MOUNTAIN OAK FORESTS

Contents

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Concept: Mountain Oak Forests occur on Blue Ridge and foothills slopes and ridges and are dominated by various species of *Quercus*. Most of them were once naturally dominated or codominated by *Castanea dentata*. These forests make up much of the mountain landscape at low to moderate elevations and may be extensive at all but the highest elevations.

Distinguishing Features: Mountain Oak Forests are distinguished from most other mountain communities by dominance or codominance by *Quercus* and, formerly, *Castanea dentata*. Rare examples may be dominated bv *Carya* spp. Montane Oak Forests can usually be easily distinguished from Piedmont and Coastal Plain Oak Forests by location on or above the Blue Ridge escarpment, or in rugged areas in the South Mountains, Brushy Mountains, and other mountain-like foothill ranges. They are also distinguished by flora. A large pool of species is typical of the Blue Ridge but is scarce or absent to the east, at least in North Carolina. *Castanea dentata*, still present as root sprouts in many occurrences, was once the most important distinguishing species. *Rhododendron maximum, Rhododendron catawbiense, Rhododendron calendulaceum, Gaylussacia baccata, Pyrularia pubera, Pinus strobus*, *Magnolia fraseri, Tsuga caroliniana, Tsuga canadensis, Magnolia acuminata*, *Acer pensylvanicum*, *Pinus pungens*, and *Pinus rigida* are additional species sometimes in Mountain Oak Forests but rarely present in Piedmont communities. *Quercus falcata, Quercus stellata*, and *Pinus echinata* are typical Piedmont species that are usually absent in Mountain Oak Forests but may be present in particular communities.

Sites: Mountain Oak Forests occur on open slopes, ridge tops, spur ridges, and even low rises and flats in valleys. Slopes are usually convex or planar. These communities range from the lowest elevations to the tops of many mountain ranges or to the edge of the spruce-fir forests around 5500 feet. At low to middle elevations, they generally make up the majority of the natural landscape. At higher elevations, they become increasingly confined to south- and west-facing slopes.

Soils: Most mountain soils, with the exception of wetland soils, can potentially support Mountain Oak Forests. They may have a wide range of depth, rock content, and chemistry. Most soils are Typic Hapludults or Typic Dystrudepts.

Hydrology: Mountain Oak Forests are well drained, and they range from marginally mesic through dry-mesic to almost the driest sites.

Vegetation: Mountain Oak Forests are almost always dominated at least weakly by some combination of *Quercus alba, Quercus rubra, Quercus montana*, or *Quercus coccinea*, with a few unusual sites dominated by some species of *Carya* or by *Quercus velutina*. Most once had *Castanea dentata* as the dominant or codominant canopy tree and have developed stronger oak dominance since its widespread mortality in the early 1900s. Other trees that sometimes form part of the canopy include *Acer rubrum*, any species of *Pinus*, and a variety of mesophytic species shared with Mountain Cove Forest communities. Canopies generally are fairly continuous, though gaps are naturally abundant. Abundant understory tree species in many communities include *Oxydendrum arboreum, Nyssa sylvatica, Cornus florida, Amelanchier arborea,* and *Acer pensylvanicum*, as well as root sprouts of *Castanea dentata*. Many communities have substantial shrub layers dominated by various members of the Ericaceae, especially *Kalmia latifolia,*

Rhododendron maximum, Gaylussacia baccata, Gaylussacia ursina, Vaccinium pallidum, Vaccinium stamineum, and *Rhododendron calendulaceum*. Other shrubs that are widespread include *Pyrularia pubera*, *Ilex montana*, and *Calycanthus floridus*. Herb layers vary widely. Some acid-tolerant species are widespread, including *Chimaphila maculata, Goodyera pubescens, Galax urceolata, Lysimachia fraseri, Maianthemum racemosum, Uvularia* spp., and *Solidago* spp. Less common communities have herbaceous flora more typical of rich soils, many shared with Rich Cove Forests. A suite of herb species characteristic of somewhat open, frequently burned habitats is present in some of the drier communities at lower elevations and probably was more extensive when fire was more frequent.

Dynamics: Under natural conditions, Mountain Oak Forests are uneven-aged, with numerous old trees present but with trees of a broad range of ages intermixed at a fine scale. While most of the remaining forests have been altered by logging, a number of uncut remnants exist where this structure can be observed, and older second-growth stands can be seen beginning to develop this structure. The newer understandings of the role of fire in these communities, discussed below, do not change this understanding. The dominant oaks are among the most long-lived tree species in North Carolina, with maximum life spans of 400-600 years, 300 years for associated hickories (literature summarized in Loehle 1987). Successful regeneration of canopy trees occurs primarily in small canopy gaps caused by the death of one or a few trees. Trees produce irregular seed crops, with mast years resulting in large numbers of seedlings that survive for several years beneath the canopy. The oaks that establish in canopy gaps generally are from this pool of advanced regeneration.

Ongoing processes such as lightning and severe thunderstorms create individual gaps. Occasional extensive disturbances such as hurricanes create many gaps throughout a stand at one time, but most of the individual gaps are small openings the size of one or a few trees. At a stand scale, old-growth is expected over the vast majority of the landscape, while at a fine scale there is dynamic equilibrium of gaps in different stages of succession. The fine-scale dynamics are represented by the state-transition models produced by the Landfire program, though it is difficult to test how accurate the details are. Estimates of gap formation rates have generally been an average of 0.5-1% per year for canopy tree mortality in a wide variety of forests (Lorimer 1980, Lorimer 1989, Greenberg, et al. 1997, Greenberg, et al. 2011). Greenberg, et al. (2011), in Bent Creek Experimental Forest, found an overall average rate of about 1% canopy mortality/year over 15 years. About half was from "oak decline," at a steady rate of 0.5% per year. 0.4% was caused by wind throw, all during two hurricanes. 0.1% was attributable to lightning and unknown causes. However, both the oak decline and wind throw mortality were concentrated on *Quercus coccinea*, a shorter-lived species that has increased in abundance with past logging. Mortality rates were much lower for other species of oaks that are more typically dominant in old-growth forests, with the lowest rates for *Quercus montana*.

Besides wind storms, recent decades have seen several ice storms that caused widespread disturbance, including many small gaps and a short-lived widespread decrease in canopy shade. Abel (1934) noted the impacts of earlier severe ice storms, with oral reports of 4 in the previous 75 years. Oaks were found to be intermediate in sensitivity to ice damage, compared to other species. Damage was greater in pole size stands and uniform canopies, as well as to earlier

successional species such as *Acer rubrum, Robinia pseudo-acacia*, and *Quercus coccinea*, suggesting that ice storms would cause less damage in more natural old-growth forests.

One of the most important dynamic aspects of the present Montane Oak Forests is the ongoing effect of the loss of *Castanea dentata* due to the chestnut blight (*Cryphonectria parasitica*) in the 1920s and 1930s. Root sprouts remain common, though rarely do they become large enough to flower before succumbing to the blight. The effect of the loss of the most abundant tree species acted as a widespread disturbance. Several studies documented how *Quercus rubra, Quercus montana, Quercus alba*, and *Acer rubrum*, already present, quickly filled in the space and led to the tree composition that still dominates these forests (Keever 1953, Woods and Shanks 1959, Karban 1978, McCormick and Platt 1980). Some areas where *Castanea* was more strongly dominant and established oaks could not fill the space regenerated in successional species. Stephenson and Fortney (1998), in Virginia, reported that existing canopy oaks and hickories had filled in the gaps in the 20 years after chestnut mortality. However, by 1993, *Acer rubrum*, scarce before, had drastically increased, and *Quercus rubra* had surpassed the previously dominant *Quercus montana* and abundant *Quercus alba*. Day and Monk (1974) suggest that the dense stands of *Kalmia* and *Rhododendron maximum* resulted from the chestnut blight. It is worth noting that the demise of the chestnut trees occurred near the start of effective fire control and that logging was widespread both before and after it. The coincidence of these changes makes it difficult to determine the most important causes.

Following severe canopy disturbance such as clerarcutting, examples tend to regenerate as even-aged successional forests dominated by *Liriodendron tulipifera*, *Acer rubrum*, and *Robinia pseudo-acacia*, often with large numbers of sprouts of understory species. Various oaks often are present, but in much smaller numbers. Carter, et al. (2000), sampling successional forests in the high rainfall area around Highlands, found *Robinia pseudo-acacia*, *Betula lenta*, and *Liriodendron tulipifera* to be common early successional species over a broad range of environments and elevation, but they also found some *Carya glabra, Quercus coccinea, Quercus rubra*, and *Quercus alba* present in early successional forests in xeric and intermediate sites at mid to high elevations. Somewhat different successional patterns appear to have prevailed after timber harvest in the early 20th century. Most areas regenerated to the characteristic oaks, in unnaturally even-aged stands but without a large component of successional species. This appears to be true both in stands regenerated before the chestnut blight and those regenerated in the several decades after. Because much early logging was at least somewhat selective, unmarketable older oaks often remain in moderate numbers. *Quercus coccinea*, a short-lived oak that responds well to severe disturbance, increased in some stands, even becoming dominant or codominant in some, but apparently not in the majority of stands. *Acer rubrum* is increasing in many oak forests in recent decades but did not become abundant in the canopy after earlier logging. Though potentially long-lived, *Liriodendron* is scarce or absent in older second-growth stands. Dying *Robinia* and snags of this decay-resistant species are visible in many second growth forests but generally do not appear to have been dominant.

Fire has been recognized as an important ecological driver in Mountain Oak Forests, with knowledge increasing rapidly in the last couple of decades. It is increasingly being recognized that fire likely is a crucial process and that the near-universal removal of fire is altering forests. It is generally acknowledged that human-caused fire was frequent after European settlement and

during the widespread logging of the early 1900s, ending abruptly with the advent of fire control in the 1930s. It is more difficult to determine fire regimes before settlement, but Lafon et al. (2017), in their synthesis and meta-analysis of tree ring studies, charcoal studies, and other evidence, indicate that burning was widespread and frequent in pre-European times in the Southern Blue Ridge and Ridge-and-Valley, though less so in the Appalachian Plateau.

It is also difficult to tell how much the presettlement fire regime was human-caused versus natural. Earlier historical explorers reported that Native Americans ignited forests regularly. Such travelers tended to follow Indian paths and stay in Indian villages, giving them a biased view of how much human influence there was on the land, but it is clear that human-caused fires were common at least in those areas. Less clear is how much they changed the frequency, intensity, and seasonality of fire and how much human ignition merely preempted burning that would have happened without them. Though data are sparse, Lafon, et al. (2017) did not find evidence that fire frequencies were greater in areas with dense prehistoric human populations than in sparsely populated areas, nor did frequencies greatly decline in the period after Native American populations were decimated by European diseases but before settlers arrived. Aldrich, et al. (2009), in a long fire history in Virginia, found no significant difference in fire frequency between times of low and very high human presence.

Lightning ignition is believed by many not to be adequate to explain historical fire regimes; however, post-settlement burning is not always differentiated from the less frequent presettlement regime nor is the likely feedback of increased flammability with more burning easy to account for. At present, almost all large wildfires are human-caused. Cohen, et al. (2007) reported 122 fires in 56 years of record in Great Smoky Mountains National Park and 16 fires in 8 more recent years. While a selected set of the latter were allowed to burn and did not become large, it is not known how the other fires would have spread if not suppressed. It is likely those selected to be allowed to burn were those least likely to spread far. In any case, the large number of species that are well adapted to fire suggests a history of fire extending back well before Native American agriculture and, indeed, before human presence in North America. Increasing the amount of fire by prescribed burning and by allowing naturally ignited fires to burn where possible can be expected to be beneficial to oak forests. It may be noted that burning tends to favor more drought-tolerant species, and that burning is additionally likely to make forests better adapted to future climatic warming and drying.

Most natural and human-caused fires were low to moderate in intensity. Because the dominant canopy trees are tolerant of such fires, fire likely was not a major cause of canopy gaps. Instead, as suggested by McEwan, et al. (2013) for an old-growth oak forest in Kentucky, and generalized by Lafon, et al. (2017), fire's primary role was as a filter of the pool of young trees that is present when canopy gaps are formed by wind, lightning, or other natural disturbance. Fire determined what species could regenerate, while the time and location of regeneration of individuals was determined by formation of canopy gaps by wind, lighting, ice, and occasional hotter fires. The dominant oak species, with the exception of *Quercus coccinea*, tolerate fire better than the associated hardwoods as seedlings and saplings as well as mature trees. Allocation of resources to roots makes them better able to sprout repeatedly if burned, giving them an advantage over most trees. *Castanea dentata* too shows adaptation to fire (Belar, et al. 2018).

More frequent fire presumably also led to much lower understory density, longer persistence times for canopy gaps, resulting more open canopies, and denser herb layers than can thrive in the present shady conditions. Forests therefore could support more abundant and diverse shade-intolerant species. These characteristics would make for easier fire spread in these forests. Holzmueller, et al. (2009), looking at oak-hickory forests burned different numbers of times in the Great Smoky Mountains, found increased species richness in burned areas, and this persisted 15-22 years after the fire. The author has observed similar effects of fire, notably including areas where canopy density was not reduced. Oak and hickory seedlings were denser in burned sites. Other tree seedlings were often also dense, but with more variability. Vander Yacht, et al. (2018) reported little effect of single burns without canopy disturbance in Mountain Oak Forests at Green River Game Land. Overall, the studies of effects of prescribed fire across the larger region have led to variable effects on understories and herb layers. It must be noted that the expected effects are the result of a chronic fire regime and its effects on population dynamics. The effects of decades of missing fire are not immediately reversed. The expected higher diversity consists mostly of conservative species adapted to that regime, species that are slow to colonize and that now have reduced populations. More severe prescribed fires and wild fires generally result in the appearance of a few ruderal species in large numbers. These are sometimes mistakenly interpreted as successful restoration of fire-tolerant lower strata, if species are not distinguished or if their ecology is not considered.

There has been growing concern in recent decades that oaks are failing to regenerate throughout the eastern deciduous forest region, including the Blue Ridge and Piedmont of North Carolina (Loftis and McGee 1993, Rodewald 2003, Knott, et al. 2019). While this phenomenon is widespread in the region, details in these sources show substantial variation, including local areas where it does not appear to be occurring. Because the detection of this pattern is at a broad scale, much of the area affected is influenced by ongoing timber management and variation in logging practices.

It can be observed in many Mountain Oak Forests that oaks are scarce or absent in the understory, and other species are gradually replacing them in the canopy. If the prevalence of the introduced Asiatic oak weevil (*Cyrtepistomus castaneus*) found in southern Ohio (Lombardo and McCarthy 2008) is widespread in the Appalachians, it may be contributing to the reduction in oak regeneration by feeding on the roots and leaves of oak seedlings. However, oak seedlings can be observed to be abundant in most Mountain Oak Forests after mast years; it is saplings and understory trees that are scarce. Various shade-tolerant mesophytic trees in the understory are believed to have increased shading on the ground, reducing the survival and growth of the less shade-tolerant oak seedlings. *Acer rubrum* is by far the most common species appearing to replace oak in most Montane Oak Forests, but at higher elevations, *Acer saccharum, Betula alleghaniensis*, and other species of Northern Hardwood Forests also are dense in understories and increasing in overstories. In more mesic oak forests, *Tsuga canadensis* and species of cove forests are abundant in smaller sizes and appear to be increasing. Abella and Shelburne (2003) documented the establishment of *Pinus strobus* and abundance of young pines in an oak forest at Ellicott Rock Wilderness where none had been present before 1900 and few even after 1950. Once a dense understory is established, the forest floor is too shady for oak seedlings to grow to saplings, and the established shade-tolerant trees capture more of the canopy gaps.

The term mesophication has been applied to this process (Nowacki and Abrams 2008), because the tree species that are increasing are more mesophytic than the oaks. Mesophication also changes the environment within the forest, with humidity increased beneath a dense understory, a thicker duff layer developing, and the thinner leaves of mesophytic trees matting down and holding moisture more than oak leaves do. This creates a feedback, whereby the effect of removing fire is to make forests less able to burn. The higher humidity and thicker duff may also favor mesophytic species; however, given the increased root competition with denser vegetation and the lower water use efficiency of most mesophytic species, moisture may not actually be more available to seedlings.

Mesophication is believed to result from lack of fire, though there are views that subtle climate changes could be behind it. McEwan, et al. (2011) and Nowacki and Abrams (2014) cite statistics indicating that the overall range of eastern oak forests was wetter after 1970 than in the earlier 1900s, coinciding with the period of rapid maple increase, and that there were more droughts in the several centuries before 1900. It is very difficult to sort the effects of fire suppression and rainfall shifts from other phenomena, including loss of chestnut, the recovery from extensive logging in the early 1900s, and increasing deer populations.

It should be noted that, though *Acer rubrum* has mesophytic characteristics such as shade tolerance and susceptibility to fire, it has an extremely broad moisture tolerance and does well in dry sites. It also has ruderal characteristics such as prolific seeding, widespread seed dispersal, and rapid seedling growth in high light. It benefitted from the chestnut blight and increased following logging. While the increase of *Tsuga*, *Rhododendron maximum*, *Fagus grandifolia*, and other species suggests a general increase in mesophytic species, their expansion is much more limited. Other species that are not considered mesophytic have also increased and potentially interfere with regeneration of oak and even pines; these include *Nyssa sylvatica, Oxydendrum arboreum,* and *Kalmia latifolia*. The more extensive spread of *Acer rubrum*, along with the increase of *Liriodendron*, may be due to their ruderal characteristics, an accumulating effect of growing seed rain resulting from generations of drastic canopy opening in the landscape by chestnut blight, land clearing, and logging. Nevertheless, this spread would not have happened in a landscape with more frequent fire, and a return to the earlier fire regime begins reversing it. *Acer rubrum* stems can be observed to be killed by fires that do not kill oaks of similar size, across a wide range of sizes. However, given *Acer rubrum's* vigorous sprouting, only repeated fire can reduce its abundance in the long term.

Though there is general agreement that the natural fire regime (or past fire regime whether natural or not) would have produced different forest structure, with more open canopies, the appropriate density is not easily determined. The extreme openness suggested by some managers, such as the thinning to woodland and even savanna density done in the experiments of Vander Yacht, et al. (2018), does not seem supported as a natural condition in the Mountain Oak Forests of North Carolina. The sources they cite in support are in other regions, with different climates. Savannas and barrens such as those found on the fringe of the tallgrass prairies far to the west occurred in North Carolina only on rare extreme soils. The early ecological studies of forests in the Southern Blue Ridge do not depict landscapes of oak savanna. Seminal studies in uncut forests, such as Whittaker (1956), were done within a couple decades of the beginning of effective fire control,

well before a fire-maintained sparse understory could have turned an open savanna into the dense forests he found. y.

