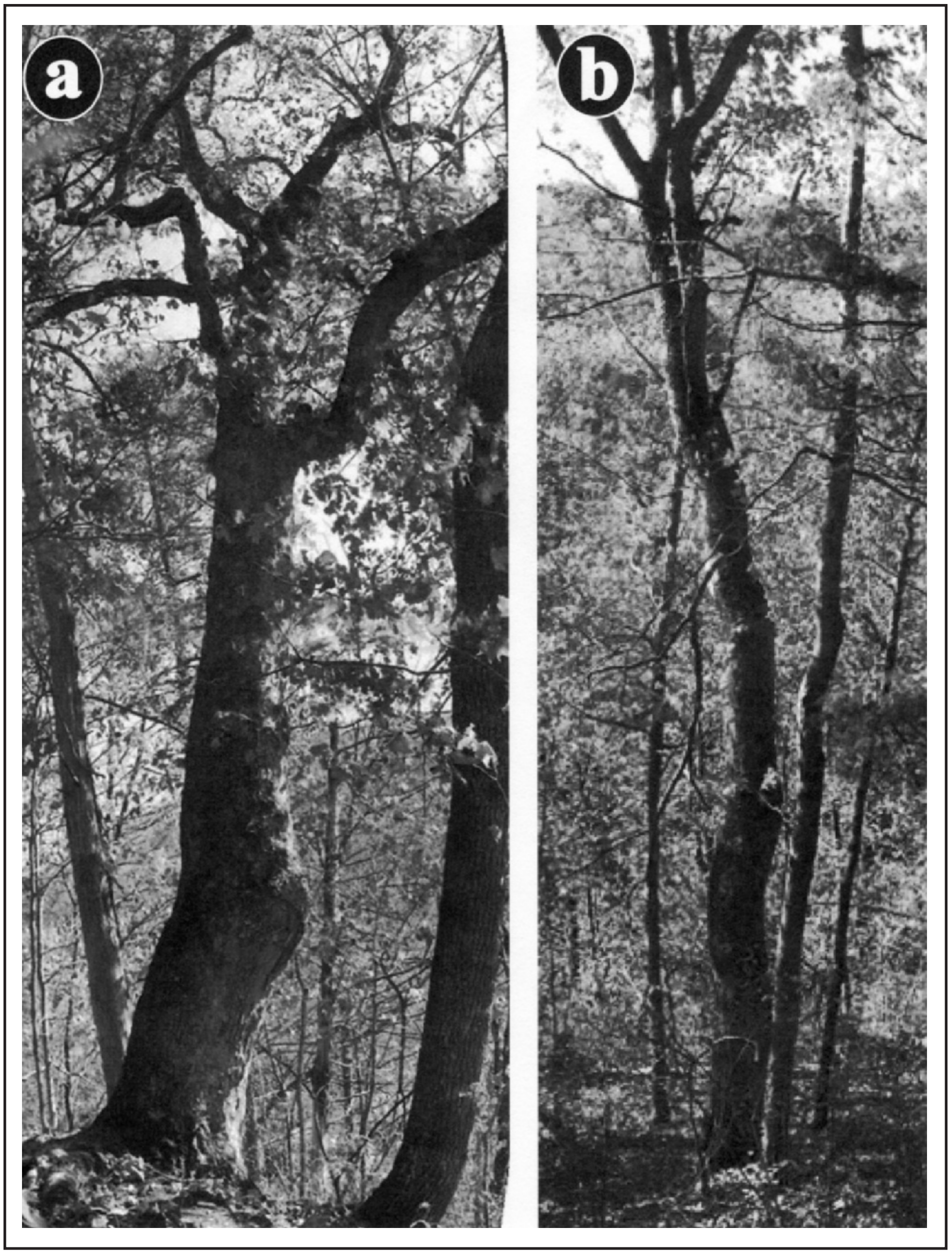

Figure 3. Examples of bole characteristics that assist with identification of old trees. a) A 399-yr old *Q. muehlenbergii* with low stem taper. b) A 349-yr old *Q. muehlenbergii* showing extreme sinuosity. Image in (a) courtesy of A. Wiggs.

systems points to a tree that grows slower than surrounding trees because of reduced competitive abilities in the acquisition of water, nutrients, and solar radiation. When a tree with a small crown volume also has a medium to large diameter, an investigator can have higher confidence that they are in the presence of an old tree. A tree with balding bark, a smaller crown size, and larger, sinuous stem with low taper suggests the passage of a relatively long period of time since establishment.

Ecological Indicators of Old Trees

Though not a cause of great age, trees in certain ecological settings are more likely to be old trees, even in forests that have been harvested. For example, trees growing on dry, steep, south to southwest-facing slopes with low-fertility soils towards the western edge of the EDF are more likely to be old (Stahle and Chaney 1994; Therrell et al. 1998; but see Cook and Jacoby 1977 for physical site conditions in the moister portion of the EDF). These sites have low productivity and are less likely to have been harvested because few trees reach commercial size, are often inaccessible, or have an architectural form that reduces forest-product value (see the Uttertown, N.J., case study for further discussion).