It is similarly not well supported that thinning to woodland or savanna density will restore the herb and shrub layers of fire-maintained systems. Indeed, Vander Yacht, et al. (2018), although interpreting their results from thinning as beginning to reverse mesophication, present data showing their North Carolina study area to have drastic increases in *Acer rubrum* and understory species, as well as in *Rubus*, *Rhus*, other ruderal species, and most of the shrub species already present. Though oak saplings increased, the increase in undesired species was much greater. Without repeated fire, the thinned forests in their study will become more dominated by mesophytic species than before. With repeated fire, the burned-only forests would be more dominated by oaks than the thinned forests. The most crucial question for natural area management and ecological restoration, whether oaks would capture canopy gaps that form naturally, does not appear to have been addressed in any of the recent studies of fire effects. Most studies also do not assess herbs in detail. In general, burning can be observed to increase the vigor of any established individuals of most herbaceous species. Where the burn is intense enough to kill many canopy trees, ruderal herbs and briers appear or increase, just as they do with cutting of canopy trees. Establishment of new individuals of the long-lived species expected in regularly burned natural communities generally is sparse and slow in both mild and severe burns.

Appropriate fire return intervals for Mountain Oak Forests are still uncertain but probably are about 10 years. Frost's (1998) small scale map of presettlement fire frequency, based on fire compartment size and vegetational indicators, showed 13-25 years for the western mountains of North Carolina and 8-12 years for the eastern part and the Asheville Basin. Aldrich, et al. (2009), in dry pine sites in Virginia, found mean fire intervals of 7.3-15.9 in different stands, with a wide range of 2-59 years in individual stands. Likely natural fire regimes can also be inferred to some degree from the ecology of the dominant species. More frequent fire would make regeneration of oaks difficult, confining it to rare longer fire-free intervals. Belar, et al. (2018) found physiological and structural characteristics of chestnut saplings that suggest they are more tolerant of shade than *Quercus rubra*, but less tolerant of drought and less able to keep resprouting after multiple top-kills. They concluded chestnut could benefit from occasional fire and from canopy gaps, but their evidence suggests somewhat less fire and less open forest than might be inferred from oak ecology alone.

Besides affecting the structure of oak forests, fire may affect the boundaries between them and adjacent communities. Oaks are naturally present in more mesophytic forests in smaller numbers. Logging may increase their abundance in mesophytic sites. It is unclear how much of the concern about lack of oak regeneration is in sites that may be returning to a naturally lower density of oak after having had it increased by past logging or clearing. Dey and Fan (2008) used the terms "oak accumulator systems" and "recalcitrant oak accumulator systems", noting that in more mesophytic sites oak seedlings are numerous but compete poorly and, being less vigorous, are more prone to being killed by fire. In dry sites, in contrast, fire preferentially benefits oaks.

Along with the increase of mesophytic trees, there has been interest in evergreen heaths in mountain forests. Monk, et al. (1985) noted in their study in chestnut oak forests that both *Rhododendron maximum* and *Kalmia latifolia* plants averaged 38 years, dating them to the 1940s,

with plants of all sizes clustering at that age. Only a couple of individuals were older than the chestnut blight. They note that these species can be an important component of biomass in some forests (though they would be less so in an old-growth forest with larger trees). It is difficult to tell how much of the abundant evergreen heath coverage in the region as a whole is a recent phenomenon, and it is difficult to tell which of several potential causes is most important. Whittaker (1956) found abundant heath communities in the Great Smoky Mountains just a couple of decades after effective fire suppression began and after chestnuts had died. His study included forests that had not been logged. But the extent of heath shrubs on the landscape was not quantified. As with the spread of mesophytic trees, the removal of fire is the most likely cause for whatever expansion has occurred. *Kalmia latifolia* and evergreen *Rhododendron* spp. sprout after burning but less vigorously and less quickly than most hardwood trees or most deciduous shrubs. Deciduous heaths, especially *Gaylussacia baccata, Gaylussacia ursina*, and *Vaccinium pallidum*, can have extensive cover in oak forests as well. All sprout vigorously after burning. The early result of more fire would be more cover of the deciduous species at the expanse of *Kalmia latifolia*, though long term more frequent fire might result in lower density of all.

Oaks are generally more tolerant of drought than other trees species in the region, with the exception of most pine species. *Quercus rubra* generally is associated with more mesic sites, *Quercus montana* with the driest sites, and *Quercus alba* with intermediate moisture levels. *Quercus coccinea* appears to have a broader moisture tolerance, but this species is short lived and appears to have been a smaller component of natural forests than of the younger forests at present. However, Blackmamn and Ware (1982), based on direct measurements of soil moisture at two sites in Virginia, caution against assuming *Quercus rubra* always indicates moister conditions than *Quercus montana*.

Comments: The Mountain region has had a number of studies that have described forest vegetation patterns and classified communities into types. Whittaker (1956) was particularly influential, given its thoroughness at an early date. This work guided and helped structure decades of subsequent site description and more focused studies and was the single largest influence in structuring the mountain forest portion of the 4th approximation and previous approximations. However, its focus was a single mountain range, the Great Smoky Mountains, and in fact was largely confined to the middle and western Tennessee side of the range. Several more recent studies on particular mountain ranges or regions in North Carolina have shown the similarities and contrasts in forest vegetation patterns, including McLeod (1988 – Black and Craggy Mountains) and Newell (1997 – Linville Gorge, Shining Rock Wilderness, Joyce Kilmer-Slickrock Wilderness). All have identified topography and elevation as important factors differentiating communities. Later studies, drawing on the large accumulated body of plot data, especially Ulrey (2002), have identified soil chemistry as an important independent factor.

References:

Abella, S.R. and V.B. Shelburne. 2003. Eastern white pine establishment in the oak landscape of the Ellicott Rock Wilderness, Southern Appalachian Mountains. Catanea 68: 201-210.

Abel, C.A. 1934. Influence of glaze storms upon hardwood forests in the southern Appalachians. Journal of Forestry 32: 35-37.

Aldrich, S.R., C.W. Lafon, H.D. Grissino-Mayer, G.G. DeWeese, and J.A. Hoss. 2009. Three centuries of fire in montane pine-oak stands on a temperate forest landscape. Applied Vegetation Science 13: 36-46.

Belar, E.P., M.R. Saunders, and S.M. Handhaeuser. 2018. Growth traits of juvenile American chestnut and red oak as adaptations to disturbance. Restoration Ecology 26: 712-719.

Blackman, D. and S. Ware. 1982. Soil moisture and the distribution of *Quercus prinus* and *Quercus rubra*. Castanea 47: 360-367.

Carter, R. E., Jr., N.J. Myers, V.B. Shelburne, and S.M. Jones. 2000. Ecological land classification of the high rainfall belt of the Southern Appalachian Mountains. Castanea 65: 258-272.

Cohen, D., B. Dellinger, R. Klein, and B. Buchanan. 2007. Patterns in lightning-caused fires at Great Smoky Mountains National Park. Fire Ecology 3: 68-82

Day, F.P., and C.D. Monk. 1974. Vegetation patterns on a Southern Appalachian watershed. Ecol. 55: 1064-1074.

Dey, D.C. and Z. Fan. 2008. A review of fire and oak regeneration and overstory recruitment. In: Proceedings of the 3rd fire in eastern oak forests conference. USDA Forest Service Northern Research Station General Technical Report NRS-P-46.

Frost, C.C. 1998. Presettlement fire frequency regimes of the United States: a first approximation. In Pruden, T.L. and L. A. Brennan (Eds). Fire in ecosystem management: shifting the paradigm from suppression to prescription. Tall Timbers Fire Ecology Conference Proceedings No. 2. Tall Timbers Research Station, Tallahassee, FL.

Greenberg, C. H., T.L. Kyset, and J.H. Spear. 2011. Temporal patterns of oak mortality in a Southern Appalachian Forest (1991-2006). Natural Areas Journal 31: 131-133.

Holzmueller, E.J., S. Jose, and M. Jenkins. 2009. The response of understory species composition, diversity, and seedling regeneration to repeated burning in Southern Appalachian oak-hickory forests. Natural Areas Journal 29: 255-262.

Karban, R. 1978. Changes in an oak-chestnut forest since the chestnut blight. Castanea 43: 221-228.

Keever, C. 1953. Present composition of some stands of the former oak-chestnut forests in the southern Blue Ridge Mountains. Ecology 34: 44-45.

Knott, J.A., J. M. Desprez, C. M. Oswalt, and S. Fei. 2019. Shifts in forest composition in the eastern United States. Forest Ecology and Management 433: 176-183.

Lafon, C.W., A.T. Naito, H.D. Grissino-Mayer, S.P. Horn, and T.A. Waldrop. 2017. Fire history of the Appalachian region: a review and synthesis. USDA Forest Service Southern Research Station General Technical Report SRS-219.

Loehle, C. 1987. Tree life history strategies: the role of defenses. Canadian Journal of Forest Research 18: 209-222.

Loftis, D. L. and C.E. McGee. 1993. Oak regeneration: serious problems, practical solutions. USDA Forest Service Southern Research Station General Technical Report SRS-84. , Asheville, NC.

Lombardo, J.A. and B.C. McCarthy. 2008. Forest management and Curculionid weevil diversity in mixed oak forests in southeastern Ohio. Natural Areas Journal 28: 363-369.

Lorimer, C.G. 1980. Age structure and disturbance history of a southern Appalachian virgin forest. Ecology 61: 1169-1184.

Lorimer, C.G. 1989. Relative effects of small and large disturbances on temperate hardwood forest structure. Ecology 70: 565-567.

McCormick, J. F. and R. B. Platt. 1980. Recovery of an Appalachian forest following chestnut blight, or Catherine Keever – you were right. American Midland Naturalist 104: 264-273.

McEwan, R.W., J.M. Dyer, and N. Pederson. 2011. Multiple interacting ecosystem drivers: Toward an encompassing hypothesis of oak forest dynamics across eastern North America. Ecography 34: 244-256.

McEwan, R.W., N. Pederson, A. Cooper, J. Taylor, R. Watts, and A. Hruska. 2013. Fire and gap dynamics over 300 years in an old-growth temperate forest. Applied Vegetation Science 17: 312-322.

McLeod, D.E. 1988. Vegetation patterns, floristics, and environmental relationships in the Black and Craggy Mountains of North Carolina. Ph.D. dissertation, University of North Carolina, Chapel Hill.

Monk, C.D., D.T. McGinty, and F.P. Day, Jr. 1985. The ecological importance of *Kalmia latifolia* and *Rhododendron maximum* in the deciduous forest of the southern Appalachians. Bulletin of the Torrey Botanical Club 112: 187-193.

Nowacki, G.J., and M.D. Abrams. 2008. The demise of fire and "mesophication" of forests in the Eastern United States. BioScience 58: 123-138.

Nowacki, G.J. and M.D. Abrams. 2014. Is climate an important driver of post-European vegetation change in the eastern United States? Global Change Biology. Doi: 10.1111/geb 12663.

Rodewald, A.D. 2003. Decline of oak forests and implications for forest wildlife conservation. Natural Areas Journal 23: 368-371.

Stephenson, S.L. and R.H. Fortney. 1998. Changes in forest overstory composition on the southwest-facing slope of Beanfield Mountain in southwestern Virginia. Castanea 63: 482-488.

Ulrey, C.J. 2002. The relationship between soil fertility and the forests of the Southern Appalachian region. PhD dissertation, North Carolina State University.

Vander Yacht, A.L., P.D. Keyser, S.A. Barrioz, C. Kwit, M.C. Stambaugh, W.K. Clatterbuck, and D.M. Simon. 2018. Reversing mesophication effects on understory woody vegetation in mid-southern oak forests. Forest Science (in press).

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs 26: 1-80.

Woods, F.W., and R.E. Shanks. 1959. Natural replacement of chestnut by other species in the Great Smoky Mountains National Park. Ecology 409: 349-361.

KEY TO MOUNTAIN OAK FORESTS

1. Forests (or occasional open woodlands) at high elevations, generally above 4500 feet elevation. Canopy dominated by *Quercus rubra*; except for ecotonal communities with abundant *Quercus montana*, no other oaks are abundant. *Betula alleghaniensis, Fagus grandifolia, Aesculus flava, Acer saccharum*, or other mesophytic hardwoods may approach codominance, or may be more abundant in density but subordinate in basal area .....**High Elevation Red Oak Forest** (see Key A below)

1. Communities at low to high elevation, but not as above.

2. Substrate dolomite or limestone; canopy containing appreciable or codominant *Quercus muhlenbergii* or *Juglans nigra* ..... **Calcareous Oak–Walnut Forest**

2. Substrate not dolomite or limestone; canopy not dominated by *Quercus muhlenbergii* or *Juglans nigra*.

3. Forest dominated by *Quercus rubra*, at low to moderate elevations (generally below 4500 feet), with little or no *Quercus alba* or *Quercus montana*.

4. Low elevation forest (below 3600 feet) dominated by *Quercus rubra* without appreciable *Quercus montana* or *Quercus alba*, and without appreciable numbers of more mesophytic species (sometimes with abundant *Carya glabra* or other species). ..... **Low Montane Red Oak Forest**

4. Low to moderate elevation forest on sheltered concave slopes, codominated by *Quercus rubra* along with diverse mesophytic species such as *Betula lenta, Tilia americana* var. *heterophylla, Aesculus flava*, and *Magnolia acuminata*, with a lush herbaceous layer .... **Rich Cove Forest (Red Oak Subtype) in Montane Cove Forests**

3. Forest low to high elevation but dominated or codominated by other *Quercus* species (though *Quercus rubra* may be codominant.

5. Forest containing appreciable amounts of *Quercus alba*, which may be dominant, codominant, or less abundant but making up more than 10% of the canopy cover or basal area.

6. Rare forests of exposed high elevation sites, above 4500 feet, strongly dominated by *Quercus alba* .....**High Elevation White Oak Forest**

6. Forests with *Quercus alba* weakly dominant or present in a mix with several other species such as *Quercus rubra, Quercus montana, Quercus coccinea*, and *Carya* spp; rare to common, at low to high elevation, on exposed or sheltered, convex or concave slopes..... ..... **Montane Oak–Hickory Forest** (see key C below).

5. Forest dominated *Quercus montana, Quercus coccinea*, rarely Q*uercus velutina*, sometimes with abundant pines, without as much as 10% *Quercus alba*. Most often on convex topography of ridges or sharp ravines, but may cover large parts of the landscape .... **Chestnut Oak Forest** (see key B below)

Key A. High Elevation Red Oak Forest

1. Forest on a well-developed boulderfield, with large, detached rocks covering near 100% of the ground surface, generally with open spaces between and beneath many of the boulders; soil consisting of pockets of material accumulated on or between boulders; herb and shrub layers sparse and containing species capable of growing on rock or in shallow soil.

1. Forest not on a well-developed boulderfield, though substantial loose rock or bedrock may be present; shrub and herb layer various but their structure and composition not greatly affected by boulder cover.

2. Community occurring on sharp ridge tops or shallow soils; shrub layer dense, and dominated by evergreen, generally ericaceous, species

3. Canopy notably open and stunted.... **High Elevation Red Oak Forest (Stunted Woodland Subtype)**

3. Canopy not notably open and stunted..... .**High Elevation Red Oak Forest (Heath Subtype)**

2. Community occurring on slopes or broader ridgetops, on a variety of soils; shrub layer open to moderate, predominantly of deciduous species.

4. Herb layer containing significant numbers of species shared with Rich Cove Forests, such as *Actaea racemosa*, *Collinsonia canadensis*, *Solidago curtisii*, *Sanguinaria canadensis*, and *Caulophyllum thalictroides*. Canopy containing species of rich mesophytic sites, such as *Acer saccharum*, *Prunus serotina, Carya ovata*, and *Tilia americana* var. *heterophylla*. Substrate amphibolite, calc-silicate, or other mafic or calcareous rock ..... **High Elevation Red Oak Forest (Rich Subtype)**

4. Herb layer sparse to dense, but lacking species of rich mesophytic sites as above. Canopy lacking species of rich sites, though it may have other species typical of Northern Hardwood Forest.

5. Forest structure orchard-like, with trees somewhat stunted but canopy not notably open, with limited understory and shrub layer, and with a dense but not rich herbaceous layer generally dominated by *Carex pensylvanica* or *Angelica triquinata* ..... **High Elevation Red Oak Forest (Orchard Forest Subtype)**

5. Forest structure more typical, not orchard-like; generally with a moderate understory and deciduous shrub layer, and with a sparse to moderately dense herb layer with a greater variety of species..... **High Elevation Red Oak Forest (Typic Herb Subtype)**

Key B. Chestnut Oak Forest

1. Forest on a well-developed boulderfield, with large, detached rocks covering near 100% of the ground surface, generally with open spaces between and beneath many of the boulders; soil consisting of pockets of material accumulated on or between boulders; herb and shrub layers sparse and containing species capable of growing on rock or in shallow soil. ..... **Chestnut Oak Forest (Boulderfield Subtype)**

1. Forest not on a well-developed boulderfield, though substantial loose rock or bedrock may be present; shrub and herb layer various but their structure and composition not greatly affected by boulder cover.

2. Canopy with *Pinus strobus* naturally occurring in more than minor amounts, often codominant; (Note that *Pinus strobus* may be introduced in plantations or old fields, occasionally by under planting, and that its abundance where it naturally occurs may be increased or decreased by logging and alteration of fire regimes. This subtype applies to areas where its presence appears natural ..... **Chestnut Oak Forest (White Pine Subtype)**

2. Canopy without *Pinus strobus* naturally present, or present in only small amounts.

3. Trees in addition to *Quercus montana* and *Quercus coccinea* more xeric, generally *Pinus* spp., or *Quercus velutina*; shrub layer dense to moderate, dominated by *Kalmia latifolia, Gaylussacia baccata, Gaylussacia ursina*, *Vaccinium pallidum,* or occasionally *Rhododendron minus, Rhododendron carolinianum,* or other evergreen Ericaceae; if *Rhododendron maximum* is abundant, more xerophytic shrubs are also abundant; community on ridge tops, upper slopes, spur ridges, or convex slopes. ..... **Chestnut Oak Forest (Dry Heath Subtype)**

3. Trees in addition to *Quercus montana* more mesophytic, generally *Quercus rubra* or species shared with Acidic Cove Forest; lower strata various.

4. Community occurring on north-facing slopes, sheltered slopes, or other mesic areas; shrub layer usually dense, dominated by *Rhododendron maximum*; canopy usually containing mesophytic species such as *Betula lenta*, *Liriodendron tulipifera, Halesia tetraptera, Betula alleghaniensis*, or *Tsuga canadensis.* ..... **Chestnut Oak Forest (Mesic Subtype)**

4. Occurring on a variety of topography, but not generally strongly mesic sites; shrub layer sparse to moderate, dominated by deciduous species such as *Rhododendron calendulaceum, Vaccinium stamineum, Pyrularia pubera*, or other species of less extreme sites; herb layer sparse to dense,

containing widespread species of acidic forests or occasionally species of basic soils.....
.....**Chestnut Oak Forest (Herb Subtype)**

Key C. Montane Oak–Hickory Forest

1. Forest on a well-developed boulderfield, with large, detached rocks covering near 100% of the ground surface, generally with open spaces between and beneath many of the boulders; soil consisting of pockets of material accumulated on or between boulders; herb and shrub layers sparse and containing species capable of growing on rock or in shallow soil. .....
..... **Montane Oak–Hickory Forest (Boulderfield Subtype)**

1. Forest not on a well-developed boulderfield, though substantial loose rock or bedrock may be present; shrub and herb layers various but their structure and composition not greatly affected by boulder cover.

2. Forest occurring at low elevations on sites with westerly or southerly aspect or otherwise dry. Canopy containing species typical of low elevation dry areas, particularly *Pinus echinata*, *Quercus falcata*, and *Quercus stellata*, though *Quercus alba*, *Quercus montana*, and *Quercus coccinea* generally dominate and pines are not codominant; herb layer naturally containing species typical of dry, fire maintained areas, such as *Schizachyrium scoparium, Baptisia tinctoria, Iris verna* var. *smalliana*, *Viola pedata*, and *Silphium reniforme*, though these may have become confined to edges or have been lost due to exclusion of fire.

3. Community occurring on mafic rock substrate; additionally containing species indicative of basic soil conditions, such as *Fraxinus americana, Fraxinus biltmoreana, Frangula caroliniana, Rosa carolina*, or *Ptelea trifoliata. .....* **Montane Oak–Hickory Forest (Low Dry Basic Subtype)**

3. Community lacking species indicative of basic soil conditions; all species acid-tolerant .....
..... **Montane Oak–Hickory Forest (Low Dry Subtype)**

2. Community occurring at low to high elevation, but in less dry sites and lacking the above suite of species indicating low elevation dry conditions.

4. Community occurring on mafic or calcareous rock substrate; herb layer containing significant numbers of species shared with Rich Cove Forests, such as *Actaea racemosa*, *Collinsonia canadensis*, *Solidago curtisii*, *Sanguinaria canadensis*, and *Caulophyllum thalictroides; c*anopy containing species of rich mesophytic sites, such as *Acer saccharum*, *Prunus serotina, Carya ovata*, and *Tilia americana* var. *heterophylla*, though usually dominated by *Quercus rubra*, *Quercus alba*, and *Carya* spp.
..... **Montane Oak–Hickory Forest (Basic Subtype)**

4. Community occurring on felsic rock or other acidic rocks; lacking species indicative of basic soil conditions.

5. Canopy with *Pinus strobus* naturally occurring in more than minor amounts, often codominant; (Note that *Pinus strobus* may be introduced in plantations or old fields, occasionally by under planting, and that its abundance where it naturally occurs may be increased or decreased by logging and alteration of fire regimes. This subtype applies to areas where its presence appears natural .....**Montane Oak–Hickory Forest (White Pine Subtype)**

5. Community lacking *Pinus strobus* as a natural codominant or abundant species; canopy generally dominated by combinations of *Quercus alba, Quercus montana*, and *Quercus rubra*, with varying amounts of *Carya* spp.....**Montane Oak–Hickory Forest (Acidic Subtype)**

HIGH ELEVATION RED OAK FOREST (TYPIC HERB SUBTYPE)

Concept: High Elevation Red Oak Forests are *Quercus rubra* or one-time *Castanea dentata–Quercus rubra* forests, without *Quercus alba,* at higher elevations, generally above 3500 feet and ranging up to the highest elevations of any oak forest. The Typic Herb Subtype includes the central concept of the type, the most widespread and abundant of High Elevation Red Oak Forest subtypes. Herbs and deciduous shrubs generally occur at moderate density.

Distinguishing Features: High Elevation Red Oak Forests are distinguished by having *Quercus rubra* dominating the canopy cover or basal area under current natural conditions (with *Castanea* largely eliminated), having no appreciable presence of *Quercus alba*, and occurring at elevations above about 3500 feet. *Quercus rubra* predominates over *Picea rubens* and over the mesophytic hardwoods of Northern Hardwood Forest, at least among older canopy trees. High Elevation Red Oak Forest is distinguished from Montane Oak–Hickory Forest, which may have abundant *Quercus rubra*, by having less than 10% *Quercus alba* in the canopy.

The Typic Herb Subtype is distinguished by not meeting the criteria for the other subtypes. It has a shrub layer dominated by deciduous species rather than evergreen, or a sparse shrub layer with less than 20% cover, and an herb layer that may vary widely in density and species composition but which is not a dense lawn of *Carex pensylvanica*. The flora lacks significant presence of species indicative of less acidic soils with higher base saturation, such as *Fraxinus americana, Tilia americana var. heterophylla, Actaea racemosa, Caulophyllum thalictroides, Prosartes lanuginosa, Collinsonia canadensis*, and *Sanguinaria canadensis*. This subtype is distinguished from the Stunted Heath Subtype by having a full stature canopy, more than 8 meters tall unless very young.

Synonyms: *Quercus rubra / (Vaccinium simulatum, Rhododendron calendulaceum) / (Dennstaedtia punctilobula, Thelypteris noveboracensis*) Forest (CEGL007300).
Ecological Systems: Central and Southern Appalachian Montane Oak Forest (CES202.596).

Sites: High Elevation Red Oak Forests occur on open slopes and ridge tops, usually on convex topography. They range from a low of around 3500 feet elevation to the upper elevation limit of oak forests, around 5900 feet. Most are on warm slope aspects (south and west), though they may be on cooler aspects at lower elevations.

Soils: A wide variety of soil series is mapped. Porters (Humic Dystrudept), Wayah (Typic Humadept), and Chestnut (Typic Dystrudept) are most frequent. Most other mapped soils are Inceptisols, but some are Ultisols.

Hydrology: Sites are well-drained but mesic due to cool temperatures and high rainfall at their high elevations.

Vegetation: The forest canopy is dominated by *Quercus rubra*, probably usually var. *ambigua*, and may be closed or somewhat open. Before the chestnut blight, some examples had *Castanea dentata* codominant but this species apparently was less dominant than in other oak forests (Whittaker 1956). *Quercus montana* may codominate in lower elevation transitional examples.

Mesophytic hardwoods, particularly *Betula alleghaniensis, Fagus grandifolia*, *Acer rubrum*, or *Acer saccharum* may codominate in many examples. The same mesophytic species often dominate the understory. CVS plot data show *Acer pensylvanicum* and *Amelanchier arborea* fairly constant and *Magnolia fraseri* less frequent but sometimes dominant in the understory. The shrub layer usually is sparse to open, though it may be dense. *Castanea dentata* sprouts, *Rhododendron calendulaceum*, *Ilex montana*, and *Vaccinium corymbosum* are the most constant species and sometimes dominant. Other species that sometimes dominate include *Vaccinium corymbosum, Vaccinium erythrocarpum, Vaccinium simulatum*, *Corylus cornuta, Viburnum acerifolium, Hamamelis virginiana, Gaylussacia ursina*, and, in forests with canopy disturbance, *Rubus canadensis* or *Rubus alleghaniensis*. The evergreen shrubs *Rhododendron maximum, Kalmia latifolia, Rhododendron catawbiense*, or *Rhododendron minus* may be present in small numbers. The herb layer ranges from dense to sparse. Plot data show *Parathelypteris noveboracensis* and *Dennstaedtia punctilobula* with high constancy and sometimes overwhelmingly dominant. Other high constancy species that do not tend to dominate include *Lysimachia quadrifolia, Medeola virginica, Dioscorea villosa*, *Maianthemum racemosum,* and *Conopholis americana*. Other species that may dominate in plots include *Athyrium asplenioides, Carex pensylvanica, Ageratina altissima* var. *roanensis, Anemone quinquefolia,* and *Maianthemum canadense*. A diverse suite of herbs may occur less frequently, including *Clintonia umbellula, Arisaema triphyllum, Eurybia chlorolepis, Osmundastrum cinnamomeum, Osmundastrum claytoniana, Nabalus latissimus, Nabalus serpentaria, Goodyera pubscens, Polystichum acrostichoides, Silene stellata, Stellaria pubera, Oclemena acuminata*, and *Amianthium muscitoxicum*. Natural Heritage Program descriptive reports and local studies report similar composition (e.g., Day and Monk 1974, DeLapp 1978, Elliott and Hewitt 1997, McLeod 1988, Newell 1997, Rohrer 1983, Whigham 1969).

Range and Abundance: Ranked G4. The Typic Subtype occurs throughout the mountains of North Carolina, in every range that reaches 4000 feet. The equivalent association ranges from Georgia northward to West Virginia.

Associations and Patterns: High Elevation Red Oak Forest occurs in large patches below the spruce-fir forests in the highest mountain ranges and at the tops of lower and more southerly ranges. In the zone where it is abundant, it often occurs in a mosaic, occupying the warmer slope aspects while Northern Hardwood Forest occupies the cooler. It may grade to Montane Oak–Hickory Forest or Chestnut Oak Forest at lower elevations. The Typic Herb Subtype may grade to the Heath Subtype on sharper topography or shallower soils and may abruptly transition to the Rich Subtype if the geologic substrate changes.

Variation: The Typic Herb Subtype shows substantial variation in its lower strata, but it is not obvious how to structure it into variants. Whittaker (1956) indicated that higher elevations had less *Castanea dentata* originally and therefore less alteration by the chestnut blight. He suggested many of the differences between high and low elevations might be the result of that different disturbance, but the previous difference in *Castanea* abundance hints at other elevation-related differences as well. DeLapp (1978) classified High Elevation Red Oak Forest into seven phases. Three would fall within the Typic Herb Subtype. His deciduous heath phase and mixed fern phase do not seem distinguishable in later experience. His third phase, described as having dense *Corylus cornuta*, is intriguing, as this species is not at all frequent in the CVS plots for this community, and only one plot has as much as 10-25% cover. Other communities where the author has observed

Corylus cornuta appear to fit the Rich Subtype better. Given this uncertainty, no variants are recognized.

Dynamics: The Typic Subtype is similar to most Montane Oak Forests in its dynamics, including natural occurrence as uneven-aged, old-growth forests and in having most tree regeneration in small to medium canopy gaps. However, its location at higher elevation likely leads to more exposure to disturbance by wind and ice and less by drought. It is somewhat uncertain how fire dynamics compare to those in other oak forests, though fire is believed to be important. The cooler, moister climate, shorter growing season, greater snowfall, and the association with less flammable Northern Hardwood Forests might suggest less frequent fire; however, the location at tops of slopes, where fires can spread from extensive slopes below, may compensate for this.

It is widely observed that many examples of High Elevation Red Oak Forest, particularly of this subtype, have a dense understory of mesophytic trees characteristic of Northern Hardwood Forest canopies (*Betula alleghaniensis, Aesculus flava, Acer saccharum*, and others). *Quercus rubra* is often scarce or absent from the understory, and the forests appear to be succeeding to Northern Hardwood Forest. Patches where old canopy oaks have died may already be dominated by these species, though they can generally be recognized as belonging to a surrounding stand still dominated by *Quercus rubra*. The failure of oak regeneration and the transition to mesophytic hardwoods seems to be more pronounced or faster than in lower elevation oak forests. As in those forests, the likely reason is loss of fire. *Quercus rubra* appears to be less tolerant of fire than the dominants of other Montane Oak Forests, but it is more tolerant than the thin-barked mesophytic species with which it competes.

Comments: Communities comparable to High Elevation Red Oak Forests have been recognized in most plot classification studies, such as McLeod (1988), Newell (1997), and Ulrey (2002), as well as Whittaker (1956) and earlier works. Most recognize only a single class corresponding to High Elevation Red Oak Forest. Where more classes are recognized (e.g., Newell 1997), the boundaries placed on their units do not always correspond closely with those of the Typic Herb Subtype. DeLapp (1978) conducted detailed analysis of High Elevation Red Oak Forests, recognizing several subdivisions comparable to most of the subtypes now recognized.

Some literature specifically indicates that the oak in this community is the taxon now called *Quercus rubra* var. *ambigua*, but most sources do not distinguish varieties. Weakley (2018) indicates a break in elevational range of the two varieties near the lower limit of High Elevation Red Oak Forest, but it is not known if this community is exclusively characterized by the higher elevation variety.

Rare species: Vascular plants – *Lilium grayi, Lysimachia fraseri, Platanthera peramoena, Rhododendron vaseyi, Robinia hispida* var. *kelseyi*, *Thermopsis mollis*. Nonvascular plants – D*icranum undulatum*. Animals – *Aegolius acadicus, Catharus guttatus, Coccyzus erythropthalumus, Parus atricapillus, Sphyrapicus varius.*

References:

Day, F.P., Jr., and C.D. Monk. 1974. Vegetation patterns on a southern Appalachian watershed. Ecol. 55: 1064-1074.

DeLapp, J.A. 1978. Gradient analysis and classification of the high elevation red oak community of the Southern Appalachians. M.S. Thesis, North Carolina State University, Raleigh.

Elliott, K.J., and D. Hewitt. 1997. Forest species diversity in upper elevation hardwood forests in the Southern Appalachian Mountains. Castanea 62: 32-42.

McLeod, D.E. 1988. Vegetation patterns, floristics, and environmental relationships in the Black and Craggy Mountains of North Carolina. Ph.D. dissertation, University of North Carolina, Chapel Hill.

Newell, C. L. 1997. Local and regional variation in the vegetation of the Southern Appalachian Mountains. PhD. Dissertation, University of North Carolina, Chapel Hill.

Rohrer, J.H. 1983. Vegetation patterns and rock type in the flora of the Hanging Rock Area, North Carolina. Castanea 48: 189-205.

Ulrey, C.J. 2002. The relationship between soil fertility and the forests of the southern Appalachian region. PhD. Dissertation, North Carolina State University, Raleigh.

Valentine, D.W. 1983. Forest vegetation distribution in relation to soils and other environmental characteristics in the Black Mountains of North Carolina. M.S. Thesis, Duke University.

Weakley, A.S. Flora of the Southern and Mid-Atlantic States. Working Draft of 20 August 2018.

Whigham, D.F. 1969. Vegetation patterns on the north slopes of Bluff Mountain, Ashe County, North Carolina. J. Elisha Mitchell Scientific Society 85: 1-15.

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs 26: 1-80.

HIGH ELEVATION RED OAK FOREST (RICH SUBTYPE)

Concept: High Elevation Red Oak Forests are *Quercus rubra* or one-time *Castanea dentata-Quercus rubra* forests, without *Quercus alba,* at higher elevations, generally above 3500 feet. The Rich Subtype includes red oak forests of mafic rock or comparable substrates, whose flora contains species typical of high pH, base-rich sites.

Distinguishing Features: High Elevation Red Oak Forests are distinguished by having *Quercus rubra* making up more than 50 percent of the canopy cover under current natural conditions (with *Castanea* largely eliminated), while occurring at elevations above about 3500 feet. The Rich Subtype is distinguished from all other subtypes by having a substantial presence of base-loving plants. *Fraxinus americana* and *Acer saccharum* are generally important in the canopy, and *Prunus serotina, Aesculus flava*, and *Tilia americana var. heterophylla* may also be present. Herbs more typical of Rich Cove Forest, such as *Actaea racemosa, Caulophyllum thalictroides, Prosartes lanuginosa, Collinsonia canadensis, Sanguinaria canadensis*, and *Impatiens pallida*, are abundant. Ericaceous shrubs are not dominant but may be present in small numbers.

It can be difficult to distinguish the Rich Subtype from Rich Cove Forests at its lower elevations. *Quercus rubra* also dominates in Rich Cove Forest (Red Oak Subtype) and can be abundant in other subtypes of Rich Cove Forest, especially in ecotonal areas. The classification of High Elevation Red Oak Forest (Rich Subtype) should be used where *Quercus rubra* dominance is extensive in a stand that is primarily on exposed or convex slopes; it should not be used in ecotones where the combination of oak dominance with rich herbs is narrow. Rich Cove Forest (Red Oak Subtype) occurs on concave slopes in upper drainages, and grades to other subtypes of Rich Cove Forest below. The floristic differences among these communities need further clarification. High Elevation Red Oak Forest (Rich Subtype), while sharing many herbaceous species with Rich Cove Forest, typically has them at lower density and has different species dominant.

Synonyms: *Quercus rubra - Fraxinus americana - Acer saccharum / Actaea racemosa - Caulophyllum thalictroides - Collinsonia canadensis* Forest (CEGL004256).
Ecological Systems: Central and Southern Appalachian Montane Oak Forest (CES202.596).

Sites: The Rich Subtype occurs on open slopes and ridge tops comparable to those of the Typic Herb Subtype but with a substrate of amphibolite, calc-silicate, or other mafic or calcareous rock. Examples range from 3500 feet or a bit lower up to about 5500 feet elevation.

Soils: Most examples are mapped as Porters (Humic Dystrudept), some as Edneyville (Typic Dystrudept), or Unaka (Humic Dystrudept). A wide variety of other series is mapped occasionally, most Inceptisols but some Ultisols.

Hydrology: Sites are well-drained but mesic due to cool temperatures and high rainfall at their high elevations.

Vegetation: This community's close-to-somewhat-open canopy is dominated by *Quercus rubra*, but often only weakly so. The oak probably is usually var. *ambigua*. Some examples had *Castanea dentata* codominant; it is unclear if Whittaker's (1956) observation of less *Castanea* in red oak

forest applies to this subtype or not. A varying set of species characteristic of rich mesophytic sites is present in the canopy; one may codominate or they may collectively make up a moderate to large minority of the canopy. CVS plot data and extensive observations show high constancy and sometimes high cover for *Acer saccharum, Prunus serotina, Fraxinus americana, Tilia americana* var. *heterophylla*, *Betula lenta, Carya ovata, Carya cordiformis, Magnolia acuminata, Aesculus flava, Acer rubrum, Carya glabra*, and *Betula alleghaniensis*. These same species may make up much of the understory, though *Acer pensylvanicum, Amelanchier laevis, Crataegus macrosperma*, or *Ostrya virginiana* may dominate the understory instead. Shrubs generally have low cover, and only a few species, *Castanea dentata* sprouts, *Ilex montana*, and *Rhododendron calendulaceum*, have constancy as high as 50%. *Hydrangea arborescens* and *Ribes cynosbati* are are also fairly frequent. Vines are not prominent, but *Isotrema macrophyllum* or *Parthenocissus quinquefolia* may be locally abundant. The herb layer is moderate in density. In CVS plots, *Solidago curtissii* is almost always present but not often dominant, but in observations later in the growing season it often is dominant. *Agertina altissima* var. *roanensis*, *Eurybia chlorolepis*, *Parathelypteris noveboracensis*, and *Carex pensylvanica* also may dominate sizeable areas at least in some seasons. A diversity of herbs typical of rich sites is usually present, along with most of the species abundant in the Typic Herb Subtype. Species with high constancy in CVS data include *Prosartes lanuginosa, Arisaema triphyllum, Collinsonia canadensis, Sanguinaria canadensis, Maianthemum racemosum, Dioscorea villosa, Caulophyllum thalictroides, Conopholis americana, Polystichum acrostichoides, Actaea racemosa, Asclepias exaltata, Clintonia umbellula, Ligusticum canadense, Botrypus virginianus, Silene stellata, Stellaria pubera, Geranium maculatum, Lysimachia quadrifolia, Veratrum parviflorum, Athyrium asplenioides, Eutrochium purpureum, Lilium superbum, Medeola virginiana, Smilax herbacea*, and *Tradescantia subaspera*. Other species with fairly high frequency include *Dryopteris marginalis, Galium triflorum, Thalictrum dioicum, Trillium erectum, Viola sororia, Galium lanceolatum, Galium latifolium, Nabalus latissimus, Polygonatum biflorum, Adiantum pedatum, Actaea pachypoda, Phryma leptostachya, Potentilla canadensis*, *Symphyotrichum cordifolium*, *Thaspium barbinode, Laportea canadensis*, and *Osmorhiza claytoniana*. Though the species present from this pool vary widely, the high species richness of this community is indicated by an average of 84 species per 1/10 hectare plot in the CVS data and by a total of over 400 species in the set of plots.