Some trees have natural poor growth forms or growth rates that lower their commercial value. As a result, these species are often left as remnants following timber harvest. Perhaps the best example of this is *N. sylvatica* (Sperduto 2000; Abrams 2007). N. sylvatica is a species with low quality wood that warps or twists when it dries. Perhaps as damming to *N. sylvatica's* commercial value is its propensity to rot (McGee 1990). In many wetlands, *N. sylvatica* has been left behind while more valuable species have been removed. For example, in a forested wetland on the southeastern edge of the Adirondack State Park in New York, *N. sylvatica* were found to be 300 to 568 yrs old while the more commercially valuable *Picea rubens* (Sarg.) were 70 to 120 yrs old (N. Pederson, unpubl. data).

Similarly, in a woodlot managed by three generations of a single family near Argyle, N.Y., *Carya glabra* (Mill.) was found to be much older than the larger *Liriodendron tulipifera*. The lack of a wood market for *Carya* in the northern Hudson Valley region (R. Cadieux, Retired N.Y.S. Forester, pers. comm.) was reflected by the releases from competition that corresponded with the oral history of timber harvesting (A. and J. Stott, private landowners, pers. comm.). Likewise, the brief economic viability of *Tsuga canadensis* ((L.). Carr.) for use in leather tanning during the latter portion of the 19th century (Goodman and Lancaster 1990) is one reason why many old-growth forests in the eastern United States contain *T. canadensis*. Thus, in addition to its existence in rugged areas like the bottom of plateau ravines, talus slopes, and wetlands (areas that are not economically conducive to timber harvesting), the historically low economic value of *T. canadensis* likely limited its heavy extraction from the EDF.

Two more examples of ecological indicators of old trees come from eastern Kentucky. First, the forest at the Floracliff State Nature Preserve in the Inner Blue-