Range and Abundance: Ranked G2. The Rich Subtype ranges through much of the Mountain region but is widely scattered. It is extensive only in a few areas such as the Amphibolite Mountains, portions of the Craggy Mountains, Great Balsam Mountains, and Nantahala Mountains, where amphibolite is abundant. It may be endemic to North Carolina, though the association is considered potential in Tennessee and would be possible in Georgia or southern Virginia.

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Associations and Patterns: The Rich Subtype can occur in large patches, occupying the tops and warm sides of mountains. It may also occur in small patches, associated with dikes or small bodies of mafic rock. In extensive mafic rock areas, it grades to Northern Hardwood Forest (Rich Subtype) in more mesic sites and may grade to Montane Oak–Hickory Forest (Basic Subtype). It may also change more rapidly to other subtypes of High Elevation Red Oak Forest at geologic contacts.

Variation: Examples vary substantially in the abundance of canopy associates with *Quercus rubra* and in the herb layer, but no clear patterns have been recognized.

Dynamics: The Rich Subtype is believed to be similar to the Typic Herb Subtype in its dynamics and generally similar to most other Montane Oak Forests. The general pronounced increase in mesophytic trees and failure of regeneration of oaks is similar in this subtype, though with a larger set of mesophytic species. Some of the characteristic trees of this subtype are not tolerant of fire and would have been less abundant under a natural fire regime, while others, such as *Carya ovata* and *Fraxinus americana*, may have been moderately tolerant and similar in abundance.

Comments: This subtype is closely related to Montane Oak–Hickory Forest (Basic Subtype) and to Northern Hardwood Forest (Rich Subtype). The three are differentiated largely by their canopy dominants. They share a sizeable suite of "rich" or "base-loving" herbs, understory, and canopy trees that are common in Rich Cove Forests but that occur on ridges, higher slopes, and drier slope aspects only in association with amphibolite, calc-silicate, or comparable rocks. This suite is diverse but is smaller than the pool of species in Rich Cove Forest, and species usually occur in different proportions. Often species such as *Solidago curtissii*, *Eurybia chlorolepis*, or *Ageratina altissima* var. *roanensis* are dominant and the "rich" herbs are limited in cover.

This subtype was specifically recognized only relatively recently (2008), later than the Typic Herb, Heath, and Orchard Forest subtypes and their equivalent NVC associations. It is described in some site-specific descriptions but is rare enough that it is not apparent in most vegetation studies. It appears to be included in DeLapp's (1978) tall herb phase, given that several characteristic species are mentioned in the description. Recognition in other local studies is usually amibiguous.

Quercus rubra - Carya ovata - Fraxinus americana / Actaea racemosa - Hydrophyllum virginianum Forest (CEGL008518) is an analogous association in the Central Appalachians. Plot data analysis by the Virginia Natural Heritage Program (2007) found North Carolina's Rich Subtype to be distinct from this association.

Rare species: Vascular plants – *Carex woodii, Euphorbia purpurea, Platanthera peramoena, Pyrola elliptica, Rhododendron prinophyllum, Rhododendron vaseyi, Silene ovata*. Animals – *Catharus guttatus, Coccyzus erythropthalmum, Dendroica caerulea, Parus atricapillus, Sphyrapicus varius*.

References:

DeLapp, J.A. 1978. Gradient analysis and classification of the high elevation red oak community of the Southern Appalachians. M.S. Thesis, North Carolina State University.

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs 26: 1-80.

HIGH ELEVATION RED OAK FOREST (HEATH SUBTYPE)

Concept: High Elevation Red Oak Forests are *Quercus rubra* or one-time *Castanea dentata-Quercus rubra* forests, without *Quercus alba,* at higher elevations. Elevations are generally above 3500 feet, but some examples of the Heath Subtype are as low as 3000 feet. The Heath Subtype includes forest with well-developed shrub layers of predominantly evergreen heaths, typically occurring on narrow ridges, rocky areas, or strongly convex slopes.

Distinguishing Features: High Elevation Red Oak Forests are distinguished by having *Quercus rubra* making up more than 50 percent of the canopy cover under current natural conditions (with *Castanea* largely eliminated), having no appreciable presence of *Quercus alba,* and occurring at high elevations, above 3000 feet. At lower elevations, examples transitional to Chestnut Oak Forest, with large minorities of *Quercus montana*, are common.

The Heath Subtype is distinguished from the Herb, Rich, and Orchard Forest subtypes by naturally having more than half of the shrub cover of evergreen species and having greater than 20 percent shrub cover. It is distinguished from the Stunted Woodland Subtype by having a full stature canopy, not stunted by wind (more than 8 meters tall unless young). The Stunted Woodland Subtype generally has more mixed canopy composition, less strongly dominated by *Quercus rubra*.

Synonyms: *Quercus rubra / (Kalmia latifolia, Rhododendron catawbiense, Rhododendron maximum) / Galax urceolata* Forest (CEGL007299).
Ecological Systems: Central and Southern Appalachian Montane Oak Forest (CES202.596).

Sites: The Heath Subtype occurs on strongly convex topography, more convex and more exposed than that of the Typic Herb Subtype. Elevations are primarily 3500-5500 feet, but examples may extend high and may be found as low as 3000 feet.

Soils: A wide variety of soil series is mapped. Wayah (Typic Humadept), Porters (Humic Dystrudept), and Burton (Typic Humadept) are most frequent. Most other mapped soils are Inceptisols, but some are Ultisols.

Hydrology: Sites are well-drained but mesic due to cool temperatures and high rainfall at their high elevations. The Heath Subtype presumably is better drained than the Typic Subtype.

Vegetation: The forest is dominated by *Quercus rubra*, probably usually var. *ambigua*. Associated canopy species often include *Quercus montana* at lower elevations, *Betula lenta*, *Betula alleghaniensis*, and occasionally *Picea rubens* at the highest elevations. The mixture of mesophytic hardwoods in the canopy appears to be generally less in this subtype than in others. *Acer rubrum, Acer pensylvanicum*, and *Amelanchier arborea* are most often the dominant understory species, while *Nyssa sylvatica* and *Oxydendrum arboreum* are less often abundant. The shrub layer is dense to moderate, with *Kalmia latifolia, Rhododendron maximum*, or *Rhododendron catawbiense* dominant. *Castanea dentata* sprouts, *Vaccinium corymbosum,* and *Ilex montana* are the most constant or frequent other shrubs, and *Vaccinium simulatum, Vaccinium erythrocarpum, Clethra acuminata*, *Eubotrys recurva, Vaccinium stamineum, Gaylussacia ursina*,

or *Vaccinium stamineum* are less frequently abundant. *Smilax rotundifolia* may form tangles in patches. The herb layer is low in density and in diversity. *Galax urceolata* is the only relatively constant species. *Conopholis americana, Lysimachia quadrifolia, Medeola virginica*, and *Maianthemum racemosum* are fairly frequent. Other species in few plots but reported in descriptions include *Pteridium aquilinum, Coreopsis major, Melampyrum lineare, Dennstaedtia punctilobula, Goodyera pubescens, Amianthium muscitoxicum*, and *Ageratina altissima* var. *roanensis*,

Range and Abundance: Ranked G4. This subtype probably occurs in most, if not all, mountain ranges, throughout the mountains of North Carolina, but is much less extensive than the Typic Herb Subtype. The association ranges from Virginia to Georgia.

Associations and Patterns: The Heath Subtype occurs in small to large patches, below the spruce-fir zone in the highest mountain ranges and up to the tops of lower and more southerly ranges. Though generally on the sharpest ridge tops or spur ridges, it may also occur on other topography around rock outcrops. It usually occurs in a mosaic with the Typic Herb Subtype and with Northern Hardwood Forest. Small patches of High Elevation Rocky Summit or High Elevation Granitic Dome.

Variation: DeLapp (1978) recognized three phases that fall within this subtype. Because of the fairly clear distinction in dominant shrubs and reported associations with different environments, they are recognized as variants:
1. Mountain Laurel Variant has a shrub layer dominated by *Kalmia latifolia* and occurs on drier slopes with shallow soil.
2. Great Rhododendron Variant has a shrub layer dominated by *Rhododendron maximum* and occurs at lower elevation and with more shelter. It is conceptually transitional to Chestnut Oak Forest (Mesic Subtype).
3. Catawba Rhododendron Variant has a shrub layer dominated by *Rhododendron catawbiense* and occurs at higher elevation, highly exposed sites. It is much less common than the other variants.
It may be noted that the range of undergrowth species composition among these three variants is no larger than in the Typic Herb and Rich subtypes, but the simpler composition allows ready distinction among variants. Other variation includes often abundant *Quercus montana* at lower elevations and admixture of *Picea rubens* in some examples at higher elevations.

Dynamics: Dynamics of the Heath Subtype are similar to those of other High Elevation Red Oak Forests and of most oak forests. The more exposed locations for this subtype presumably lead to more intense fire behavior when fires occur. Exposure may also lead to more lightning strikes and more frequent wind disturbance, creating more canopy gaps and a younger age overall. The interaction of fire with the shrub component needs further investigation. All of the dominant shrubs sprout after burning, but observations suggest they don't recover quickly. A more natural fire regime might lead to a different composition, though it is expected to still be distinguishable from other subtypes.

Comments: Although the evergreen heath component would appear to make this subtype easy to recognize, and it was clearly distinguished by DeLapp (1978), it does not always appear in general

vegetation studies. Whittaker (1956) noted an absence of *Kalmia*, didn't mention evergreen *Rhododendron* species, and emphasized a submesic composition with deciduous shrubs in his red oak-chestnut forest. The description of the red oak forests in McLeod (1988) did not mention evergreen shrubs. Newell's (1997) fine-scale classification distinguished Heath Subtype vegetation in Shining Rock Wilderness but not in Joyce Kilmer-Slickrock. Nevertheless, many CVS plots have been attributed to it. It is unclear if the lack of mention indicates that it is absent in many areas that have other subtypes, or if, being a small minority of the High Elevation Red Oak Forest, it is overlooked.

This subtype occurs in topographic settings that, at lower elevations, often support Pine–Oak/Heath. Transitional communities containing pines seem possible but are not generally noted.

Rare species: Vascular plants – *Rhododendron vaseyi*. Nonvascular plants – *Dicranum undulatum*. Animals – *Plethodon wehlei, Sphyrapicus varius*.

References:

DeLapp, J.A. 1978. Gradient analysis and classification of the high elevation red oak community of the Southern Appalachians. M.S. Thesis, North Carolina State University, Raleigh.

McLeod, D.E. 1988. Vegetation patterns, floristics, and environmental relationships in the Black and Craggy Mountains of North Carolina. Ph.D. dissertation, University of North Carolina, Chapel Hill.

Newell, C.L. 1997. Local and regional variation in the vegetation of the Southern Appalachian Mountains. PhD. Dissertation, University of North Carolina, Chapel Hill.

Whitaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs 26: 1-80.

HIGH ELEVATION RED OAK FOREST (ORCHARD FOREST SUBTYPE)

Concept: High Elevation Red Oak Forests are *Quercus rubra* forests, or one-time *Castanea dentata-Quercus rubra* forests, without *Quercus alba,* at higher elevations. The Orchard Forest Subtype consists of examples at the highest elevations, generally above 5000 feet, with low shrub cover and a dense but low-diversity herb layer dominated by *Carex* spp. or other species typical of the highest elevations.

Distinguishing Features: High Elevation Red Oak Forests are distinguished by having *Quercus rubra* dominating the canopy cover or basal area at higher elevations under current natural conditions, having no appreciable presence of *Quercus alba*. The Orchard Forest Subtype is distinguished from all other subtypes by having little shrub layer and a dense but low diversity herb layer dominated by *Carex pensylvanica*, other *Carex* spp., *Ageratina altissima, Danthonia compressa, Claytonia caroliniana, Angelica triquinata*, or other species typical of the higher elevations. The more diverse species of the Typic Herb Subtype are absent or scarce, and the characteristic shrubs, such as *Rhododendron calendulaceum* and *Ilex montana* are also scarce. *Rhododendron catawbiense* and other evergreen heaths may be present but are sparse. The canopy trees in the Orchard Forest Subtype often are gnarled and short, appearing stunted.

Synonyms: *Quercus rubra / Carex pensylvanica - Ageratina altissima var. roanensis* Forest (CEGL007298).
Ecological Systems: Central and Southern Appalachian Montane Oak Forest (CES202.596).

Sites: The Orchard Forest Subtype tends to occur on gentle to moderate slopes, broad ridges, and in ridgetop gaps, but may be on steeper on steeper slopes. It occurs at the highest elevations where oak forests are found, generally above 5000 feet.

Soils: Examples may occur on a variety of high elevation soils, most often Typic Humadepts such as Cheoah, Oconaluftee, Tanassee, Balsam, or Wayah.

Hydrology: Sites are well-drained but mesic due to cool temperatures, high rainfall, and frequent fog at their high elevations.

Vegetation: The forest canopy is dominated by *Quercus rubra*, probably always var. *ambigua*. Trees may be stunted or gnarled. The canopy often is more open than most oak forests. As in other High Elevation Red Oak Forests, *Castanea dentata* may have been less important in this community than in most Montane Oak Forests (Whittaker 1956), but its sprouts are often present. Mesophytic hardwoods, particularly *Betula alleghaniensis, Fagus grandifolia*, *Acer rubrum*, or *Acer saccharum* may codominate in many examples, and *Picea rubens* may be present. The understory is often sparse, but may be moderate to dense. It consists of the same species found in the canopy, and may also include *Crataegus* spp., *Amelanchier arborea, Acer pensylvanicum*, or other species. Shrubs are sparse, but some *Ilex montana, Hamamelis virginiana, Vaccinium simulatum, Rhododendron catawbiense, Rhododendron maximum*, or other species may be present. In areas with canopy disturbance, *Rubus alleghaniensis* or *Rubus canadensis* often becomes abundant. The herb layer is dense and lush, but low in diversity. *Carex pensylvanica* is the most characteristic species, but other *Carex* spp., *Danthonia compressa, Dennstaedtia*

punctilobula, Parathelypteris noveboracensis, Angelica triquinata, Ageratina altissima var. *roanensis, Oclemena acuminata, Festuca subverticillata, Claytonia caroliniana*, or other species of high elevations may be abundant.

Range and Abundance: Ranked G2. Examples are scattered in the higher elevation ranges, with most in the Great Balsam Mountains and possibly in the Great Smoky Mountains. The association also occurs in Tennessee, where it may be confined to the Great Smoky Mountains.
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Associations and Patterns: The Orchard Forest Subtype usually occurs in large patches, sometimes in small patches. It often grades to other subtypes of High Elevation Red Oak Forest and to Northern Hardwood Forest, including the Beech Gap Subtype.

Variation: No variants are recognized.

Dynamics: The high elevation and moistness of this community likely makes fire less important than in other High Elevation Red Oak Forests, but it may still be important for determining the boundary with Northern Hardwood Forest and for preventing mesophytic hardwoods from replacing the oak. The lush herb layer probably carries fire well only in the dormant season. This subtype may be more subject to natural disturbance by ice and wind.

Many, if not all, examples of this subtype have been grazed in the past. While forest grazing was very widespread even in the high mountains, the typical location of the Orchard Forest Subtype in gaps and on broad ridge tops may have led to more intense grazing. It is sometimes suggested that some of the distinctive characteristics are a result of grazing. This may be true of the common limited understory and shrub layer, and possibly for the strong graminoid dominance in the herb layer. Worton and Smathers (1981) found that tree ages at Frying Pan Gap were bimodal, with a 30 year gap around 1860-1890, presumably due to grazing but possibly caused by fire.

Comments: There is some confusion or disagreement over circumscription of this community. As defined here, it is a community of the highest elevations, bearing an analogous relationship to other High Elevation Red Oak Forests that the Beech Gap Subtype does to other Northern Hardwood Forests. The corresponding NVC association appears to be conceived more broadly, defined by a threshold of 20% shrub cover and extending to lower elevation. It is unclear how much this would broaden the concept of this subtype and narrow the concept of the Typic Herb Subtype, but potentially significantly. Shrub cover in the Typic Herb Subtype is variable, and portions of many occurrences might cross the 20% threshold, making such a definition strongly dependent on the scale observed. The G2 rank may not really apply with that definition. I have retained the narrower orchard forest concept, believing it to be more likely to correlate with other characteristics of the ecosystem and to define a unit of conservation interest. However, further investigation is needed.

Rare species: Vascular plants – *Rhododendron vaseyi*. Nonvascular plants – *Dicranum undulatum*.

References:

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs. 26: 1-80.

Worton and Smathers. 1981.

HIGH ELEVATION RED OAK FOREST (STUNTED WOODLAND SUBTYPE)

Concept: The Stunted Woodland Subtype is a rare, poorly understoood *Quercus rubra* woodland of extremely exposed narrow ridges and peaks or edges of rock outcrops, where canopy trees are notably stunted, short, and low in density. Conceptually it lies on the boundary of High Elevation Red Oak Forest and Montane Oak–Hickory Forest, with *Quercus rubra* sometimes strongly dominant and *Quercus alba* sometimes codominant. It has a dense shrub layer which is dominated by evergreen heath species but sometimes is fairly diverse.

Distinguishing Features: The Stunted Heath Subtype is distinguished from other subtypes of High Elevation Red Oak Forest and Montane Oak–Hickory Forest by a more open and very short canopy, less than 8 meters tall even when mature. Trees may be only 5 meters tall and may branch barely above the shrub layer canopy. Care is needed to apply this subtype only to the most extremely stunted forests, as well as to distinguish it from young forests which will develop taller stature over time. Examples of other subtypes on ridges may have gnarled trees and canopies that are shorter than those of less exposed forests, but these are not as short unless they are young. The distinction from High Elevation Red Oak Forest (Heath Subtype) is most subtle, since it too has a dense evergreen shrub layer and may be somewhat stunted. The Stunted Heath Subtype is distinguished from the Orchard Forest Subtype, which may have a notably stunted canopy, by having a well-developed, generally very dense, shrub layer.

Synonyms: Synonyms: *Quercus rubra / Rhododendron catawbiense - Rhododendron arborescens* Woodland (CEGL004503).
Ecological Systems: Central and Southern Appalachian Montane Oak Forest (CES202.596).

Sites: The Stunted Heath Subtype occurs on sharp ridge tops, peaks, and edges of rock outcrops, where it is exposed to extremes of wind and where soils presumably are shallow or extremely rocky. Known examples range from 3400-5000 feet elevation.

Soils: This subtype occurs on rocky or shallow soils. The few examples are mapped as a variety of soil series, primarily Dystrudepts and Humadepts, with no two of the few known examples being the same.

Hydrology: This subtype presumably is the driest of the subtypes of High Elevation Red Oak Forest, given the exposed and convex topographic setting.

Vegetation: The Stunted Woodland Subtype has a short-stature, open canopy usually dominated by *Quercus rubra*, sometimes with *Quercus alba* codominant or abundant. One apparent example is codominated by *Quercus coccinea*. The most frequent understory or minor canopy species is *Amelanchier arborea*, but *Acer rubrum* is also frequent. Unexpected mesophytic species such as *Tsuga canadensis* or *Betula lenta* may be present. *Castanea dentata* sprouts are abundant in most examples, suggesting this species was a major part of the canopy. The shrub layer is tall and dense. *Kalmia latifolia* or *Rhododendron catawbiense* dominate, but the shrub layer often is fairly diverse. Other shrub species include *Vaccinium corymbosum, Rhododendron maximum, Ilex montana, Rhododendron calendulaceum, Lyonia ligustrina*, *Aronina melanocarpa, Menziesia pilosa, Clethra acuminata, Eubotrys recurva, Viburnum cassinoides*, *Gaylussacia frondosa*, and in higher

elevation examples, *Vaccinium erythrocarpum, Viburnum lantanoides*, and *Sorbus americana*. *Smilax rotundifolia* or *Smilax glauca* may form tangles. Herbs generally are sparse. *Pteridium aquilinum* is the most frequent species. Other species may include *Melampyrum lineare, Danthonia spicata, Lysimachia quadrifolia, Campanula divaricata*, and in high elevation examples, *Eurybia chlorolepis, Oclemena acuminata*, and *Angelica triquinata*.

Range and Abundance: Ranked G2, but perhaps better treated as G2? Examples are very widely scattered throughout most of the Mountain Region. The association is also known in Georgia and is considered possible in Tennessee and South Carolina.

Associations and Patterns: The Stunted Woodland Subtype occurs in small patches, generally grading to other subtypes of High Elevation Red Oak Forest or Montane Oak–Hickory Forest, sometimes to High Elevation Granitic Dome or other rock outcrop communities.

Variation: The few known examples are more variable than for most communities, with different shrub layer dominants. The highest elevation examples have a number of high elevation species not found in the other examples, as noted in the vegetation description.

Dynamics: Little is known about the dynamics of the Stunted Woodland Subtype. The stunted canopy suggests harsh conditions that limit tree growth and damage canopies frequently, probably wind and ice. Lightning too can be expected to be more frequent in these exposed locations. Unusually severe fires, associated with location on ridges, along with dry conditions, may also be a cause of open canopies and small trees. The dense shrub layer may develop simply because of the open canopy, but also may be related to the conditions that form Heath Balds.

Comments:
The Stunted Woodland Subtype was recognized in the 4th Approximation and the NVC to cover distinctive vegetation which did not fit other forest categories. No published literature clearly describes it. It is conceptually transitional to Heath Bald, especially to the Southern Mixed Subtype. However, the dynamics and ecological relationships of this subtype are particularly poorly known, and the conditions that create its distinctive vegetation structure may not be the same in all cases. Understanding is inhibited by the difficulty in recognizing it in earlier site descriptions and also in recognizing its distinctive structure in plot data. No published quantitative studies appear to recognize it. Given its rarity, plots that represent it may be dismissed as outliers in quantitative analysis.

This subtype appears to be quite rare, and many apparently-suitable sites do not have it. The corresponding NVC association is described as being particularly tied to granitic domes, but only a few examples in North Carolina are associated with them. The majority of our examples are on sharp ridge tops.

Rare species: Nonvascular plants – *Dicranum undulatum, Gymnoderma lineare*. Animals – *Sphyrapicus varius*.

References:

HIGH ELEVATION RED OAK FOREST (BOULDERFIELD SUBTYPE)

Concept High Elevation Red Oak Forests are *Quercus rubra* or one-time *Castanea dentata–Quercus rubra* forests, without *Quercus alba,* at higher elevations, generally above 3500 feet and ranging up to the highest elevations of any oak forest. The Boulderfield Subtype encompasses very rare examples on well-developed boulderfields. Substrates are comparable to High Elevation Birch Boulderfield Forest and Rich Cove Forest (Boulderfield Subtype), but mesophytic trees are present in only small numbers if at all.

Distinguishing Features: The Boulderfield Subtype of High Elevation Red Oak Forest, like the High Elevation Birch Boulderfield Forest and the Boulderfield Subtype of Rich Cove Forest, Chestnut Oak Forest, and Montane Oak–Hickory Forest, is distinguished by occurring on well-developed boulderfields, with near complete cover by large rocks, substantial open space beneath the rocks, soil limited to accumulations on top of and between rocks, and lower vegetation strata substantially influenced by the rock cover. High Elevation Red Oak Forest (Boulderfield Subtype) is distinguished from boulderfield subtypes of other communities by having canopy composition dominated by *Quercus rubra*, with no *Quercus alba*, little or no *Quercus montana*, and few or no mesophytic trees other than *Betula alleghaniensis* and *Betula lenta*. Because the lower strata, especially the herb layer, are less dense in oak forests than in Rich Cove Forest or Northern Hardwood Forest communities, the recognition of the Boulderfield Subtype of High Elevation Red Oak Forest may be more subtle and require more attention to extreme rock cover and space beneath the rocks. Many High Elevation Red Oak Forests are rocky but most do not have enough surface boulder cover to affect community composition.

Synonyms: No NVC equivalent.
Ecological Systems: Southern Appalachian Oak Forest (CES202.886).

Sites: The Boulderfield Subtype may occur on convex, planar, or somewhat concave slopes, generally moderate to steep. It may potentially be on the edges of relict periglacial boulderfields, which tend to be in steeply plunging coves, or it may occur on talus beneath rock outcrops. The boulders may be smaller than those in the Rich Cove Forest subtype or in High Elevation Birch Boulderfield, but it is uncertain if this is universally true. Examples might occur anywhere in the elevational range of High Elevation Red Oak Forest, roughly 3500-5900 feet.

Soils: Soil consists of accumulations of organic matter on and among the boulders (Lithic Dystrochrepts), but patches are generally small and are inclusions in soil map units.

Hydrology: Conditions are generally dry-mesic or mesic due to topography and elevation, but moisture may vary drastically at very fine scale. Shallow soil pockets maybe become dry very quickly. Seepage areas are less likely to be present than in more mesic boulderfields. However, large established trees may be rooted beneath the boulders and have a greater supply of moisture.

Vegetation: This subtype is only recently discovered, and the range of its vegetation is not known. All examples will be dominated by *Quercus rubra*, at least weakly. In the one known example, *Betula lenta* is also present in the canopy and the understory contains *Betula alleghaniensis, Acer pensylvanicum, Acer spicatum*, and *Amelanchier laevis*. Some vines, especially *Isotrema*

macrophyllum and *Smilax rotundifolia,* are present. The herb layer is sparse, with herbs occurring primarily in soil patches at the base of trees. Species include *Athyrium asplenioides, Trillium grandiflorum, Thalictrum thalictroides, Goodyera pubescens, Carex* spp., and *Viola* spp. If other examples are found, they may contain a few other tree species, especially *Quercus montana*, and are likely to share herb species with other boulderfield communities. Such species might include *Polypodium virginianum, Dryopteris marginalis*, and *Sedum ternatum*. Herb species typical of other High Elevation Red Oak Forest subtypes may also be present in small numbers.

Range and Abundance: Unranked but likely G1. This community is newly recognized, and only a single small example is known. A few more may be discovered, but it is unlikely that more than a handful of examples will be found.

Associations and Patterns: High Elevation Red Oak Forest (Boulderfield Subtype) is a small patch community. It is most likely to be surrounded by other subtypes of High Elevation Red Oak Forests but might be associated with boulderfield subtypes of other communities.

Variation: Nothing is known of variation at present.

Dynamics: While stand dynamics presumably are similar to other oak forests, canopy gaps last longer because of the difficulty of tree establishment. Fire may be less of an influence because of the discontinuous leaf litter cover on the surface.

Comments: This community is more similar to other High Elevation Red Oak Forest subtypes than High Elevation Birch Boulderfield is to Northern Hardwood Forests, so it is recognized as a subtype rather than a full type. This subtype is one of the most recently recognized communities, added to the 4th Approximation well after the guide was published. Analogous boulderfield subtypes have also been found for Chestnut Oak Forest and Montane Oak–Hickory Forest. More work is needed to fully characterize all of these boulderfield communities. The description is based on only a single known example. However, it is likely that a few other examples have been overlooked because a community had not been described to link them to. However, some reported oak-dominated boulderfields have proven to be the more mesophytic Boulderfield Subtype of Rich Cove Forest, with a limited oak component.

All of the oak boulderfield forests are expected to be extremely rare and likely of limited extent. However, it should be noted that the Boulderfield Subtype of Rich Cove Forest, while uncommon, proved to be less extremely rare than it appeared when first defined.

Rare species: No rare species are known to be associated with this community. As with other boulderfields, it may be an important habitat for small mammals, including rare species.

References: No references specific to this community have been identified.

HIGH ELEVATION WHITE OAK FOREST

Concept: High Elevation White Oak Forests are strongly dominated by *Quercus alba* and occur on exposed ridges at higher elevations, without the mixture of canopy species typical of Montane Oak–Hickory Forest.

Distinguishing Features: The High Elevation White Oak Forest type is distinguished from all other high elevation forest types by having *Quercus alba* naturally making up 75% or more of the canopy cover.

Synonyms: *Quercus alba / Kalmia latifolia* Forest (CEGL007295).
Ecological Systems: Central and Southern Appalachian Montane Oak Forest (CES202.596).

Sites: High Elevation White Oak Forest occurs on broad ridges, flats, and upper slopes, generally, perhaps exclusively, above 4000 feet.

Soils: Soils associated with this community are not well understood. Baranski (1975) suggests they are relatively deep, and that *Quercus montana* replaces *Quercus alba* on rocky soils. However, some known occurrences seem to have thin soils near rock outcrops, and others are mapped on soil maps as rocky. The most frequently mapped series is Porters, a Humic Dystrudept.

Hydrology: Sites are well-drained and relatively dry due to exposure to wind and convex topography, but they are cooler and presumably less stressed than comparable sites at lower elevations.

Vegetation: This forest is strongly dominated by *Quercus alba*. Sometimes no other canopy species is present, sometimes *Carya glabra* may be abundant, and *Quercus rubra, Quercus coccinea*, or *Quercus velutina* may sometimes be present as a significant minority. The trees generally are stunted and relatively short. There may be little understory, but unusually dense *Castanea dentata* sprouts have sometimes been noted, and *Nyssa sylvatica, Oxydendrum arboreum*, *Cornus florida*, or *Robinia pseudo-acacia* may be present. The shrub layer is usually dense, dominated by *Kalmia latifolia* or occasionally *Gaylussacia ursina*. Herbs are sparse where shrubs are dense, and usually consist of widespread species such as *Athyrium asplenioides*. One example has a well-developed herb layer dominated by *Euphorbia purpurea*, with a number of species characteristic of rich sites.

Range and Abundance: Ranked G2Q. This community appears very rare in North Carolina, but uncertainty about identification of several examples makes its abundance uncertain. All or almost all examples are south of Asheville, most in the high rainfall area near the Georgia and South Carolina border. The association is attributed to South Carolina, Georgia, and Tennesssee, but this too may be confused by issues of circumscription.

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Associations and Patterns: High Elevation White Oak Forest usually occurs as fairly small patches, most well under 100 acres. They are often associated with High Elevation Red Oak Forest. At least a couple are associated with High Elevation Granitic Domes.

Variation: Substantial variation exists in known examples, but the community is not well enough understood to define variants. The example on Riley Knob, on amphibolite substrate and with a rich herb layer, probably warrants a distinct variant.

Dynamics: The high elevation exposed position of this community makes it particularly subject to damage by wind, lightning, and ice. Barnaski (1975) noted that trees in these areas often had small yellowish leaves, gnarled shape, and numerous epicormic branches, and attributed this to frost damage. Fire dynamics are probably similar to those of High Elevation Red Oak Forest.

Comments: This remains one of the most problematic community types, with few known well-developed examples and uncertainty as to how distinct it is from other types. Variation in circumscription by different users have led to some confusion of the concept and uncertainty about plot assignment. Some of the few descriptive reports have only limited description of this community.

The concept of a high elevation white oak forest owes much to Whittaker's (1956) study of the Great Smoky Mountains, where he reported a distinct break between low elevation *Quercus alba* forest and those of high elevations. He suggested there were actually two distinct populations or ecotypes of the species. He apparently was not alone. Baranski (1975) quotes a 1952 letter by W.H. Camp to H.J. Oosting, talking of the existence of two ecotypes separated from each other by at least 1500 feet in elevation. Whittaker (1956) described a community with *Quercus alba* strongly dominant, though with *Quercus rubra* usually present, with an open canopy and small trees, above 4500 feet. Carter et al., (2000) too, in their analysis of old-growth plots in the high rainfall area around Highlands, found *Quercus alba* indicative of higher elevations (above 4000 feet) in their data set of old-growth forests, along with *Castanea dentata* and *Gaylussacia ursina*. *Quercus rubra*, in contrast, was indicative of mid elevations, below 4000 feet.

Baranski (1975) addressed the question of ecotypes, demonstrating that *Quercus alba* as a species ranges continuously in elevation, without a break elsewhere in North Carolina, and even on the North Carolina side of the Great Smoky Mountains. He did confirm that Whittaker's primary study area, in the central and western Tennessee side, lacks the species at mid elevations. Baranski's focus was on the species and its overall abundance in broad areas, and he did not always note how it fit into specific communities. But he did note that above 4000 feet it became more prominent and that open flat ridgetops and open slopes could support almost pure *Quercus alba* stands. These trees were small and stunted looking and had smaller leaves and acorns, which he attributed to weather conditions rather than ecotypic variation.

Whittaker's concept of a montane white oak forest was adopted by a number of observers. The concept was expanded to accommodate lower elevations and more mixed communities that were found in North Carolina. The recognition of the Montane Oak–Hickory Forest with the 3rd Approximation led to narrowing the montane white oak forest concept to something more like its original intent. It thus is narrowly defined here, limited to elevations above 4000 feet and to forests strongly dominated by *Quercus alba*.

Since Montane Oak–Hickory Forests, with mixed canopy composition, can also range to similarly high elevations, occur in similar sites, and overlap in the range of dominants in lower strata, further

study is needed into how distinct High Elevation White Oak Forest is, even with a narrow definition. It is retained at present because some examples that seem to fit it well can be found. Other records are described in ways that make it hard to tell which community they represent. Further investigation is particularly needed here.

Rare species: Vascular plants – *Euphorbia purpurea, Rhododendron vaseyi*.

References:

Baranski, M.J. 1975. An analysis of variation within white oak (Quercus alba L.). NC Agricultural Experiment Station Tech. Bul. No. 236.

Carter, R.E., Jr., N.J. Myers, V.B. Shelburne, and S.M. Jones. 2000. Ecological land classification of the high rainfall belt of the Southern Appalachian Mountains. Castanea 65: 258-272.

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecol. Monogr. 26: 1-80.

MONTANE OAK–HICKORY FOREST (ACIDIC SUBTYPE)

Concept: Montane Oak–Hickory Forests are common mountain forests dominated by mixtures of oaks with *Quercus alba* as a significant component. The Acidic Subtype covers the broad ranges of examples with typical acid-loving herbs and heath shrubs. This subtype lacks indicators of circumneutral soils and also lacks low elevation dry-site species.

Distinguishing Features: All Montane Oak–Hickory Forests are distinguished from other Mountain Oak Forest communities by having a canopy containing significant *Quercus alba* (10% of the canopy or more) mixed with other oaks, hickories, or pines. Chestnut Oak Forest, Low Montane Red Oak Forest, and High Elevation Red Oak Forest have very little or no *Quercus alba*. High Elevation White Oak Forest has a canopy strongly dominated by *Quercus alba* and a dense heath layer occurring at elevations above 4000 feet. Montane Oak–Hickory Forests are distinguished from Oak–Hickory Forests of the Piedmont by having a significant component of montane flora, such as *Castanea dentata, Rhododendron calendulaceum, Kalmia latifolia, Magnolia fraseri*, and *Gaylussacia ursina*.

The Acidic Subtype is distinguished from the closely related White Pine Subtype by the absence or scarcity of *Pinus strobus* in the canopy. It is distinguished from the Basic Subtype by the absence or scarcity of plants that prefer circumneutral or higher soil pH, species such as *Fraxinus americana, Tilia americana* var. *heterophylla*, *Collinsonia canadensis, Sanguinaria canadensis, Actaea racemosa*, and *Caulophyllum thalictroides*. It is distinguished from the Low Dry Subtype by the absence of more typically Piedmont xerophytic species such as *Pinus echinata, Quercus falcata, Quercus stellata*, and *Quercus marilandica*.

Synonyms: *Quercus alba - Quercus (rubra, prinus) / Rhododendron calendulaceum - Kalmia latifolia - (Gaylussacia ursina)* Forest (CEGL007230).
Ecological Systems: Southern Appalachian Oak Forest (CES202.886).

Sites: Montane Oak–Hickory Forest (Acidic Subtype) occurs on ridge tops and on upper to lower slopes, spur ridges, and some valley flats. It occurs over a tremendous range of elevation, from 1000-5800 feet, with examples common over most of that range.

Soils: This community occurs on a broad range of uplands soils, mostly Typic Hapludults such as Chester, Evard and Watauga, or Typic Dystrudepts such as Ashe, Chestnut, Porters, and Stecoah.

Hydrology: Sites are well drained, and conditions generally are dry-mesic to dry.