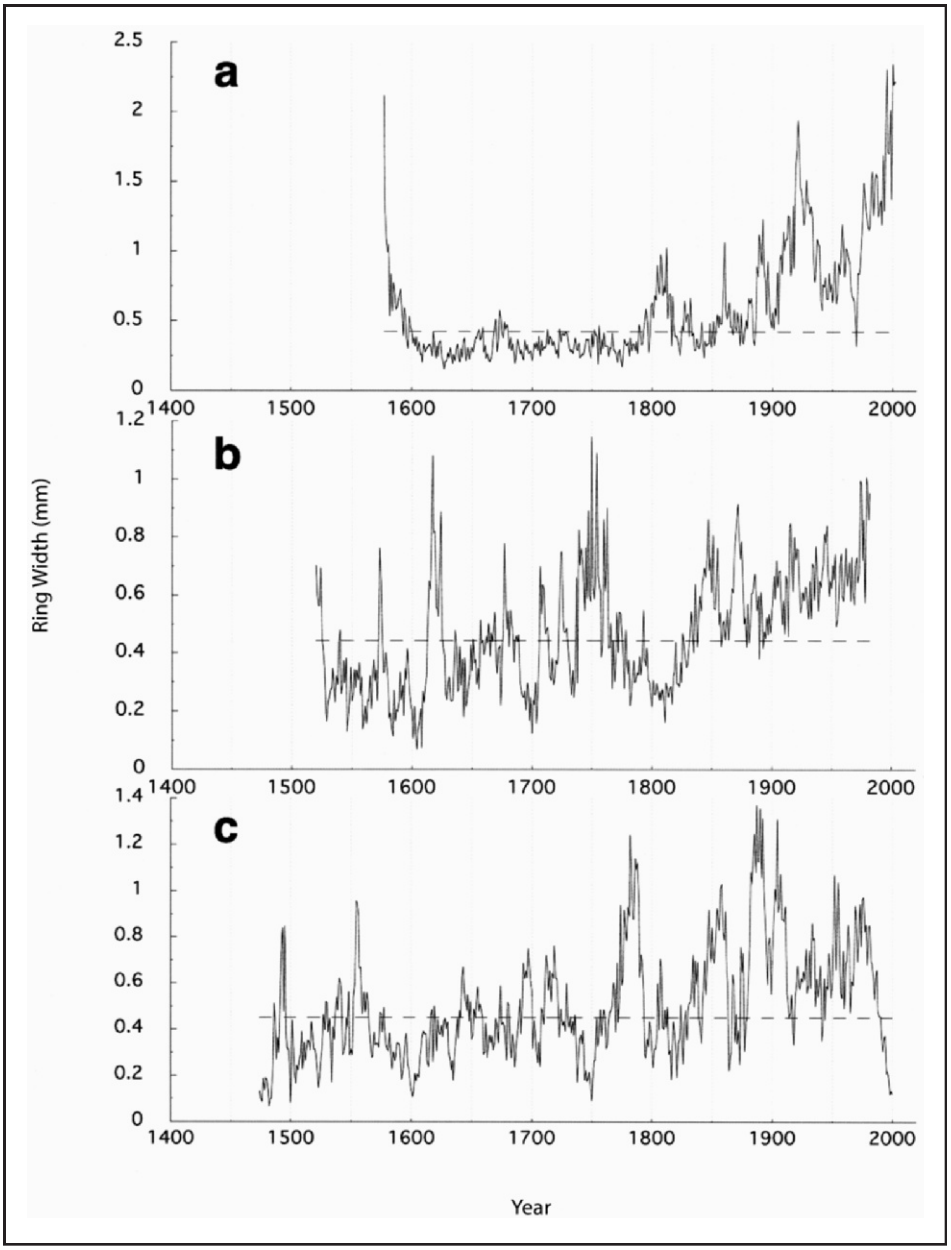

Figure 4. Raw ring width patterns of old a) *Q. montana* (428 yrs), b) *Q. alba* (464 yrs), and c) *N. sylvatica* (536 yrs). The horizontal dashed lines represent media ring width. Note that ring width was predominantly below the median width for much of the first 200 years of each tree's life.

grass Region of Kentucky has many *Q. muehlenbergii* (Engelm.) with bark, bole, and crown indicators of old trees. Because many of these trees have sinuous boles, their economic value is compromised. Therefore, tree architecture within this forest helps account for the presence of old trees within 30 km of the region's second largest city and only 50 km from the first major settlement in Kentucky. An additional factor for the high number old *Q. muehlenbergii* in Floracliff is that the species rarely gets to be of commercial size value regardless of its growth history (Sander 1990). Therefore, a combination of low growth rates and poor tree form results in the persistence of many old *Q. muehlenbergii* in the Inner Bluegrass Region of Kentucky and likely contributes to the same patterns for similar commercially low value taxa in other regions of the EDF and elsewhere.

The second example of an ecological indicator in eastern Kentucky comes from a collection of *Q. montana* on Whittleton Ridge, a heavily cut forest in the Daniel Boone National Forest. A search for old trees along the ridge edge identified seven trees exceeding 200 yrs of age, out of only 25 trees cored. Many of these trees were sinuous or situated near the cliff precipice. Being perched on a cliff edge likely makes the cutting and removal of these trees dangerous, difficult, and not economically viable.

Case Studies

While the characteristics above hold true for many of the EDF species, there appears to be specific characteristics for certain species and ecological setting that should be expanded upon. In the following case studies, I: (1) highlight specific age characteristics for *L. tulipifera*, and (2) describe the ecological setting of an unusually old forest in a second case.

Case Study: *Liriodendron tulipifera*

L. tulipifera, commonly known as yellow-poplar or tulip-poplar, is a fast-growing, shade-intolerant, early-successional species (Beck 1990). Aside from its unique leaf shape and rather large flower for a temperate tree, one of the best identifying characteristics of the species is its straight and often large, columnar trunk. While the bark, trunk, and crown characteristics of old trees described above hold true for this species, including sinuosity (Figure 7), one of the most consistent external characteristics of > 200 year old *L. tulipifera* trees is a broken top (Figure 8). *L. tulipifera* trees with broken tops and reiterations, lateral branches re-forming a new crown below the point of breakage, have often turned out to be at least 200 yrs old, occasionally greater than 300 yrs old and, in one case, > 500 yrs old (Eastern OLDLIST 2010). While trees with broken tops can have thinner crowns, broken tops also suggest a growth history of slower radial growth as stored; and newly-created carbohydrates are likely used to re-establish its crown and leaf area. When broken tops are found on individuals with diameters of medium to larger sizes, it is often the case that these trees have been growing slower than those without severe crown damage.