Vegetation: The forest is dominated by varying combinations of *Quercus alba, Quercus rubra, Quercus montana*, and *Quercus coccinea*. Any of these species may be most abundant, but *Quercus alba* is always present in more than token numbers. *Carya glabra, Carya tomentosa, Quercus velutina, Acer rubrum*, and *Liriodendron tulipifera* are also frequent in the canopy. *Castanea dentata* once dominated or codominated and remains highly constant in the understory or shrub layer. Highly constant understory species in CVS plot data include *Oxydendrum arboreum, Sassafras albidum, Nyssa sylvatica,* and *Cornus florida*. *Magnolia fraseri, Prunus serotina*, and *Amelanchier arborea* are also frequent, as are some of the canopy species. The shrub layer is extremely variable. Many examples have open shrub layers with a mix of species that

includes *Kalmia latifolia, Rhododendron calendulaceum, Gaylussacia ursina, Rhododendron maximum, Vaccinium pallidum, Vaccinium stamineum*, or *Pyrularia pubera*. Some examples have dense shrub layers strongly dominated by *Kalmia latifolia*, *Gaylussacia ursina*, or *Vaccinium pallidum*. The herb layer generally is low in density and diversity under current conditions. *Chimaphila maculata, Goodyera pubescens*, and *Dioscorea villosa* have high constancy. Other frequent species include *Lysimachia quadrifolia*, *Parathelypteris noveboracensis, Galax urceolata, Hylodesmum nudiflorum, Potentilla canadensis, Viola hastata, Medeola virginica,* and *Gillenia trifoliata*. Under more natural fire regimes, species of the suite of fire-tolerant herbs, such as *Danthonia spicata, Schizachyrium scoparium, Coreopsis major, Iris verna*, and *Tephrosia virginiana*, likely would be abundant, at least in some examples.

Range and Abundance: Ranked G5. This is one of the most extensive communities in the Mountain region of North Carolina, making up a large part of the landscape at low to moderate elevations south of Asheville. It is abundant in most parts of the region, though it is scarce in parts of the Blue Ridge escarpment. The association ranges from Virginia to Georgia.

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Associations and Patterns: The Acidic Subtype is a matrix community in many places, making up a significant part of the landscape along with Acidic Cove Forest and Rich Cove Forest, grading to Chestnut Oak Forest and Pine–Oak/Heath on the sharper ridges and grading to High Elevation Red Oak Forest and Northern Hardwood Forest at higher elevations. In the foothills and northern Blue Ridge escarpment, it often occurs in small patches in gaps or upper coves, with Chestnut Oak Forest dominating the landscape. At lower elevations, below 2000 feet, it may grade to the Low Dry Subtype on south- or west-facing slopes. The Acidic Subtype may give way abruptly or gradually to the Basic Subtype where the underlying geology changes.

Variation: Montane Oak–Hickory Forest (Acidic Subtype) is one of the most broadly circumscribed communities, covering a wide range of topography and elevation. Its vegetation is also very variable, though less so than its geographic and physical site range would suggest. The specific canopy dominants often vary over short distances, defying separation, while the same mix can to be present from the lowest to the highest elevations. The variation is complex, and quantitative analyses on different data sets have not identified consistent divisions within it. Two variants are tentatively recognized, with the understanding that it may also be appropriate to create additional variants.

1. Dry Heath Variant is analogous to the Dry Heath Subtype of Chestnut Oak Forest, with a dense to moderate shrub layer dominated by *Kalmia latifolia, Gaylussacia ursina*, *Vaccinium pallidum*, or other clonal Ericaceous shrubs. It may be appropriate to recognize separate variants for each of these dominants, as is done in Chestnut Oak Forest.
2. Herb Variant is analogous to the Herb Subtype of Chestnut Oak Forest, with an open shrub layer not strongly dominated by one of the above species, often having *Rhododendron calendulaceum* or other species abundant. Herbs may be sparse or denser.

Dynamics: Dynamics of this community are generally similar to those of Montane Oak Forests as a whole, including regeneration dynamics and an important role for moderate fire.

Following severe canopy disturbance such as logging, examples tend to regenerate as successional forests dominated by *Liriodendron tulipifera*, *Acer rubrum*, and *Robinia pseudo-acacia*, often with

large numbers of sprouts of understory species. Various oaks often are present, but in much smaller numbers. Carter, et al. (2000), sampling successional forests in the high rainfall area around Highlands, found *Robinia pseudo-acacia*, *Betula lenta*, and *Liriodendron tulipifera* to be common early successional species over a broad range of environments and elevation, but also found some *Carya glabra, Quercus coccinea, Quercus rubra*, and *Quercus alba* present in early successional forests in xeric and intermediate sites at mid to high elevations.

The relationship with the similar White Pine Subtype is somewhat uncertain and needs further investigation. Abella and Shelburne (2003) documented the establishment of *Pinus strobus* and abundance of young pines in an oak forest at Ellicott Rock Wilderness where none had been present before 1900 and only small amounts since 1950. Understory and sapling pines were most strongly correlated with the presence of the few large pines. This would suggest the White Pine Subtype may simply be a fire suppression artifact or some recent alteration. However, in other places an apparently similar history does not lead to pine invasion, and the two subtypes seem more distinct.

Comments: Montane Oak–Hickory Forest was newly recognized with the 3rd Approximation and were not present in earlier editions. A comparable community was not recognized by Whittaker (1956). It apparently is not present in the part of the Great Smoky Mountains where his study concentrated, though it is extensive in the North Carolina portion. Comparable communities were recognized in studies in southern North Carolina, such as those of Racine and Hardin (1975) and Cooper and Hardin (1970). They are recognized in Newell (1997) and, though less common in his study area, by McLeod (1988).

Carter et al. (2000), in their analysis of old-growth plots in the high rainfall area around Highlands, found *Quercus alba* indicative of higher elevations (above 4000 feet) in their data set of old-growth forests, along with *Castanea dentata* and *Gaylussacia ursina*. This is similar to Whittaker's (1956) recognition of white oak forest only at higher elevation. However, the limited remaining legacy of old-growth forests may be misleading in this regard, as mature second growth Montane Oak–Hickory Forest is present throughout the elevational range in the Highlands area. Baranski (1975) emphasized the occurrence of *Quercus alba* throughout the elevation range of the North Carolina mountains.

The relationship of higher elevation examples of Montane Oak–Hickory Forest to High Elevation White Oak Forest needs clarification. The Acidic Subtype can range to high elevations and shares many species with High Elevation White Oak Forest. The latter appears to be tied to more extreme sites and to have reduced species richness, but the differences need further investigation. The distinction is confused by the application of Whittaker's (1956) high elevation white oak forest concept to lower elevation mixed forests before the development of the Montane Oak–Hickory Forest concept.

Rare species: Vascular plants – *Cirsium carolinianum, Fleischmannia incarnata, Fothergilla major, Liatris microcephala, Lysimachia tonsa, Monotropsis odorata, Rhododendron vaseyi, Sisyrinchium dichotomum, Thermopsis fraxinifolia, Thermopsis mollis*. Nonvascular plants – *Canoparmelia amabilis*. Animals – *Aneides aeneus, Crotalus horridus, Eumeces anthracinus, Plethodon yonahlossee, Sphyrapicus varius.*

References:

Abella, S.R., Shelburne, V.B. (2003). Eastern white pine establishment in the oak landscape of the Ellicott Rock Wilderness, southern Appalachian Mountains. Castanea, 68(3), 201-210.

Baranski, M.J. 1975. An analysis of variation within white oak (Quercus alba L). North Carolina Agricultural Experiment Station Bulletin No. 236.

Carter, R.E., Jr., N.J. Myers, V.B. Shelburne, and S.M. Jones. 2000. Ecological land classification of the high rainfall belt of the Southern Appalachian Mountains. Castanea 65: 258-272.

Cooper, A.W., and J.W. Hardin. 1970. Floristics of the gorges on the southern Blue Ridge escarpment. In: The distributional history of the biota of the Southern Appalachians, Part II: Flora. VPI & SU Research Division Monographs 2.

McLeod, D.E. 1988. Vegetation patterns, floristics, and environmental relationships in the Black and Craggy Mountains of North Carolina. Ph.D. dissertation, University of North Carolina, Chapel Hill.

Newell, C. L. 1997. Local and regional variation in the vegetation of the Southern Appalachian Mountains. PhD. Dissertation, University of North Carolina, Chapel Hill.

Racine, C.H., and J.W. Hardin. 1975. The vascular flora and vegetation in the Green River Gorge, North Carolina. Castanea 40: 319-345.

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs 26: 1-80.

MONTANE OAK–HICKORY FOREST (BASIC SUBTYPE)

Concept: Montane Oak–Hickory Forests are dominated by mixtures of oaks with *Quercus alba* as a significant component. The Basic Subtype encompasses forests of mafic rock or comparable substrates, whose flora contains species typical of high pH, base-rich sites.

Distinguishing Features: All Montane Oak–Hickory Forests are distinguished from other Mountain Oak Forest communities by having a canopy containing significant *Quercus alba* (10% of the canopy or more) mixed with other oaks, hickories, or pines. The Basic Subtype is distinguished from the Acidic Subtype and the Low Dry Subtype by the combination of limited heath shrub abundance and abundance of mesic herbs. Characteristic species such as *Pycnanthemum montanum, Tradescantia subaspera, Solidago curtisii, Podophyllum peltatum, Dichanthelium boscii*, and *Brachyelytrum erectum* are often abundant, but Rich Cove Forest and base-loving species such as *Collinsonia canadensis, Arisaema triphyllum, Actaea racemosa, Caulophyllum thalictroides, Sanguinaria canadensis, Adiantum pedatum, Euphorbia purpurea*, and *Philadelphus inodorus* are also usually present. Additional canopy species associated with more mesophytic or more base-rich communities are also often present, with *Fraxinus americana* and *Magnolia acuminata* especially characteristic. This subtype is potentially confused with Rich Cove Forest (Red Oak Subtype), but is distinguished by occurring in more topographically exposed settings and having a less mesophytic flora, as well as by having *Quercus alba* as a major component. While a number of herbaceous and woody species are shared with Rich Cove Forests, they represent a distinct subset of rich mesophytic species. Many of the associated species in this community are of drier sites.

Synonyms: *Quercus alba - Quercus rubra - Quercus prinus / Collinsonia canadensis - Podophyllum peltatum - Amphicarpaea bracteata* Forest (CEGL007692).
Ecological Systems: Southern Appalachian Oak Forest (CES202.886).

Sites: The Basic Subtype occurs on ridge tops and on upper to lower slopes, spur ridges, and some valley flats comparable to those of the Acidic Subtype, but with a substrate of amphibolite, calc-silicate, or other mafic or calcareous rock. It occurs over a tremendous range of elevation, from 1000 feet up to 5200 feet or higher.

Soils: Soils tend to have higher pH, higher base saturation, and higher concentrations of calcium, magnesium, and several other cations, compared to the prevailing soils of the region and those of the Acidic Subtype. This suite of characteristics is called basic, but rarely if ever is the pH above neutral. Soils mapped for this community include a broad range of upland soils that are not distinguished by their chemical characteristics and are usually shared with other subtypes. Most are Typic Hapludults such as Evard, Cowee, and Fannin, or Typic Dystrudepts such as Ashe, Chestnut, and Porters.

Hydrology: Sites are well-drained, and conditions generally are dry-mesic to dry. As with many communities of mafic rock, some of the flora suggests moister conditions than the topographic position or canopy composition suggest.

Vegetation: The forest generally is dominated by varying combinations of *Quercus alba, Quercus rubra, Carya glabra*, and less frequently, *Quercus montana*. A significant minority of species

characteristic of basic soils is present. Most constant of these species are *Fraxinus americana* and *Prunus serotina*. Other frequent canopy species include *Betula lenta, Quercus velutina, Carya cordiformis*, and less frequently but sometimes abundant, *Carya ovata*, *Acer saccharum, Tilia americana* var. *heterophylla,* or *Juglans nigra*. High constancy understory species in CVS plot data are *Castanea dentata* sprouts, *Acer rubrum, Nyssa sylvatica, Sassafras albidum, Cornus florida,* and *Oxydendrum arboreum*, and other frequent species include *Acer pensylvanicum, Magnolia acuminata*, and *Amelanchier arborea*. Shrubs generally are sparse. *Cornus alternifolia, Corylus americana*, *Calycanthus floridus, Hydrangea arborescens*, and various *Vaccinium* spp. sometimes occur. Vines are not generally abundant, but *Toxicodendron radicans* and *Parthenocissus quinquefolia* are highly constant. The herb layer is usually moderate in density and is diverse. In addition to widespread species such as *Maianthemum racemosum*, *Dioscorea villosa*, *Solidago curtisii*, *Polystichum acrostichoides, Lysimachia quadrifolia*, and *Medeola virginica*, herbs include several of a large suite of base-loving or mesophytic herbs shared with Rich Cove Forest and not generally present in other oak forests. High constancy species in CVS plots are *Amphicarpaea bracteata, Collinsonia canadensis, Uvularia perfoliata, Conopholis americana, Actaea racemosa, Dichanthelium boscii,* and *Galium latifolium*. Other frequent species include *Hylodesmum nudiflorum, Tradescantia subaspera, Eurybia divaricata, Polygonatum biflorum, Goodyera pubescens, Prosartes maculata, Sanguinaria canadensis, Parathelypteris noveboracensis, Eutrochium purpureum, Clintonia umbellula, Chimaphila maculata, Stellaria pubera, Nabalus* sp., *Carex pensylvanica, Ageratina altissima*, and *Pycnanthemum montanum*. Less frequent species that are nevertheless characteristic of the Basic Subtype include *Thalictrum dioicum, Phryma leptostachya, Symphyotrichum cordifolium, Phegopteris hexagonoptera, Hylodesmum glutinosum, Adiantum pedatum, Ligusticum canadense, Brachyelytrum erectum, Bromus pubescens*, and *Laportea canadensis*. The Basic Subtype is among the most species rich of mountain communities. CVS plots average 77 species per 1/10 hectare plot.

Range and Abundance: Ranked G3. This community is scattered throughout the Mountain region and the foothills but is substantially less abundant than the Acidic Subtype. The association ranges southward to Georgia.

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Associations and Patterns: The Basic Subtype may occur as small patches amid acidic communities or may occur in large patches. Where amphibolite is extensive, it may occur in a mosaic with High Elevation Red Oak Forest (Rich Subtype), Northern Hardwood Forest (Rich Subtype), Rich Cove Forest (Montane Rich Subtype), Montane Cliff (Mafic Subtype), and other basic soil communities. At the edges of mafic rock substrate, the Basic Subtype may give way abruptly to other subtypes of Montane Oak–Hickory Forest, but often is bordered instead by Chestnut Oak Forest. It often grades downslope to Rich Cove Forest, which may be the Montane Rich or Foothills Rich Subtype.

Variation: No variants are recognized, though further analysis may identify distinct groupings. Examples vary in how strongly basic they appear to be, based on their flora, with species such as *Brachyelytrum, Phegopteris*, and *Tradescantia* in less basic examples and *Phryma, Adiantum*, *Tilia americana* var. *heterophylla*, and *Juglans nigra* suggestive of more basic conditions.

Dynamics: Dynamics are similar to those of Mountain Oak Forests in general. Although mesophytic tree species of rich soils are characteristic of this community, they presumably have increased with the lack of fire and the death of chestnuts.

Comments: This community is one of several associated with basic soils and mafic rocks, with a distinctive flora sharing many species that normally are confined to more mesic sites. This distinction is not made in most of the early studies of vegetation, though it was recognized in many site-specific reports and is clear in McLeod (1988) and some other later studies. Ulrey (2002) noted that this may be because many study areas, such as the Great Smoky Mountains, have limited variation in geology. His analysis of CVS data from across the region clearly demonstrated the importance of the soil chemistry gradient as well as of topography. Ulrey (2002) also articulated the curious fact that the chemical differences that seem to drive community patterns are not the nutrients most limiting to plant production.

Rare species: Vascular plants – *Adlumia fungosa, Carex amplisquama, Carex hitchcockiana, Carex purpurifera, Carex roanensis, Collinsonia tuberosa, Collinsonia verticillata, Cypripedium parviflorum, Euphorbia purpurea, Gillenia stipulate, Hackelia virginiana, Heuchera pubescens, Isotria medeoloides, Liatris microcephala, Liatris turgida, Melica nitens, Polygala senega, Pyrola elliptica, Silene ovata, Silphium perfoliatum, Sisyrinchium dichotomum, Spiraea corymbose, Thermopsis fraxinifolia, Thermopsis mollis, Tradescantia virginiana.* Animals – *Dendroica cerulea, Plethodon welleri*.

References:

McLeod, D.E. 1988. Vegetation patterns, floristics, and environmental relationships in the Black and Craggy Mountains of North Carolina. Ph.D. dissertation, University of North Carolina, Chapel Hill.

Ulrey, C.J. 2002. The relationship between soil fertility and the forests of the southern Appalachian region. PhD. Dissertation, North Carolina State University, Raleigh.

MONTANE OAK–HICKORY FOREST (LOW DRY SUBTYPE)

Concept: Montane Oak–Hickory Forests are dominated by mixtures of oaks with *Quercus alba* as a significant component. The Low Dry Subtype covers the distinctive lower elevation examples with flora indicative of drier acidic conditions, including species more common in the Piedmont as well as many species characteristic of the Blue Ridge. These communities are usually on dry slope aspects, but they may be associated with a broader range of topography on sand soils. Fire appears to be particularly important for these communities.

Distinguishing Features: The Low Dry Subtype is distinguished from the other subtypes by the occurrence of characteristic lower elevation species such as *Quercus falcata*, *Quercus stellata*, and *Pinus echinata* in the canopy and a suite of low elevation, fire-tolerant herbs, while lacking species indicative of basic soils. The characteristic tree species are indicators that may be present only in small numbers. Characteristic fire-tolerant species include *Baptisia tinctoria, Silphium compositum, Solidago odora, Iris verna, Pityopsis graminifolia*, and *Tephrosia virginiana*. This subtype lacks any of the richer flora characteristic of the Basic Subtype or Low Dry Basic Subtype, but it shares many heath shrub species with the Acidic Subtype. The Low Dry Subtype is distinguished from the Southern Mountain Pine–Oak Forest by having less pine (though pines are often present in small numbers).

Synonyms: *Quercus alba - Quercus coccinea - Quercus falcata / Kalmia latifolia - Vaccinium pallidum* Forest (CEGL007691).
Ecological Systems: Southern Appalachian Oak Forest (CES202.886).

Sites: The Low Dry Subtype typically occurs on convex or planar slopes or spur ridges that face south or west. Examples are at lower elevations, with few getting much above 3000 feet.

Soils: Soils are similar to those in other acidic Mountain Oak Forests. Most are mapped as Typic Hapludults such as Evard, Cowee, and Edneyville. However, the most extensive occurrences are associated with rocky, sandy soils mapped as Ashe (Typic Dystrudept).

Hydrology: Sites are well-drained and drier than other Montane Oak Forests due to low elevation and dry slope aspects.

Vegetation: The forest is dominated by a mix of trees, with *Quercus alba* always present and usually codominant or dominant. *Quercus velutina, Quercus coccinea, Quercus montana, Pinus echinata, Carya glabra*, and *Carya pallida* are also highly constant in plot data and in other observations, and *Pinus rigida* too is frequent. *Quercus falcata* and *Quercus stellata* are characteristic indicator species, usually present in stands but often at low density, so that they are not always found in plot data. Understory species with high constancy include *Nyssa sylvatica, Cornus florida,* and *Sassafras albidum*, all present in all plots, *Acer rubrum, Oxydendrum arboreum*, *Amelanchier laevis*, and *Magnolia fraseri*, all present in more than half of plots and in most other observations. *Pinus strobus* also is highly constant but is presumed to be an indicator of fire exclusion. *Prunus serotina* and *Castanea dentata* are other frequent species in the understory. The shrub layer is open to moderate in density. *Vaccinium pallidum* is most constant and most often dominant. *Kalmia latifolia, Gaylussacia baccata*, and *Vaccinium stamineum* are

also highly constant, as are the vines *Smilax glauca* and *Smilax rotundifolia*. *Castanea pumila* is also frequent. Though somewhat less frequent, *Arundinaria appalachiana* sometimes is abundant. The herb layer is ranges from sparse to fairly dense. It is presumed to be characteristically dense and diverse under natural conditions. In plot data, the most constant species are those shared with the Acidic Subtype and other dense acidic forests: *Chimaphila maculata*, *Goodyera pubescens, Dichanthelium* spp., with *Hylodesmum nudiflorum, Solidago curtisii*, *Dichanthelium commune*, and *Euphorbia pubentissima* frequent. Most characteristic, however, is a suite of species which respond well to fire and to higher light levels. *Pteridium latiusculum*, *Coresopsis major*, *Iris verna* var. *smalliana*, *Smilax biltmoreana,* and *Solidago odora* are highly constant or at least frequent in plot data and are frequently observed. A suite of other species is less constant but is characteristic, collectively allying this subtype to other dry open communities and distinguishing it from more mesic forests: *Coreopsis major, Danthonia spicata, Piptochaetium avenaceum, Lespedeza procumbens*, several *Desmodium* spp., *Tephrosia virginiana, Schizachyrium scoparium, Andropogon gerardii, Lespedeza virginica, Pityopsis graminifolia, Silphium reniforme, Hypoxis hirsuta, Ionactis linariifolia*, *Sericocarpus asteroides*, and several species of *Helianthus*. A few additional low constancy shrubs indicate similar affinities, including *Vaccinium arboreum, Symplocos tinctoria*, *Robinia hispida*, and *Rhus copallinum*. Plots are fairly diverse under present conditions, averaging 59 species per 1/10 hectare, and likely would be much more diverse if examples were frequently burned.

Range and Abundance: Ranked G2G3. This subtype is rare in North Carolina, with most examples remaining in the vicinity of DuPont State Forest, in Cherokee County, and in the South Mountains. It must once have been more common in lower mountain valleys such as those in Cherokee County and the Asheville Basin. The association is not definitely recognized in any other state, but is questionably attributed to Tennessee, Georgia, and South Carolina. It seems particularly likely to occur in Tennessee but may be treated as a different association there.
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Associations and Patterns: The Low Dry Subtype generally occurs in small to large patches, adding up to several hundred acres in the landscape mosaic of a few known sites. It usually grades to the Acidic Subtype or to Chestnut Oak Forest on less dry sites.

Variation: With the new recognition of the Low Dry Basic Subtype, no variants are recognized.

Dynamics: This subtype is presumed to be more influenced by fire than the other subtypes and other mountain oak forests, with fire maintaining a more open canopy, even less dense understory, and a correspondingly dense herb layer. Given its cooccurrence in landscapes with more mesic forests, the greater influence of fire presumably comes partly from greater fire intensity, though the dry site conditions also would increase the likelihood that any ignition would spread through the whole area and might slow the recovery of the woody vegetation.

Comments: This is a very distinctive subtype that may be considered as closely related to Southern Mountain Pine-Oak Forest or to Low Mountain Pine Forest as to other subtypes of Montane Oak–Hickory Forest. It was not distinguished in any of the early or later quantitative studies, and no such study has covered an area where it occurs. No examples were known at the time of the 3rd Approximation. It was first recognized in descriptive surveys at what became

DuPont State Forest in the 1990s. A small number of plots in the CVS database allows some quantitative description of it.

Rare species: Vascular plants – *Liatris aspera, Liatris turgida, Helianthus laevigatus*. Animals – *Aneides aeneus*.

References:

MONTANE OAK—HICKORY FOREST (LOW DRY BASIC SUBTYPE)

Concept: Montane Oak–Hickory Forests are dominated by mixtures of oaks with *Quercus alba* as a significant component. The Low Dry Basic Subtype covers the distinctive, very rare examples that combine flora indicative of drier conditions with that indicative of basic soil conditions. Many species more common in the Piedmont than the mountain are present, along with those characteristic of the Blue Ridge. This community is presently known only from the South Mountains but may be found in other places.

Distinguishing Features: The Low Dry Basic Subtype is distinguished from the other subtypes by the occurrence of characteristic lower elevation species such as *Quercus falcata*, *Quercus stellata*, and *Pinus echinata* in the canopy and suite of low elevation, fire-tolerant herbs, combined with species indicative of basic soils. The characteristic low elevation tree species are indicators that may be present only in small numbers. Characteristic fire-tolerant species include *Baptisia tinctoria, Silphium compositum, Solidago odora, Iris verna, Pityopsis graminifolia*, and *Tephrosia virginiana*. Characteristic basic soil species include *Fraxinus americana* or *biltmoreana*, *Cercis canadensis*, *Rosa carolina, Frangula caroliniana, Chionanthus virginiana, Andersonglossum (Cynoglossum virginianum), Tragia urticifolia*, and *Scleria oligantha*.

Synonyms: No NVC association is yet established.
Ecological Systems: Southern Appalachian Oak Forest (CES202.886).

Sites: The Low Dry Basic Subtype occurs on convex or planar slopes or spur ridges that face south or west, and that have amphibolite or other mafic rock substrates. The known range of occurrence is around 1400-1700 feet, but examples should be sought throughout the elevations typical of the Low Dry Subtype, up to 3000 feet or a bit higher.

Soils: Soils presumably are unusually high in pH and base saturation. The known area is mapped as Evard-Cowee complex (Typic Hapludults).

Hydrology: Sites are well drained and drier than other Montane Oak Forests due to low elevation and dry slope aspects.

Vegetation: The canopy consists of a mix of tree species in which *Quercus alba* usually is dominant or codominant, while *Quercus montana, Carya glabra,* and *Carya pallida* are abundant. Species indicative of low dry conditions, such as *Quercus stellata*, *Quercus falcata*, *Pinus echinata*, and *Carya pallida* are present. Species indicative of higher pH conditions, such as *Fraxinus americana/biltmoreana*, are characteristic and may be abundant but may be present only at low density. *Quercus velutina* also has high constancy in the known example. The understory includes frequent *Cornus florida, Diospyros virginiana, Sassafras albidum,* and *Nyssa sylvatica*. Less abundant but characteristic species include *Cercis canadensis, Prunus serotina*, and in the known example, *Prunus alleghaniensis* and *Crataegus uniflora*. The shrub layer varies. *Arundinaria appalachiana* dominates large patches in the known example. Other areas have sparser shrubs that include some notable species such as *Celtis tenuifolia* (possibly *smallii*), *Amorpha glabra*, *Chionanthus virginicus, Toxicodendron pubescens*, *Rosa carolina*, and *Frangula caroliniana*, as well as more widespread species such as *Vaccinium pallidum* and *Vaccinium*

stamineum. *Muscadinia rotundifolia, Parthenocissus quinquefolia*, and *Vitis aestivalis* may be abundant on the ground. The herb layer includes large areas dominated by *Piptochaetium avenaceum*. Other high constancy or frequent herbs include *Clitoria mariana, Coreopsis major, Solidago odora, Carex nigromarginata, Chimaphila maculata, Dichanthelium commutatum, Endodeca serpentaria, Galium circaezans, Helianthus divaricatus, Iris verna* var. *smallii*, *Lespedeza repens, Lespedeza violacea, Mimosa microphylla, Scleria oligantha, Solidago petiolaris, Symphyotrichum pretense, Tragia urticifolia*, and *Parthenium integrifolium*. Less frequent in plots but characteristic or indicative herb species include *Agrimonia pubescens, Agrimonia microcarpa, Brickellia eupatorioides, Cunila origanoides, Danthonia sericea, Euphorbia pubentissima, Cynoglossum virginianum, Liatris spicate, Lithospermum virginianum, Phaseolus polystachyos, Silphium reniforme, Tetragonotheca helianthoides, Angelica venenosa, Pityopsis graminfolia, Schizachyrium scoparium*, and *Tephrosia virginiana*. The plot data show high species richness, averaging 77 species per 1/10 ha.

Range and Abundance: Ranked G1. At present, this community is known at only one site in the South Mountains. It may be found at other places within the range of the Low Dry Subtype, and possibly in other states, but likely is extremely rare.

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Associations and Patterns: This community occurs as small patches. The known example is associated with other subtypes of Montane Oak–Hickory Forest, including the Low Dry Subtype and Basic Subtype, and with Low Elevation Basic Glade.

Variation: Only a single occurrence is known. If more are found, they may be fairly different.

Dynamics: As in the Low Dry Subtype, this subtype is presumed to be more influenced by fire than the other subtypes and other Montane Oak Forests, with fire maintaining a more open canopy, even less dense understory, and a correspondingly dense herb layer. The abundance of *Arundinaria appalachiana* might also be maintained by fire. Given its cooccurrence in landscapes with more mesic forests, the greater influence of fire presumably comes partly from greater fire intensity, though the dry site conditions also would increase the likelihood that any ignition would spread through the whole area and might slow the recovery of the woody vegetation.

Comments: This subtype has been recognized only recently. It was not included in the 2012 edition of the 4th Approximation Guide, as its status was still being considered. It was first identified by Kevin Caldwell and Lloyd Raleigh after 2010. Several CVS plots were sampled in 2013, giving some basis for quantitative description. The known site has a number of unusual floristic characteristics, in other communities as well as in this one. If other examples of the Low Dry Basic Subtype are found, they may be substantially different, but should be recognizable by a combination of flora indicative of warm dry conditions and of basic soils.

Rare species: Vascular plants – *Helianthus laevigatus, Liatris aspera, Liatris turgida, Matelea decipiens, Prunus alleghaniensis*, *Tradescantia virginiana*.

References:

MONTANE OAK–HICKORY FOREST (WHITE PINE SUBTYPE)

Concept: Montane Oak—Hickory Forests are dominated by mixtures of oaks with *Quercus alba* as a significant component. The White Pine Subtype encompasses examples with a significant component of *Pinus strobus*. Most resemble the Acidic Subtype except for the presence of *Pinus strobus*.

Distinguishing Features: The White Pine Subtype is distinguished by the combination of significant, though not necessarily dominant, *Pinus strobus* in combination with *Quercus alba* under natural conditions. *Pinus strobus* generally provides 25-75% of the canopy cover, but may be less in altered stands. It is distinguished from White Pine Forest by having no more than 75 percent of the canopy cover being *Pinus strobus* under natural conditions. It is distinguished from the White Pine Subtype of Chestnut Oak Forest by having *Quercus alba* as a significant canopy component. The White Pine Subtype should only be used where white pine is believed to be naturally present, not for forests where it has been planted or where it likely spread from nearby plantings. *Pinus strobus* that is abundant as saplings but is scarcely present in the canopy probably indicates recent invasion and should not be the basis for recognizing the White Pine Subtype unless other evidence points to it. Some *Pinus strobus* may be present in the Low Dry Subtype, which can be distinguished by the presence of more drought tolerant oaks.

Synonyms: *Pinus strobus - Quercus alba - (Carya alba) / Gaylussacia ursina* Forest (CEGL007517).
Ecological Systems: Southern Appalachian Oak Forest (CES202.886).

Sites: The White Pine Subtype occurs on ridge tops and on upper to lower slopes, spur ridges, and some valley flats. It generally occurs at lower elevations, from 1300-3000 feet, but extends up to 3500 feet or higher in the southern mountains.

Soils: This community occurs on a broad range of uplands soils, mostly Typic Dystrudepts such as Edneyville or Ashe, or Typic Hapludults such as Chester and Evard.

Hydrology: Sites are well-drained, and conditions generally are dry-mesic to dry.

Vegetation: The forest is a varying mix in which *Quercus alba* and *Pinus strobus* are both present in significant numbers in the canopy. They may be codominant, or pines may be a fairly small minority. In CVS plot data, *Liriodendron tulipifera, Carya tomentosa*, and possibly *Acer rubrum* are the only other canopy species with more than 50% frequency. *Quercus montana, Quercus rubra, Carya coccinea*, *Carya glabra*, and *Quercus velutina*, all less frequent in the plot data, are more regularly noted in other site descriptions. The understory may include a wide range of species beyond the canopy species. *Oxydendrum arboreum, Nyssa sylvatica, Cornus florida, Magnolia fraseri*, and *Sassafras albidum* are frequent in drier sites, while *Tsuga canadensis* or *Ilex opaca* can dominate the understory in more mesic occurrences. The shrub layer ranges from sparse to dense. Some examples have moderate density of *Kalmia latifolia, Gaylussacia ursina*, or *Rhododendron maximum*. Other fairly frequent shrubs in plot data include *Vaccinium pallidum* and *Symplocos tinctoria*, while *Smilax glauca* and *Smilax rotundifolia* are frequent vines. The herb layer is sparse and indicative of acidic soils, with *Goodyera pubescens, Chimaphila maculata,*

Polystichum acrostichoides, and *Parathelypteris noveboracensis* having high constancy in plot data, and *Galax urceolata, Mitchella repens, Lysimachia quadrifolia, Medeola virginica*, and *Viola hastata* being fairly frequent. Overall species richness is low, averaging 35 species per plot.

Range and Abundance: Ranked G2G3, but probably less rare than this suggests. The White Pine Subtype has an odd, discontinuous distribution. It is most abundant in the Blue Ridge escarpment and foothills, but also occurs above the escarpment in several areas. It may be more common in the high rainfall area along the South Carolina border, and it is more abundant in gorges such as Linville Gorge. It is less common than the Acidic Subtype but probably is less uncommon than the number of records suggests. The association ranges to South Carolina, Georgia, and Tennessee, and is questionably attributed to Kentucky.

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Associations and Patterns: The White Pine Subtype often is a matrix community where it occurs, forming a substantial part of the landscape mosaic. It can be associated with Montane Oak—Hickory Forest (Acidic Subtype), Chestnut Oak Forest of all subtypes, and Acidic Cove Forest, less often with Rich Cove Forest, Pine—Oak/Heath, rock outcrops, or other communities.

Variation: No variants have been recognized. Examples vary in the relative amount of *Pinus strobus*, but it is unclear when such variation is natural and when it is a result of land use history or alteration of fire.

Dynamics: As with Chestnut Oak Forest (White Pine Subtype), the reason for the occurrence of *Pinus strobus* in this subtype and not in others is not well known. It seems to be something other than the normal gradients of topography, moisture levels, and soil chemistry, since it occurs over a broad range of topography in some places and is absent in others.

Besides occurrence at low elevations, the present of *Pinus strobus* likely depends on some aspect of dynamics. It is generally regarded as intolerant of fire, though catastrophic fire may favor its regeneration. This community is somewhat associated with gorges and other rugged topography, which may reduce fire frequency while not eliminating it entirely. *Pinus strobus* saplings are fairly tolerant of shade, often persisting in large numbers in the understory in this community, and even around single isolated trees in other communities. The species appears able to take advantage of canopy gaps and to reproduce without fire. These thin-barked saplings are very susceptible to fire, and chronic fire at moderate frequency likely would prevent reproduction of this species. DeYoung (1979), studying on the Tennessee site of the Great Smoky Mountains, found stands of mixed *Pinus strobus* and *Quercus alba* that he interpreted as self-sustaining.

The response of this community to land use is particularly hard to interpret. *Pinus strobus* may potentially be either increased or decreased by past logging. Saplings appear to be invading forests where the species is not abundant in the canopy, and it is unclear if this is a situation of *Pinus strobus* acting as another mesophytic species invading in the absence of fire, or if it is returning to places where it was removed from the canopy in the past. Abella and Shelburne (2003) documented the establishment of *Pinus strobus* and abundance of young pines in an oak forest at Ellicott Rock Wilderness where none had been present before 1900 and only small amounts since 1950. In their study, and in the author's experience, understory and sapling pines

are most strongly correlated with the presence of large pines but can be very abundant where only a few large trees are present.

Abel (1934) noted that *Pinus strobus* suffered little damage from an ice storm that badly damaged oaks. Such storms are common enough that they may help the species coexist with oaks, though this does not appear to explain the variable presence and absence of the species.

Comments: Newell (1997) recognized a *Quercus alba-Pinus strobus*/*Kalmia latifolia* community in Linville Gorge that clearly is equivalent to this subtype. Callaway, et al. (1987) recognized a white oak-white pine forest which overlapped with other oak forests in ordinations. They described it as being in disturbed areas on limestone, so it is unclear if it is comparable to this natural community.

It is very difficult to distinguish natural occurrence of the White Pine Subtype from successional forests in secondary sources. The discrepancy between vegetation depicted by existing plot data and that often observed in the field may partly result from inclusion of plots in more altered forests. Also, the statistics for CVS data for this subtype are dominated by supplementation of the database by large numbers of plots from focused studies in places where white pine is particularly abundant: Ellicott Rock Wilderness (Patterson 1994) and Thompson River Gorge (Wentworth 1980).

This subtype needs further investigation into its distinctiveness. The recognition of distinct associations for white pine combinations, and the subsequent recognition in the 4th Approximation, may be an example of the "conifer bias" that is frequent in forest ecology, but that fact that the pine is present in some areas and not others suggests the likelihood that it reflects environmental or biogeographic conditions that would lead to additional differences between the subtypes.

The drivers of this odd distribution of white pine-containing communities are not known. It is apparently of long standing. Pinchot and Ashe (1897) noted: "The woodland in which white pine is the dominant coniferous tree is not extensive, but lies in isolated, small bodies along the crest, and southern and eastern slopes of the Blue Ridge or on the low hills on the west." They go on to list these areas as the South Fork New River valley of Ashe and Watauga County, the upper valley of the Linville River in Mitchell County, the valley of the French Broad River in Transylvania County, and the southern parts of Macon and Jackson County. They also note the escarpment in Wilkes and McDowell County as a place where both white and yellow pines occur together.

Rare species: Vascular plants – *Fothergilla major, Liatris turgida, Lysimachia fraseri, Monotropsis odorata, Thermopsis fraxinifolia*.