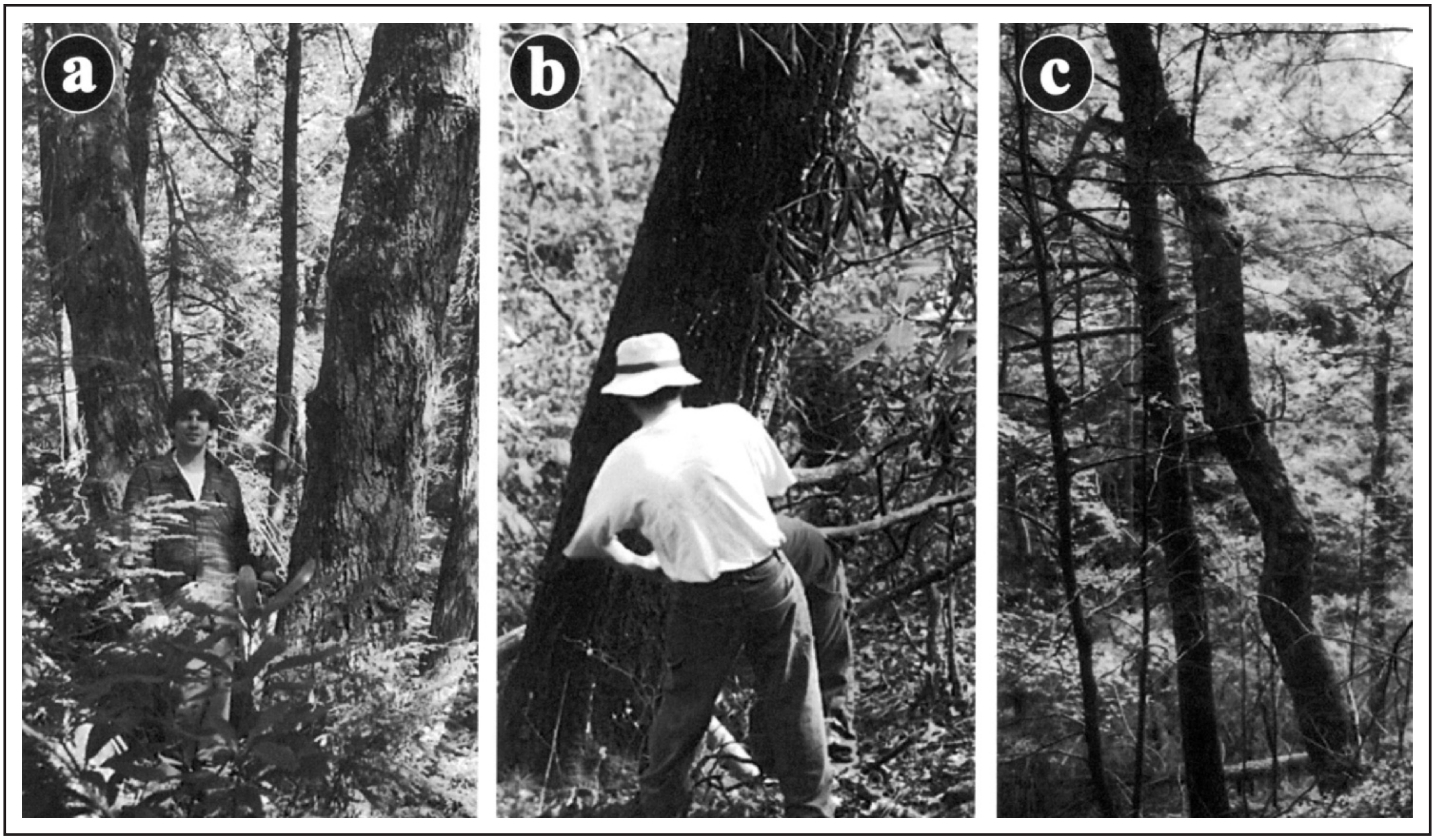

Figure 5. Size does not always infer age. Medium-sized, 400+ yr old *Q. montana* in a) Uttertown, N.J. (47.1 cm dbh, 428 yr old), b) Irish Creek, Va. (56.5 cm dbh, 411 yr old) and c) Otter Creek, Pa. (62.8 cm dbh, 427 yr old) at the time of photograph. Note the sinuosity of the old Otter Creek *Q. montana*.

It is hard to say if significant crown damage to these trees allows for greater ages as resources are shifted from growth to repair and reconstruction; size might be a more important factor in individual growth decline than age (Mencuccini et al. 2005), suggesting that greater longevity occurs in smaller trees. However, a population of a high density of 300+ yr old *L. tulipifer*a grows on acidic sites, which might have reduced growth rates beyond those caused by severe crown damage (North American Dendroecological Fieldweek 2007, unpubl. data). It has been my experience in coring 173 *L. tulipifera* that, of all the indicators of old angiosperms, a broken top with heavy branch reiteration is the most consistent indicator of old age for this species.

Case Study: Uttertown, New Jersey

Observations on the external characteristics of old trees were primarily triggered by a serendipitous traverse from a *Chameacyparis thyoides* (L.) B.S.P. ecosystem near Uttertown, New Jersey. Many scraggily, short, small diameter, but balding trees were observed, especially several unusual-looking *Q. montana* and *Q. rubra*. Closer inspection of crowns, branches, and stems suggested the potential for 250 to 300 yr old trees (Figure 9). Subsequent sampling revealed five of the 20 *Q. rubra* to be ≥ 196 yrs old (oldest = 210 yrs) and seven of the 20 *L. tulipifera* to be ≥ 210 yrs old (three of which were more than 250 yrs old, including the oldest at 273 yrs). Amazingly, of the 29 *Q. montana* cored, five were ≥ 350 yrs old, including three trees between 419 to 427 yrs old. The density of old *Q. montana, Q. rubra*, or *L. tulipifera* seemed a bit unusual (but see Orwig et al. 2001). The consistency of old tree external characteristics of the trees in this forest, balding bark, low volume crowns, sinuous trunks, and thick branches across species, was the first clue to the presence of old trees. However, it is likely that the ecological setting is the primary control of tree architecture and great ages. Much of the forest grows upon undulating, narrow, and acidic sandstone ridges. Median radial increment reflects site conditions, which range from 1.00 mm yr-1 for *Q. montana*, to 1.69 mm yr-1 for *Q. rubra*, and 1.90 mm yr-1 for *L. tulipifera*. It is likely that the slow growth and resulting poor architecture accounts for the presence of a very old forest within 60 km of New York City, a region with 400 yrs of high-impact, land-use history. Even after 200 to 400 yrs of life, most of the trees sampled still do not appear to have much commercial value. It is likely that similar settings throughout the EDF will have more old trees than those with higher levels of potential productivity.

Case Study: Evidence for the Effectiveness of External Characteristics in Identifying Old Trees.

Having noticed the presence of a few large trees at Floracliff State Nature Preserve, Kentucky, the preserve manager requested an investigation of age structure. During the initial visit, I was brought directly to a

Figure 6. Examples of crown characteristics of old trees in the Eastern Deciduous Forest. a) A 348-yr old *Q. muehlenbergii* with a few, large diameter branches in its crown. b) A 342-yr old *Q. montana* with a 'celery top.' The stem snaking through the surrounding canopy only supports a few small branches in its emergent crown.

large *Q. meuhlenbergii* with low branches and a large volume crown, a so-called "wolf" tree. Wolf trees often have tree architecture that suggests a period of growth in a forest with low tree density or pasture environment (Wessels 1997). While large, wolf trees might be younger than assumed because of increased growth rates as a result of reduced competition. After visiting the wolf tree, we discussed external characteristics of potentially old trees until we found the tree in Figure 3a, which greatly aided in conveying the characteristics presented here. Following the field visit and a classroom lecture on the characteristics of old trees, the preserve manager and assistant naturalist re-surveyed Floracliff for trees like those in Figures 3 and 5a (B. James, preserve manager, and A. Wiggs, former field technician, Floracliff Nature Sanctuary, pers. comm.). The subsequent sampling lead to an efficient coring of 20 trees, of which 12 are ≥ 250 yrs and ten ≥ 312 yrs; the oldest (Figure 3a) dates to 1611. It should be noted, however, that the first large tree, the wolf tree, dates to 1636 making it 375 yrs old in 2009. Caveat emptor!

Identification of these old trees at Floracliff was especially important because the coring permit allowed for the coring of only 20 trees. Because we searched much of the preserve before coring the maximum trees allowed, it is highly likely that the Floracliff staff identified the oldest trees in the landscape. Similarly, collection of cores from *Q. montana* on Whittleton Ridge in the Daniel Boone National Forest was limited to 25 trees. The investigators who found the oldest trees were undergraduates who, after two class lectures and two to three lab meetings on the characteristics of old trees, independently found the few *Q. montana* ≥ 200 yrs old in a heavily cutover landscape on Whittleton Ridge. These examples suggest that the information presented in this paper is readily transferable to non-specialists and can aid in the pursuit of old trees across a variety of landscapes.

Summary

Like a book, one cannot judge a tree's age by its external characteristics. And, while it is impossible to know with any certainty the age of a tree without coring, the indicators discussed here are often associated with older trees. In fact, these characteristics were recently put to the test with the discovery of a *Q. montana* on the border between old-growth and second-growth forest (Figure 10). This tree had all of the characteristics described above: balding bark, low stem taper, high stem sinuosity, a celery stalk appearance with thick, gnarled branches, and a medium-sized diameter (41.6 cm dbh). It was, however, suppressed. The real question then became "Could a *Q. montana* survive for more than 200 yrs in the understory?" The answer is a resounding yes! The age of this tree at coring height was 310 yrs.

It is hoped that the transfer of this knowledge will aid in the identification of more old trees and old-growth stands in closed-canopied forests like the Eastern Deciduous Forest. Though these trees are often in plain sight, their identification can be obscured by the commonly held concept that old trees are large. While the characteristics and environmental settings presented here generally signal the potential for old trees, there is no guarantee that they represent old ages. Exceptions abound. For example, in search for an old *Pinus palustris* (Mill.), a flat-topped individual with little taper growing on a sand ridge was spotted and thought perhaps to be more than 200 yrs in age. The core struck the pith. Subsequent analysis revealed the tree's age to be 55 yrs – caveat emptor!

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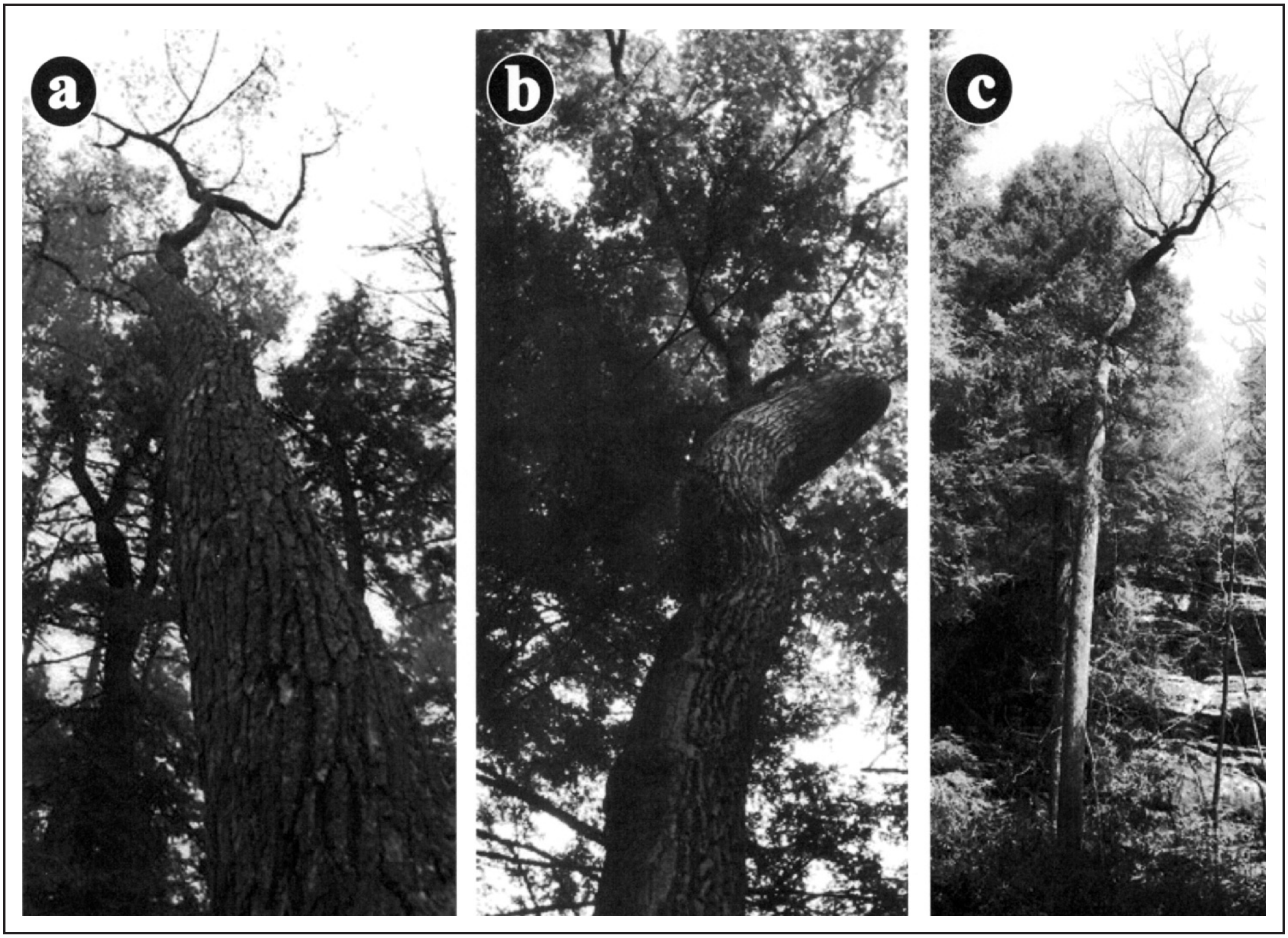

Figure 7. Examples of *L. tulipifera* showing serpentine bole and crown architecture in a) a 257-yr old tree in Uttertown, N.J., b) a 200+ yr old individual in Angel Hollow, Ky. (a hollow tree - minimum tree age is 291 yrs) (A. Cooper, unpubl. data) and c) a 200+ yr old individual in Rock Creek Research Natural Area, Ky. (K. Tackett, unpubl. data).

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Neil Pederson grew up in rural central New York State and spent much time in the Adirondack Mountains where he gained an appreciation for nature. Between his B.S. and M.S. degrees in forest ecology, he worked in the longleaf pine forests of southern Georgia, hardwood forests of northern Vermont, and then forests of Mongolia, China, and Russia before focusing on eastern U.S. forests for his dissertation. Neil taught at Eastern Kentucky University before becoming a scientist at the Tree Ring Laboratory of Lamont-Doherty Earth Observatory and Columbia University, the position he currently holds.

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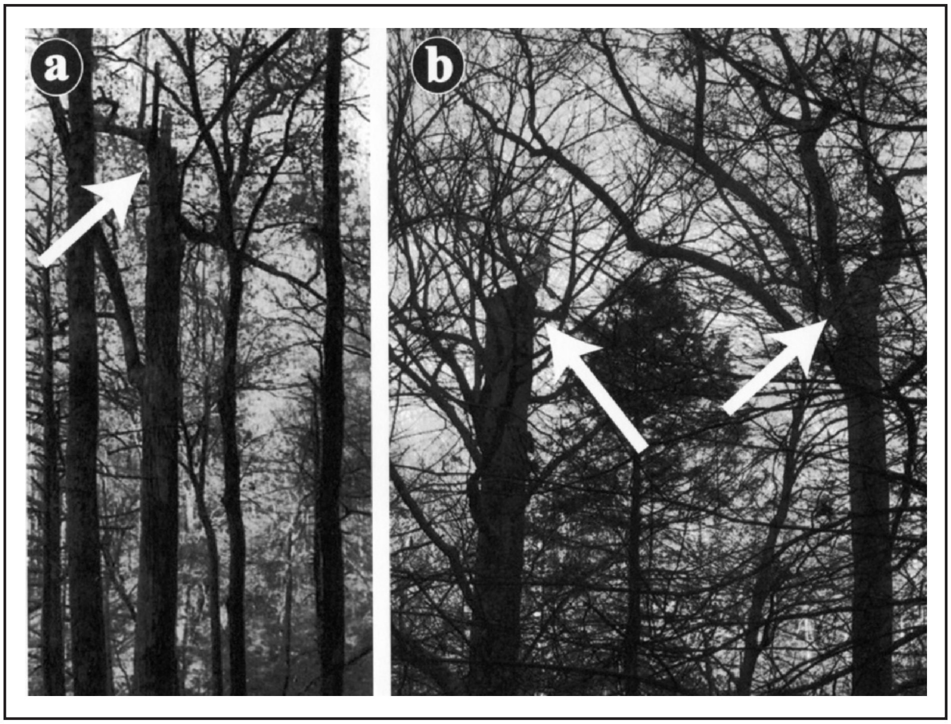

Figure 8. Examples of *L. tulipifera* with broken crowns and reiterations. a) A 250+ yr old tree in central Va. (individual was hollow). b) A 384+ yr old individual, left, and 500+ yr old individual, right, (a hollow tree dated to 1498) in the Great Smoky Mountain National Park, Tenn. Note the celery top crown in the 512+ yr old tree with a dbh of 100 cm. Arrows indicate broken tops.

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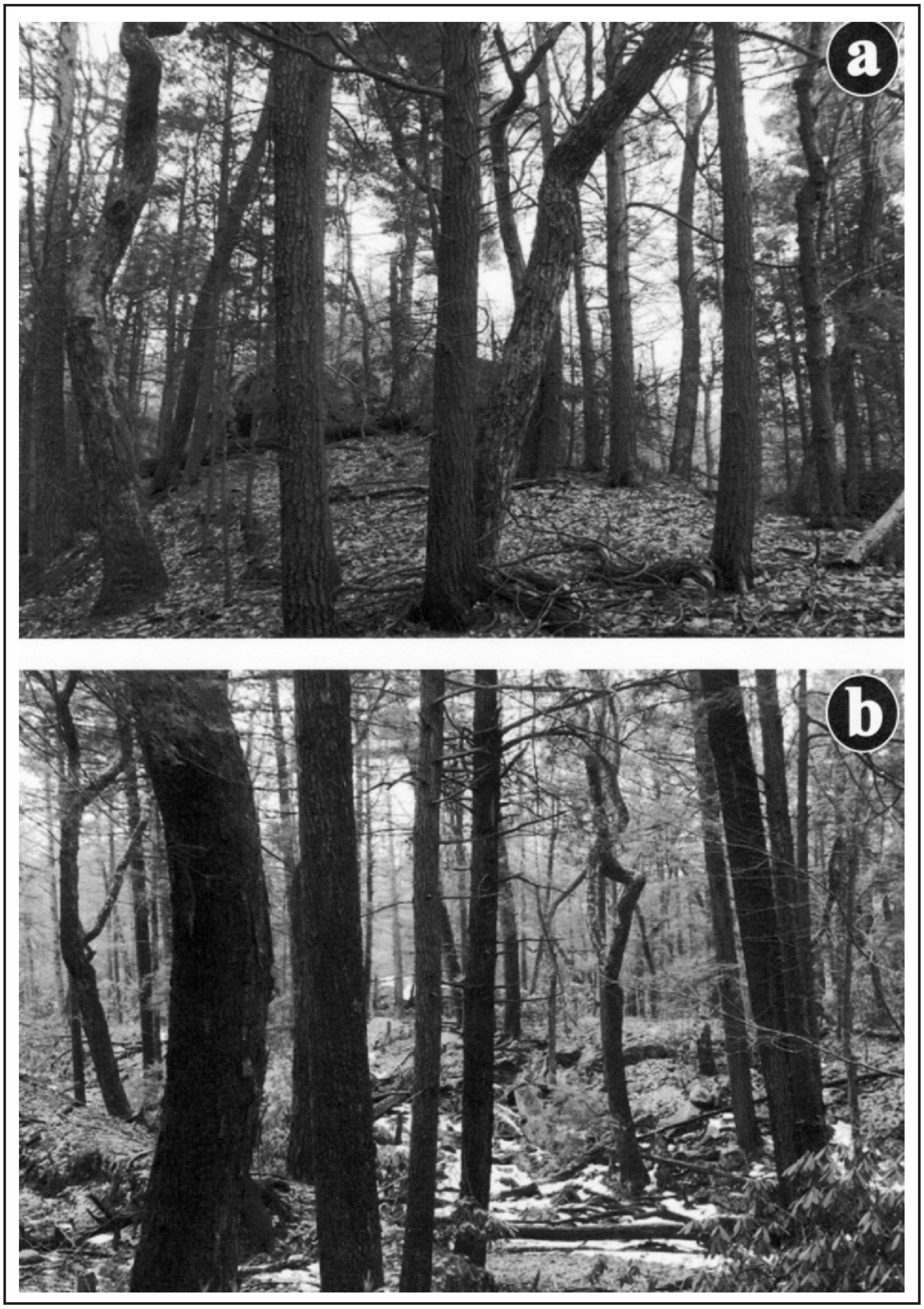

Figure 9. Scenes from the old-growth forest in Uttertown, N.J. a) A sandstone ridge with gnarled *Quercus montana* 250 to 300+ yrs of age. b) More gnarled, stunted trees in Uttertown. The sinuous tree in the foreground left of center is, unfortunately, a hollow *Betula lenta*.

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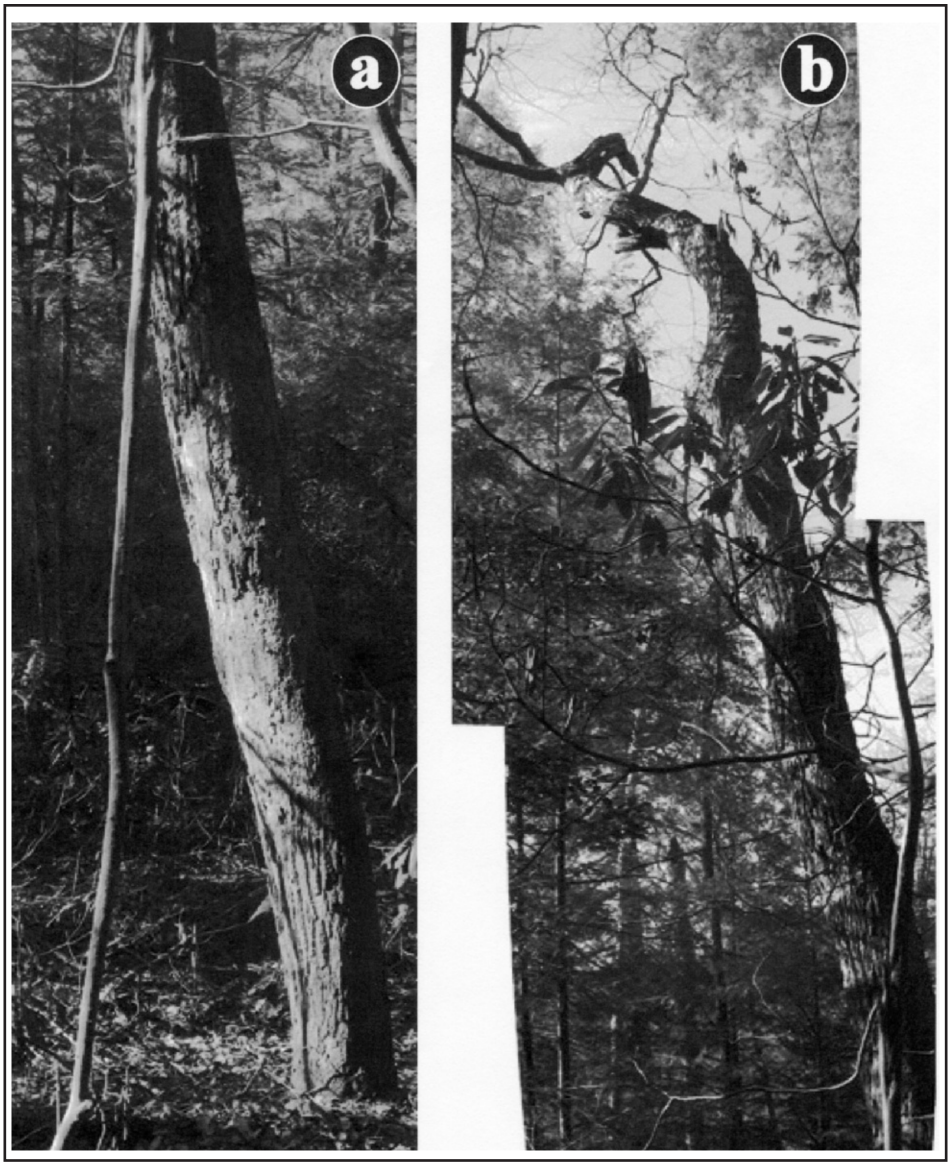

Figure 10. The 'Rosetta Oak' - a 310 yr old *Quercus montana* with all of the featured indicators of old trees. a) The balding and average diameter lower bole (dbh = 41.6 cm) and its b) sinuous, low-tapered upper trunk supporting a celery-topped crown.