References:

Abel, C.A. 1934. Influence of glaze storms upon hardwood forest in the Southern Appalachians. Journal of Forestry 32: 35-37.

Abella, S.R., and V.B. Shelburne. 2003. Eastern white pine establishment in the oak landscape of the Ellicott Rock Wilderness, Southern Appalachian Mountains. Castanea 68: 201-210.

Patterson, K. D. 1994. Classification of vegetation in Ellicott Rock Wilderness, Southeastern Blue Ridge Escarpment. M.S. thesis, North Carolina State University, Raleigh. 91 pp.

Callaway, R.M., E.E.C. Clebsch, and P.S. White. 1987. A multivariate analysis of forest communities in the western Great Smoky Mountains National Park. American Midland Naturalist 118: 107-120.

Newell, C.L. Local and regional variation in the vegetation of the Southern Appalachian Mountains. PhD. Dissertation, UNC-Chapel Hill.

Pinchot, G., and Ashe, W.W. 1897. Timber trees and forests of North Carolina. North Carolina Geological Survey Bulletin No. 6.

Wentworth, T.R. 1980. Preliminary analysis of vegetation in the Thompson River watershed, North and South Carolina. In: HJ. Lieth and E. Landolt, eds. Contributions to the knowledge of flora and vegetation in the Carolinas. Veroff. Geobot. Institut ETH, Stiftung Rubel, Zurich. No. 68.

MONTANE OAK–HICKORY FOREST (BOULDERFIELD SUBTYPE)

Concept: Montane Oak–Hickory Forest (Boulderfield Subtype) communities are forests of well-developed boulderfields, dominated by a mixture of oaks that includes *Quercus alba*, usually along with *Quercus rubra* or *Quercus montana*. Substrates are comparable to High Elevation Birch Boulderfield Forest and Rich Cove Forest (Boulderfield Subtype), but mesophytic trees are present in only small numbers if at all.

Distinguishing Features: The Boulderfield Subtype of Montane Oak–Hickory Forest, like the High Elevation Birch Boulderfield Forest and the Boulderfield Subtype of Rich Cove Forest, is distinguished by occurring on well-developed boulderfields, with near complete cover by large rocks, substantial open space beneath the rocks, soil limited to accumulations on top of and between rocks, and lower vegetation strata substantially influenced by the rock cover. Montane Oak–Hickory Forest (Boulderfield Subtype) is distinguished from boulderfield subtypes of other communities by having canopy composition comparable to other Montane Oak–Hickory Forest subtypes: dominance by a mix of oaks that includes *Quercus alba*.

Because the lower strata, especially the herb layer, are less dense in oak forests than in Rich Cove Forest or Northern Hardwood Forest communities, the recognition of the Boulderfield Subtype of Montane Oak–Hickory Forest may be more subtle and require more attention to extreme rock cover and space beneath the rocks. Many Montane Oak--Hickory Forests are rocky but most do not have enough surface boulder cover to affect community composition.

Synonyms: No NVC equivalent.
Ecological Systems: Southern Appalachian Oak Forest (CES202.886).

Sites: The Boulderfield Subtype may occur on convex, planar, or somewhat concave slopes, generally moderate to steep. It may be on the edges of relict periglacial boulderfields, which tend to be in steeply plunging coves, or it may occur on talus beneath rock outcrops. The boulders in the few known examples tend to be smaller than those in the Rich Cove Forest subtype or in High Elevation Birch Boulderfield, but it is uncertain if this is universally true. Examples might occur anywhere in the elevational range of Montane Oak–Hickory Forest.

Soils: Soil consists of accumulations of organic matter on and among the boulders (Lithic Dystrochrepts), but patches are generally small and are inclusions in soil map units.

Hydrology: Conditions are generally dry-mesic due to topography, but moisture may vary drastically at very fine scale. Shallow soil pockets maybe become dry very quickly. Seepage areas are less likely than in more mesic boulderfields. However, large established trees may be rooted beneath the boulders and have a greater supply of moisture.

Vegetation: The Boulderfield Subtype canopy is well developed, either closed or somewhat open. It is dominated by a mix that includes *Quercus alba* along with *Quercus rubra* or *Quercus montana* or both. Other tree species may include *Betula lenta, Betula alleghaniensis, Carya* spp., *Tilia americana* var. *heterophylla*, *Acer saccharum, Fraxinus americana*, or other species. The understory and shrub layer generally are sparse. *Ribes cynosbati* and *Viburnum acerifolium*

sometimes occur. Vines sometimes have extensive cover. *Toxicodendron radicans, Parthenocissus quinquefolia*, or *Isotrema macrophyllum* are the most frequent species. Lichens, or potentially bryophytes, may have extensive cover on the rocks. Otherwise, herbs are sparse. Species characteristic of rock outcrops, such as *Polypodium virginianum, Dryopteris marginalis*, and *Sedum ternatum*, are usually the most abundant. Other species that may occur in small numbers include *Uvularia puberula, Dioscorea villosa, Galium* spp., and a variety of species typical of other subtypes.

Range and Abundance: Unranked but likely G1 or G2. This community is newly recognized, but it is unlikely that more than a handful of examples will be found.

Associations and Patterns: Montane Oak–Hickory Forest (Boulderfield Subtype) occurs with other Mountain Oak Forests. It often is associated with Rich Cove Forest (Boulderfield Subtype).

Variation: Variation is not fully known. The known occurrences occur on amphibolite and have composition suggestive of high base saturation and reduced soil acidity. However, acidic versions may also be found and could be treated as variants.

Dynamics: While stand dynamics presumably are similar to other oak forests, canopy gaps last longer because of the difficulty of tree establishment. Fire may be less of an influence because of the discontinuous leaf litter cover on the surface.

Comments: As with Rich Cove Forest (Boulderfield Subtype), this community is more similar to other Montane Oak–Hickory Forests than is High Elevation Birch Boulderfield to Northern Hardwood Forests, so it is recognized as a subtype rather than a full type. This subtype is one of the most recently recognized communities, added to the 4th Approximation well after the guide was published. Analogous boulderfield subtypes have also been found for Chestnut Oak Forest and High Elevation Red Oak Forest. More work is needed to fully characterize all of these communities. The author has observed multiple examples and several more have been reported. However, some reported examples have proven to be the more mesophytic Boulderfield Subtype of Rich Cove Forest, with a limited oak component.

All of the oak boulderfield forests are expected to be extremely rare and likely of limited extent. However, it should be noted that the Boulderfield Subtype of Rich Cove Forest, while uncommon, proved to be less extremely rare than it appeared when first defined.

Rare species: No rare species are known to be associated with this community.

References: No references specific to this community have been identified.

LOW MONTANE RED OAK FOREST

Concept: Low Montane Red Oak Forest communities are low-to-mid elevation mountain forests dominated by *Quercus rubra*, without appreciable *Quercus alba*, without the distinctive features of Chestnut Oak Forest (Mesic Subtype) or Rich Cove Forest (Red Oak Subtype). The floristic composition suggests intermediate to high soil fertility, lacking the well-developed heath shrub layer of Montane Oak–Hickory Forest (Acidic Subtype) or Chestnut Oak Forest (Mesic Subtype).

Distinguishing Features: Low Montane Red Oak Forest is distinguished from most other oak forests by dominance by *Quercus rubra* without appreciable *Quercus alba* or *Quercus montana*, at low elevations. Chestnut Oak Forest (Mesic Subtype) can be codominated or occasionally dominated by *Quercus rubra*, but it has a composition indicative of very acid soils, with a prominent evergreen heath shrub layer. The distinction from High Elevation Red Oak Forest can generally be made based on elevation, but further clarification is needed for elevations near 3500 feet. The oak in Low Montane Red Oak Forest should be *Quercus rubra* var. *rubra*, while that in High Elevation Red Oak Forest generally is *Quercus rubra* var. *ambigua*, but the varieties have not been widely enough distinguished in literature or plot data to know how reliably this is true near the transition. Low Montane Red Oak Forest will lack species characteristic of higher elevations such as *Betula alleghaniensis, Acer saccharum*, or *Fagus grandifolia*, though the latter two may be present in the transition to Rich Cove Forest. Associated mesophytic species may be absent, but if present, are more likely to be *Liriodendron tulipifera, Betula lenta*, *Halesia tetraptera*, or *Magnolia acuminata*. *Quercus rubra* often is present in all subtypes of Rich Cove Forests and can be abundant enough to appear dominant in a single plot. Low Montane Red Oak Forest should be used only for more extensive stands, but distinguishing individual plots without context may be difficult. The distinction from Rich Cove Forest (Red Oak Subtype) needs further clarification, since *Quercus rubra* can be dominant throughout that community. Most examples of that community have *Tilia americana* var. *heterophylla* as a codominant or abundant tree, while it has not been noted in known examples of Low Montane Red Oak Forest. However, individual plots may be difficult to distinguish, and even some whole stands may prove ambiguous.

Synonyms: *Quercus rubra - Acer rubrum / Calycanthus floridus - Pyrularia pubera / Thelypteris noveboracensis* Forest (CEGL006192).
Ecological Systems: Southern Appalachian Oak Forest (CES202.886).

Sites: Open lower to mid slopes, with some sheltering by adjacent topography or facing north or east. Examples occur at low elevations, usually below 3000 feet but possibly up to around 3600 feet.

Soils: Soils are not well known. The known examples are mapped as a variety of widespread series of Typic Hapludults and Typic Dystrudepts.

Hydrology: Moisture conditions apparently are dry-mesic, somewhat more moist than most Montane Oak Forests.

Vegetation: Forests are dominated by *Quercus rubra*, sometimes with *Carya glabra*, *Acer rubrum*, or other species codominating but with little or no *Quercus alba* and limited *Quercus*

montana. Other canopy trees are mainly mesophytic species such as *Liriodendron tulipifera*, *Betula lenta*, or *Halesia tetraptera*. The understory consists of canopy species in combination with widespread understory species such as *Cornus florida, Nyssa sylvatica*, *Oxydendrum arboreum*, and *Castanea dentata* sprouts, and sometimes mesophytic species such as *Tsuga canadensis*. The shrub layer generally is open. *Pyrularia pubera* and *Calycanthus floridus* are characteristic. Other species include *Rhododendron calendulaceum, Vaccinium corymbosum*, and less frequently, *Hydrangea arborescens, Hydrangea radiata, Rhododendron minus, Corylus cornuta, Viburnum acerifolium, Hamamelis virginiana*, and other species. The herb layer ranges from moderate to sparse. It may be dominated by a few species, such as *Parathelypteris noveboracensis* or *Athyrium asplenioides;* may have a higher diversity of widely tolerant species such as *Lysimachia quadrifolia, Eurybia divaricata, Goodyera pubescens, Maianthemum racemosum, Medeola virginiana, Carex* spp., and *Hylodesmum nudiflorum*; or it may contain species indicative of richer soils such as *Collinsonia canadensis, Chasmanthium latifolium, Amphicarpaea bracteata, Cynoglossum virginianum, Dichanthelium boscii, Sanguinaria canadensis, Actaea racemosa*, and *Tradescantia subaspera*.

Range and Abundance: Ranked G4? but perhaps rarer. Unclear circumscription makes it difficult to determine abundance, but only a handful of occurrences have been recognized in NHP surveys. Known examples are widely but sparsely distributed in the North Carolina mountains. The association is attributed to South Carolina, Georgia, Tennessee, and Kentucky, but not Virginia.

Associations and Patterns: The community typically occurs as large patches, up to 100 to 300 acres. It is associated with other Montane Oak Forests in drier areas and with Rich Cove Forest in more mesic areas.

Variation: Two variants are recognized:
1. Typic Variant fits most of the description of vegetation above but lacks species of richer soils.
2. Rich Variant contains species typical of richer soils. This variant may be distinctive enough to warrant a separate subtype, analogous to the Basic Subtype of Montane Oak–Hickory Forest and High Elevation Red Oak Forest. Plot data may look similar for it and for Rich Cove Forest (Red Oak Subtype), and the distinction needs further clarification.

Dynamics: Dynamics are presumably similar to those of most Montane Oak Forests, but the dry-mesic sites, at the moist end of their range, may imply somewhat reduced influence of fire.

Comments: This community is particularly poorly understood. It was added to the NVC based on plot studies in other states but appears to be comparable to the red oak-pignut forest recognized by Whittaker (1956) in Tennessee. However, conceptual circumscription seems to differ among users, and descriptions and plot assignments vary as a result. Nevertheless, the verified existence of strongly *Quercus rubra*-dominated forests that are not High Elevation Red Oak Forests calls for recognition of something like this community. As defined here, Low Montane Red Oak Forest is narrower than some other uses. Forests with weak predominance of *Quercus rubra* but with significant *Quercus alba* being included in Montane Oak–Hickory Forest instead. The later recognition of Rich Cove Forest (Red Oak Subtype), and variable use of its equivalent association, has further confused the picture and calls for more comparative study.

Day and Monk (1974) found that *Quercus rubra* was the only major tree or shrub species in their Coweeta study other than *Quercus velutina* that wasn't correlated with any of their terrain-based environmental variables. They did not offer an explanation, but it may serve to illustrate the very broad ecological tolerance of the species at the low elevations of their study area.

Quercus rubra is presumed to be the most mesophytic of the Appalachian oaks, and its widespread occurrence in Rich Cove Forest and Acidic Cove Forest supports this idea. *Quercus alba* is also often present in Rich Cove Forests and other mesic sites, but tends to be less abundant. Nevertheless, Blackman and Ware's (1982) direct measurements of soil moisture in Virginia found that *Quercus rubra* stands were not always the most mesic oak forests.

Rare species:

References:

Blackman, D., and S. Ware. 1982. Soil moisture and the distribution of *Quercus prinus* and *Quercus rubra*. Castanea 47: 360-367.

Day, F.P., and C.D. Monk. 1974. Vegetation patterns on a Southern Appalachian watershed. Ecol. 55: 1064-1074.

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs 26: 1-80.

CALCAREOUS OAK–WALNUT FOREST

Concept: Calcareous Oak–Walnut Forests are very rare low elevation dry-mesic mountain slope forests on dolomite or other calcareous rocks, dominated or codominated by *Quercus muehlenbergii* and/or *Juglans nigra*.

Distinguishing Features: Calcareous Oak–Walnut Forests are distinguished from all other community types by occurrence on dolomite, limestone, or marble and canopy dominance by *Quercus rubra, Quercus muhlenbergii*, or *Juglans nigra*, along with a flora indicative of calcareous conditions. More mesophytic species are usually present but do not predominant as they do in Rich Cove Forest. Montane Oak–Hickory Forest (Basic Subtype), High Elevation Red Oak Forest (Rich Subtype), and the Rich Variant of Low Montane Red Oak Forest and of Chestnut Oak Forest (Herb Subtype) may share many species of basic soils but generally lack *Quercus muhlenbergii* and usually lack *Juglans nigra*.

Synonyms: *Quercus rubra - Quercus muehlenbergii / Hamamelis virginiana / Polymnia canadensis* Forest (CEGL007215); Basic Mesic Forest (Montane Calcareous Subtype) (3rd Approximation).
Ecological Systems: Southern Appalachian Oak Forest (CES202.886).

Sites: Calcareous Oak–Walnut Forests occur on lower to mid slopes where the substrate is calcareous rock such as limestone, dolomite, or marble.

Soils: Soils are rocky, presumably high in pH and very high in calcium. Soils are mapped as a wide variety of widespread series of Ultisols and Inceptisols, but they may represent inclusions in these map units.

Hydrology: Sites are dry-mesic to mesic, sheltered by topography but fairly rocky.

Vegetation: Forests are dominated by either *Quercus rubra*, *Quercus muhlenbergii*, or *Juglans nigra*. Other frequent abundant species include *Carya cordiformis*, *Ulmus rubra*, and *Fraxinus americana*. Other species present in smaller numbers may include *Juglans cinerea, Liriodendron tulipifera, Acer saccharum, Tilia americana* var. *heterophylla*, and other species shared with Rich Cove Forest. The understory consists mainly of the same species, sometimes along with *Cornus florida, Prunus serotina*, or *Cornus alternifolia*. *Ulmus rubra* may dominate the understory. Shrubs are not dense, but *Hamamelis virginiana* sometimes is abundant, and *Celtis tenuifolia* (?) often is present. A few vines may be abundant, especially *Isotrema macrophyllum* and *Toxicodendron radicans*. The herb layer generally is dense, diverse, and includes a number of species recognized as calciphilic as well as more widespread dry-mesic and mesic species. Species that seem to be frequent include *Eurybia divaricata, Amphicarpaea bracteata, Dichanthelium boscii, Dichanthelium commutatum, Arisaema triphyllum, Cubelium concolor, Asplenium resiliens, Pellaea atropurpurea, Actaea racemosa, Maianthemum racemosum, Muhlenbergia tenuiflora, Brachyelytrum erectum*, and *Campanula americana*. Other species that may be present and suggest the calcareous conditions include *Adiantum pedatum, Botrypus virginianus, Chasmanthium latifolium, Hylodesmum glutinosum, Eutrochium purpureum*, and *Cystopteris bulbifera*.

Range and Abundance: Ranked G1Q. This community is extremely rare, with only a few sites in North Carolina. The precise range and abundance in North Carolina is complicated by uncertain classification of a couple of possible examples; however, the total number of sites is no more than five. Well-developed examples are known from the Grandfather Mountain Window in the Catawba River valley, with less certain examples from the Hot Springs Window in Madison County and near the Little Tennessee River in Swain County. The association is defined from North Carolina and is not recognized in any other state, though it is questionably attributed to South Carolina. The taxonomic question of the G-rank probably is not warranted, though there should be greater clarification or investigation of calcareous communities in nearby Tennessee that may be similar.

Associations and Patterns: This community sometimes grades into Montane Cliff (Calcareous Subtype) on rocky outcrops contained within the forest. It often grades to Rich Cove Forest on more mesic sites. It abruptly borders various acidic forest communities at the edge of the calcareous rock substrate.

Variation: Each of the few examples is rather different in composition, and most are also heterogeneous.

Dynamics: Because of topographic sheltering and presence of rock outcrops, fire is probably less important than in most Montane Oak Forests. In steep examples, rock falls or soil movement may be important natural disturbances.

Comments: This community is poorly known. No pertinent published literature appears to exist. It was formerly treated as a subtype of Basic Mesic Forest in the 3rd Approximation but has too much montane floristic affinity to retain that treatment. The community appears, however, to be at the mesic end of the moisture range for Montane Oak Forests. The more mesic parts of some occurrences do resemble Rich Cove Forest without fitting any defined subtype well.

Although most of the sites for this community have been known for some time, and it was included under a different name in the 3rd Approximation, rarity and limited access have impeded study. A few plots have been sampled by CVS but knowledge remains limited.

Rare species: Vascular plants – *Anticlea glauca, Arabis patens, Hexalectris spicata, Hydrastis canadensis, Stachys cordata, Thaspium pinnatifidum.*

References: