THE CENTRAL HARDWOOD FOREST: ITS BOUNDARIES AND PHYSIOGRAPHIC PROVINCES

James S. Fralish[1]

ABSTRACT.—The Central Hardwood Forest (CHF) refers to the area where deciduous hardwood species overwhelmingly, but not exclusively, dominate the stands and cover types that occur as repeating units across the landscape. Transition zones where Central Hardwood species mix with species from adjacent regions identify boundaries of the region. These regions are the Northern Hardwood-Conifer Forest along the northern border, the Southeastern-Pine Forest along the eastern and southern borders, and the Tall Grass Prairie region to the west. There is a distinctness and cohesiveness to the CHF as its boundaries frequently cut across geographic features. The 18 oak and 10 hickory species that dominate stands from Missouri to West Virginia, and Wisconsin to Alabama, unify the region. The more important species such as white, black, and chestnut oak may form essentially climax communities on dry sites or successional communities on moist sites. These species may be regarded as obligate xerophytes and facultative pioneers. Such a successional/stability pattern/process is either absent or difficult to identify in other forested regions. Geographically, the region is also diverse. Physiographic provinces include the unglaciated Blue Ridge Mountains, Appalachian Plateaus, Interior Low Plateaus, and Ozark Plateaus, and the glaciated Central Lowlands. The Mississippi floodplain and Gulf Coastal Plain extend into the region. Bedrock, surface deposits, topography, and the soil mosaic vary from province to province and with subregions within provinces.

What and where is the Central Hardwood Forest region and are there boundaries that can appropriately define it? The answer to that question varies somewhat depending on which scientist, book, research report, or map is consulted (Fralish 2002). The concept of a “Central Hardwood Forest” (CHF) region was developed and used by foresters before E. Lucy Braun alluded to the region in 1950. The name apparently developed over the years from the idea that the vegetation of a relatively large area in east-central United States was dominated by broadleaf deciduous hardwoods (angiosperms) and that few commercially important conifers (gymnosperms) or evergreen angiosperms were found within the area. “Vegetation” here is defined as the sum of the stands (communities) or cover types in the region.

Using the criterion of defining the CHF by the dominance of hardwood stands and a general absence of commercial or non-commercial conifers is not completely satisfactory. The generally noncommercial redcedar (*Juniperus virginiana* L.) is the only conifer that spans the CHF, but its development as a community type is severely restricted. Limestone cedar glades are common in central Kentucky and Tennessee and a few sandstone cedar glades occur in the Shawnee Hills of southern Illinois. The species is invasive on open xeric sites such as prairies, barrens, and woodlands of Missouri and Arkansas. It may survive but seldom grows and develops (completes the life cycle) in moderately dense woods.

Other conifers in the CHF include shortleaf pine (*Pinus echinata* Mill.) and Virginia pine (*P. virginiana* Mill.) on xeric sites scattered in Kentucky and Tennessee, and the southern Appalachian Mountains. Shortleaf pine is found in only two locations in southern Illinois, scattered in the Ozark Mountains of Missouri, and as an important community type in the Boston Mountains of the Ozark Plateaus, the Coastal Plain, and the Piedmont province. The largest

---

[1]Emeritus Professor (JSF), Department of Forestry, Southern Illinois University, Carbondale, IL 62901-4411. JSF is corresponding author: to contact, call (618) 453-3341 or (618) 549-4172 or fax (618) 549-6318 or e-mail at jfralish@gte.net.

Citation for proceedings: Van Sambeek, J.W.; Dawson, J.O.; Ponder, F., Jr.; Loewenstein, E.F.; Fralish, J.S., eds. 2003. Proceedings, 13th Central Hardwood Forest conference; 2002 April 1-3; Urbana, IL. Gen. Tech. Rep. NC-234. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 565 p. [Peer-reviewed paper from invited keynote oral presentation].

part of the range of Virginia pine is in the CHF. The ranges of several other important conifers (e.g., white pine, P. strobus L.; eastern hemlock, *Tsuga canadensis* (L.) Carr; and eastern larch, Larix laricina (DuRoi) K. Koch) extend into the region. Although pitch pine (*Pinus rigida* Mill.) has a relatively small range, it is confined to the CHF.

Therefore, the name "central hardwood," should be interpreted to mean that deciduous hardwood species overwhelmingly, but not exclusively, dominate the stands and cover types that occur as repeating units across the landscape. With this definition, it should be possible to identify the boundaries of the CHF by changes in forest composition and pattern of repeating units.

One common approach to defining the CHF is the reporting of forest statistics (e.g., volumes, net growth, etc.) by states, but political boundaries do not ecologically define the boundaries of a particular forest region. For example, in the proceedings of the sixth CHF Conference, Spencer and Bones (1987) reported forest statistics by state, thus their boundary for the CHF region followed state boundaries. They included all of the states of Missouri, Iowa, Illinois, Indiana, and Ohio, but the approach excluded southern New England states and parts of various other states such as southern Wisconsin, Michigan, and Minnesota that others (e.g., Braun 1950, Kuchler 1964, Leopold and others 1998) have included. The problem is that the operational areas of research experiment stations include only entire states, and some of these states often encompass parts of different natural forest regions (e.g., Central Hardwood and Northern Hardwood-Conifer Forest) (Lull 1968, Merz 1978, Kingsley 1985).

In contrast, the "central hardwood" region of Braun (1950) included five forested subregions called the Mixed Mesophytic, Western Mesophytic, Oak-Chestnut, Oak-Hickory, and Beech-Maple (fig. 1), all of which bisect one or more states. In the Proceedings of the First CHF Conference, Clark (1976) generally defines the CHF following Braun's regions, but excludes the oak-chestnut area. Hicks (1998) based his map on and considered the silviculture of forest types in four of the five regions: Mixed Mesophytic, Western Mesophytic, Oak-Chestnut, and Oak-Hickory (Ozark Plateau subregion only). He excluded the Beech-Maple region, the northern section of the Oak-Hickory region (the glaciated Central Lowland Physiographic province), and the Prairie-Forest Transition of the Southern Division of the Oak-Hickory Section.

A third interpretation of the CHF boundary is generally outlined by Leopold and others (1998), Patton (1997), and Fralish and Franklin (2002), but with small variations (fig. 2). The three maps include the five regions identified by Braun (1950). All authors extended the CHF boundary as far west as eastern Oklahoma, to near or into Kansas and Nebraska, as far north as central Minnesota, Wisconsin, Michigan, and into Ontario. The northern boundary extends from Minnesota to Cape Cod and Massachusetts in New England and includes a portion of southeastern New York. The eastern boundary includes the Appalachian Mountains and with the southern boundary across northern Georgia, Alabama, and Mississippi. There is general agreement that northern Pennsylvania and most of New York are excluded, the communities of these states being part of the Northern Hardwood-Conifer Forest (Fralish and Franklin 2002). The primary differences, albeit minor, are that Leopold and others (1998) extends the CHF north into the southern tip of Quebec which is well into the Northern Hardwood-Conifer Forest, and well beyond the CHF area on the maps of Farrar (1995) and Scott (1995). Patton (1997) extends the region south through the southern evergreen and semi-evergreen forest of central Texas and the Coastal Plain to near the Gulf Coast.

Given the variation in location of the CHF boundaries, the intent of this manuscript will be to

1) appropriately define criteria for delineating the CHF boundaries,
2) delineate the boundaries, and
3) briefly describe the physiographic provinces and subdivisions included within the CHF region.

CRITERIA FOR DELINEATING THE CHF BOUNDARY

Bailey (1996) reviewed the question of boundary criteria and the reliability of climate, vegetation, soil, and physiography in delineating ecosystems (forest regions, formations, or biomes). It is surprising that he found all of these approaches except macroclimate less than satisfactory and dismissed them rather quickly. However, the arguments used to discount these factors need closer examination. Bailey states "Vegetation and associated fauna, or biota, are constantly changing due to disturbance and

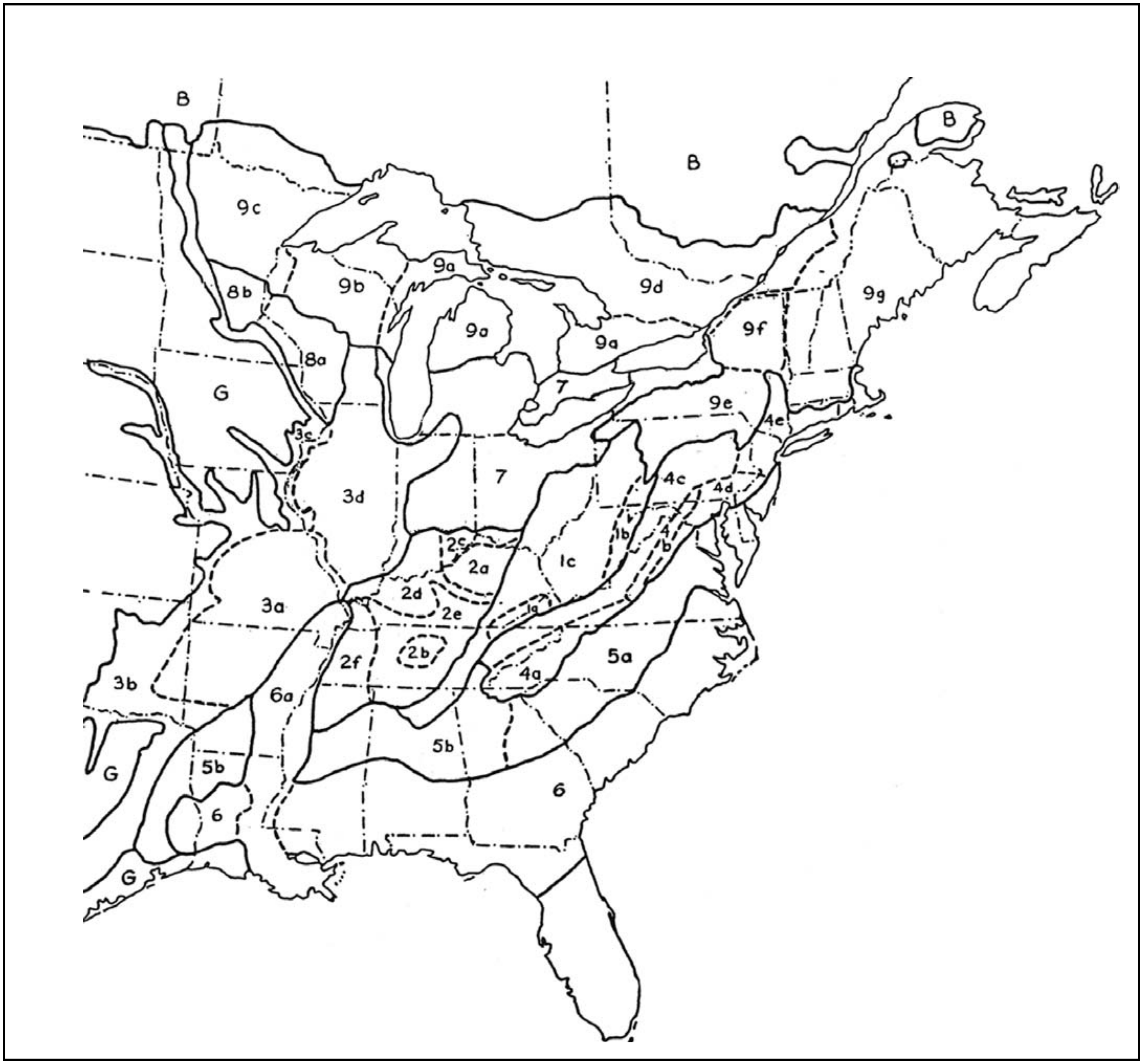

Figure 1.—*Forest and physiographic regions of eastern United States:*

(1) Mixed Mesophytic Region, a. Cumberland Mountains, b. Allegheny Mountains, c. Cumberland and Allegheny Plateaus;

(2) Western Mesophytic Region, a. Bluegrass, b. Nashville Basin, c. Area of Illinoian Glaciation, d. Hill Section, e. Mississippi Plateau Section, f. Mississippi Embayment Section;

(3) Oak-Hickory Forest Region, Southern Division, a. Interior Highlands or Ozark Plateaus, b. Forest Prairie Transition; Northern Division, a. Mississippi Valley Section, b. Prairie Peninsula Suction;

(4) Oak-Chestnut Forest Region, a. Southern Appalachians, b. Northern Blue Ridge, Ridge and Valley Section, d. Piedmont Section, e. Glaciated Section;

(5) Oak-Pine Forest Region, a. Atlantic Slope Section, b. Gulf Slope Section;

(6) Southeastern Evergreen Forest Region, a. Mississippi Alluvial Plain;

(7) Beech-Maple Forest Region;

(8) Maple-Basswood Forest Region, a. Driftless Section, b. Big Woods Section;

(9) Hemlock-White Pine Northern Hardwoods Regions, Great Lakes-St. Lawrence Division, a. Great Lake Section, b. Superior Upland, c. Minnesota Section, d. Laurentian Section; Northern Appalachian Highland Division, e. Allegheny Section, f. Adirondack Section, g. New England Section; B, Boreal Forest.

The forest of regions 1, 2, 3, 4, and 7 are considered the Central Hardwood Forest (Braun 1950).

Figure 2.—*Forest regions of North America:*

(1a) Northern Conifer-Hardwood or Boreal (spruce-Fir) Forest, closed; (1b) Northern Conifer-Hardwood forest, open savanna and barrens; (1c) Northern Conifer-Hardwood forest, Aspen Parkland;

(2a) Northern Hardwood-Conifer Forest (Sugar Maple-Yellow Birch-American Beech-White Pine Forest), Great Lakes Section; (2b) Northern Hardwood-Conifer Forest, New England Section;

(3a) Central Hardwood Forest (Oak-Hickory and mesophytic elements), Plateaus section; (3b) Central Hardwood Forest, Appalachian Mountain section;

(4a) Southeastern Pine-Hardwood Forest, Upper Coastal Plain; (4b) Southeastern Pine-Hardwood Forest, Lower Coastal Plain; (4c) Southeastern Pine-Hardwood Forest, Piedmont Plateau;

(5a) Southwestern Juniper-Pinyon Savanna; (5b) Central and Southern Rocky Mountain Mixed Conifer Forest;

(6) Northern Rocky Mountain Conifer Forest;

(7a) Northern Coastal Conifer Forest; (7b).Sierra Nevada Mountain/Southern Coastal Conifer Forest. Other zones include grassland (G), desert (D), and tundra (T), as well as the Mississippi River Valley (MRV) which has been largely cleared for farming (adapted from Fralish and Franklin 2002).

succession." However, disturbance and successional process do not imply migration of species from one forest region to another. Moreover, there is a definite repeating pattern of climax oak-hickory on thin soils and warm dry south slopes, and a pattern of succession of oak-hickory to maple on deep soils and north slopes; these patterns define most of the region from Missouri to eastern Kentucky (Appalachian Mountains). Climatically, Bailey (1980, 1985, 1994, 1995) places the CHF within the temperate climatic zone of cool to warm winters and warm to hot summers (Humid Temperate Domain, hot continental).

Bailey (1996) states that "Even less satisfactory [than vegetation] is the use of soil types as the basis for a major subdivision." "Soil type frequently does not reflect climate, because the nature of the geologic substratum influences the profile." At the Soil Type level, Bailey is correct; the profiles might change but not the soil developmental processes that operate over a large region. At the Soil Order level, there is a direct correspondence between general soil development, vegetation, and macroclimate. In the oak-hickory dominated CHF, the climate is temperate and the soils generally are classed as Alfisols (gray-brown podzolics) or as Ultisols (red-yellow podzolics) in southern sections (Soil Survey Staff 1975). In the cold Northern Conifer-Hardwood (boreal) forest dominated by spruce-fir-jack pine, the soils are classed as Spodosols (podzols). The Southern Pine-Hardwood Forest soils are Ultisols. The soils of the tall grass prairie are dark Mollisols. The relationship is so strong that regional vegetation and soil conditions could well be used to predict macroclimatic conditions (Albert and Mellilo 1991), or validate the location of ecosystem boundaries.

In terms of physiography, Bailey (1996) indicates "physiographic units cut across energy zones and their associated ecosystems." But there are some excellent examples of physiographic units that functionally identify the boundary of the CHF. Unquestionably, within a particular domain, physiography, associated topography, and soil play a major role in determining subdivisions.

The arguments of Bailey (1996) not withstanding, the most appropriate approach to establishing the location for any forest region is to let "tension zones" define the boundary. Curtis (1959) defined the Wisconsin tension zone as a transition zone (fig. 3) between two regions or vegetational formations (sensu Clements 1928) that contains some components of each region. It is implied that a tension zone is a belt where the ranges for a sufficient number of tree, shrub, herb, and animal species terminate, thus separating two adjoining regions. Animal as well as plant species may be considered in locating the zone. The identified boundary is then delineated by species restricted to each region. Henceforth, the "tension zone" will be referred to as a "transition zone" since it is defined as such.

The importance of a transition zone should not be based on its width or a specific distance, but should vary with the character of the two adjacent forest or vegetation regions. When a zone is a function of a macroclimatic pattern, it may be extremely broad (100 to 200 miles). As noted earlier, vegetation patterns show a strong relationship to macroclimatic patterns, and it can be shown that there is a considerable correspondence between the two sufficient to create a distinct boundary at least for most of the major forested regions.

Conversely, the transition zone is likely to be narrow (5 to 10 miles) when it results from an abrupt boundary that occurs where two contrasting physiographic provinces are in juxtaposition. Changes in geology (bedrock and surface deposition), topography (relief, elevation, and erosion), soil orders and associated types, and drainage/site patterns usually tend to follow and mark boundaries between physiographic provinces. Therefore, for a region the size of the CHF, the boundary may be defined by a combination of transition zones and associated geologic, topographic, edaphic, and atmospheric patterns which do not follow political (state) boundaries but which usually extend across portions of various states.

It is important to emphasize that the large forested regions of North America can not always be defined on the basis of the ranges (presence/absence) of the most important or most common tree species as the ranges of major species may extend into other forested regions. For example, many of the oak (*Quercus* L.) and hickory (*Carya* Nutt.) species of the CHF are important components of the Southern Pine-Hardwood Forest region and are infrequently found in the Northern Hardwood-Conifer Forest. Also, the ranges of sugar maple (*Acer saccharum* Marsh.), basswood (*Tilia americana* L.), American beech (*Fagus grandifolia* Ehrh.), black oak (*Quercus velutina* Lam.), and white oak (*Q. alba* L.) extend into the Northern Hardwood-Conifer, Central Hardwood, and

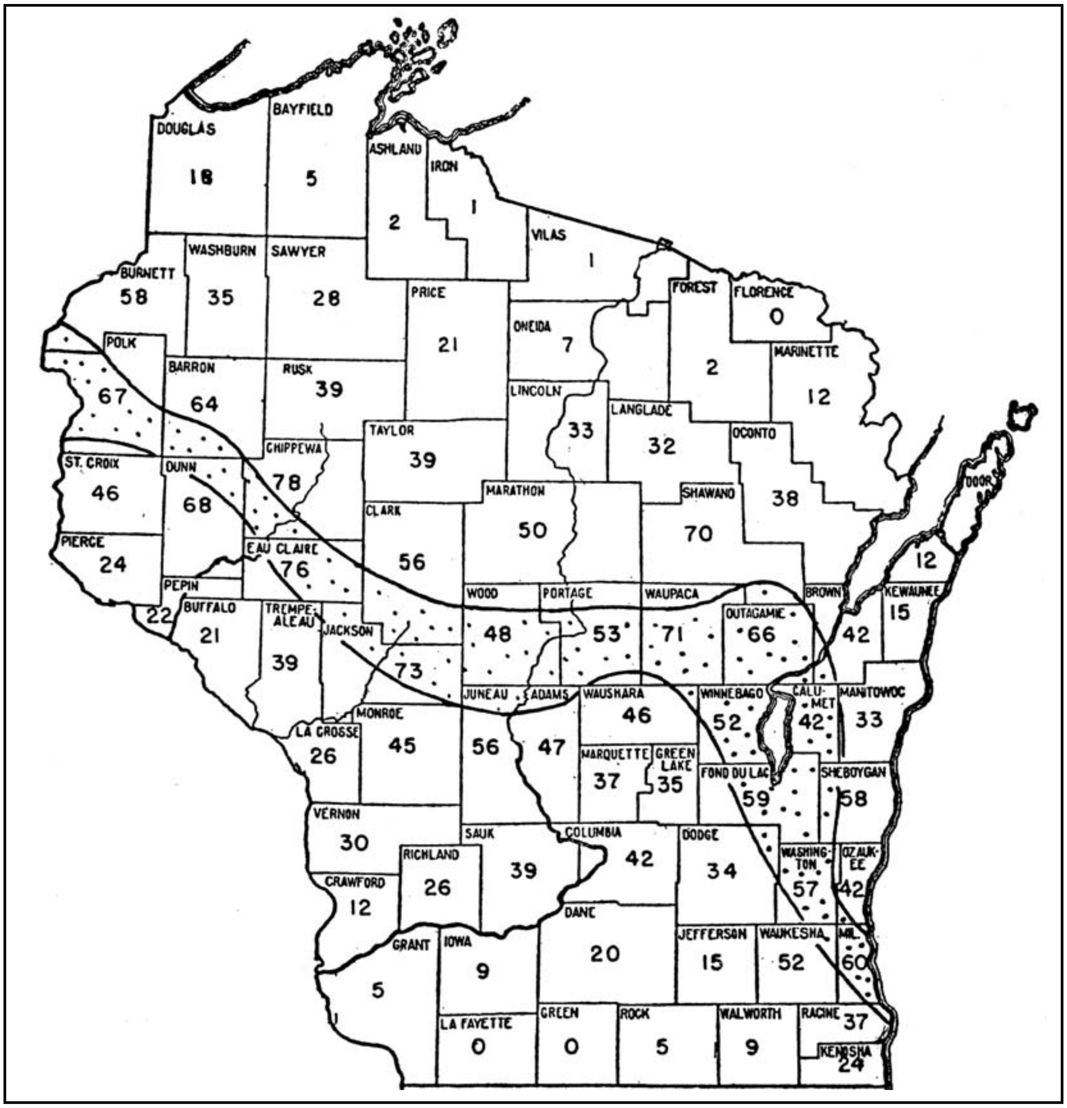

Figure 3.—*The transition (tension) zone between the Northern Hardwood-Conifer Forest and the Central Hardwood Forest in Wisconsin. The number in each county indicates the number of species whose range terminates in that county. Data is for 182 species. The shaded band is the transition zone determined by the greatest number of range terminations (Curtis 1959). Reprinted by permission of the University of Wisconsin Press*.

Southern Pine-Hardwood forests. Often parts of the ranges of major species and species of secondary importance will delineate the transition zone. Moreover, general vegetation as noted by relative importance of species, the pattern of community types, and successional process as well as soil forming processes and soil orders remain relatively constant across a region.

BOUNDARIES OF THE CENTRAL HARDWOOD FOREST

Fralish and Franklin (2002) outlined the CHF region so it distinctly contrasts with those forest and plant communities of adjacent regions, although some parts of the boundary between regions are more distinct than others (fig. 2). The Northern Hardwood-Pine forest of the Lake States (northeast Minnesota, northern Wisconsin, northern Michigan, southern Ontario, northern New York, and most of New England) has been called various names most of which include a reference to pine [white pine; red pine (*Pinus resinosa* Ait.); jack pine (*Pinus banksiana* Lamb)], eastern hemlock or yellow birch (*Betula alleghaniensis* Britton). The region to the south and east, generally including the Gulf and Atlantic Coastal Plain and Piedmont provinces, is called the Southern Pine Region, or perhaps more appropriately, the Southeastern Hardwood-Pine Region as pine has been, is being, and will continue to be replaced by hardwoods. To the west is the Great Plains, at one time covered with prairie grasses and associated forbs, but now supporting a near monoculture of introduced grasses.

Species restricted to other forest regions not only delineate the boundaries of their respective regions, but also those of the CHF; these regions include the Northern Hardwood-Conifer Forest to the north, and the southern Pine-Hardwood Forest to the east and south. Physiognomically (form and structurally), the CHF is relatively distinct from adjacent regions. Two of the three adjacent regions (Northern Hardwood-Conifer Forest; Southeastern Pine-Hardwood Forest) have five to ten conifer species as a major component. The Tall Grass Prairie Region to the west is, without question, physiognomically distinct although deciduous woodland can be found along streams and drainages (gallery forests). The distinctness of the Tall Grass Prairie-CHF boundary needs no elaboration.

Northern Boundary

In Bailey's (1996) classification, the CHF is placed in the Hot Continental Division of the Humid Temperate Domain. The Northern Hardwood-Conifer Forest directly to the north is in the Warm Continental Division. The line dividing these two forest regions is aligned northwest to southeast from Minneapolis, MN, to about Milwaukee, WI (fig. 3). It is more than coincidence that in Wisconsin, this climatic line follows Curtis' (1959) tension zone separating the area he called the northern floristic province [Northern Hardwood-Conifer Forest of sugar maple, red maple (*Acer rubrum* L.), basswood, yellow birch, and white pine] from the southern floristic province (CHF of white and black oak and hickory). This zone is relatively narrow, varying in width from 10 to 30 miles and mid-way between the two cities, angles east to west briefly to allow for the inclusion of the old lake bed of Glacial Lake Wisconsin in the CHF. Bailey's climatic line similarly breaks. In part, Curtis documented the climatic change from the northern to the southern floristic provinces when he began to develop northern forest communities at the University of Wisconsin Arboretum (Madison) and found that, while a red and white pine overstory developed, he could not establish the shrubby and herbaceous understory associated with these forests. One suggestion among several for the failure was that rain from the shorter, less frequent storms of the southern province did not penetrate the pine litter and that drought periods were more common such that soil water could not be maintained at the required level for understory plants. Curtis (1959) indicated that the same transition zone could be traced through Minnesota and Michigan. The northern boundaries of black willow (*Salix nigra* Marsh.), eastern cottonwood (*Populus deltoides* Bartr. ex Marsh.), black oak, bitternut hickory (*Carya cordiformis* (Wangenh. (K. Koch), and boxelder (*Acer negundo* L.) closely follow this transition zone eastward into Michigan to Pennsylvania while that of pignut hickory (*C. glabra* (Mill.) Sweet) coincides with the boundary from Michigan through Pennsylvania.

East across Lake Michigan on the western shore of Lower Michigan, the transition zone begins at the about same latitude as that of Milwaukee, and continues in a serpentine fashion east-northeast across Michigan (Veach 1953, 1959). It intercepts the east shore of Lake Huron near Port Huron or about midway between Detroit and the tip of the "thumb" in Huron County. As in Wisconsin, this 30-mile transition zone separates the sugar maple, American beech, basswood, and white pine of the Northern Hardwood-Conifer Forest from the white and black oak and hickory dominated communities of the CHF. Using climatic data, Albert and others (1986) show a distinct boundary about 60 miles north of that shown by Veach (1953, 1959). It would seem that the area between the boundary for the CHF mapped by Veach and the boundary shown by Albert may well be considered the transition zone.

In Ontario, the 30-mile wide transition zone begins on the west shore of Lake Huron near Goderich and Kincardine, Ontario. The narrow CHF area of Ontario between the transition zone and the United States border to the south is only 30 to 70 miles wide. Here the CHF is referred to as the Deciduous Forest region (Rowe 1972, Farrar 1995) or more generally as temperate deciduous forest (Scott 1995). Clayton and others (1977) refers to the area as the West St. Lawrence Lowland physiographic province. The soils of this part of southern Ontario are classed as gray-brown luvisols developed under deciduous or mixed deciduous forest that correspond to the older U.S. class of gray-brown podzolics (Alfisols). Some research manuscripts on this area have been included in the previous CHF Proceedings (von Althen and Webb 1978, 1980; von Althen 1987, 1989).

From its location on the northwest shore of Lake Erie, the transition zone angles south including the western one-fifth of Pennsylvania in the CHF (figs. 1 and 2). From near the border with Virginia (western section), the CHF border angles northeast across New York into Connecticut and Rhode Island to include part of Massachusetts and Cape Cod. This area of the CHF boundary is probably the least well defined because of the elevational, climatic, and soil changes associated with various mountain ranges. While specific location of the transition zone through Pennsylvania and New York varies from map to map, there is nearly universal agreement to include Cape Cod where bear oak (*Quercus ilicifolia* Wangenh.) woodland and pitch pine form communities.

There are a few species restricted to regions outside the CHF whose ranges coincide with the northern part of the CHF boundary as it has been defined here. Species of the Northern Hardwood-Conifer Forest that identify the northern boundary include balsam fir (A*bies balsamea* (L.) Mill), black spruce (*Picea mariana* (Mill) B.S.P.), red pine, and balsam popular (Populus balsamea L). White pine, eastern hemlock and yellow birch are an anomaly in that these species of the Northern Hardwood Forest generally delineate the boundary in Minnesota, Wisconsin, and Michigan, but in the east they become a component the CHF because they extend southward to follow the cool climate of the Appalachian Mountains. Here, the edge of

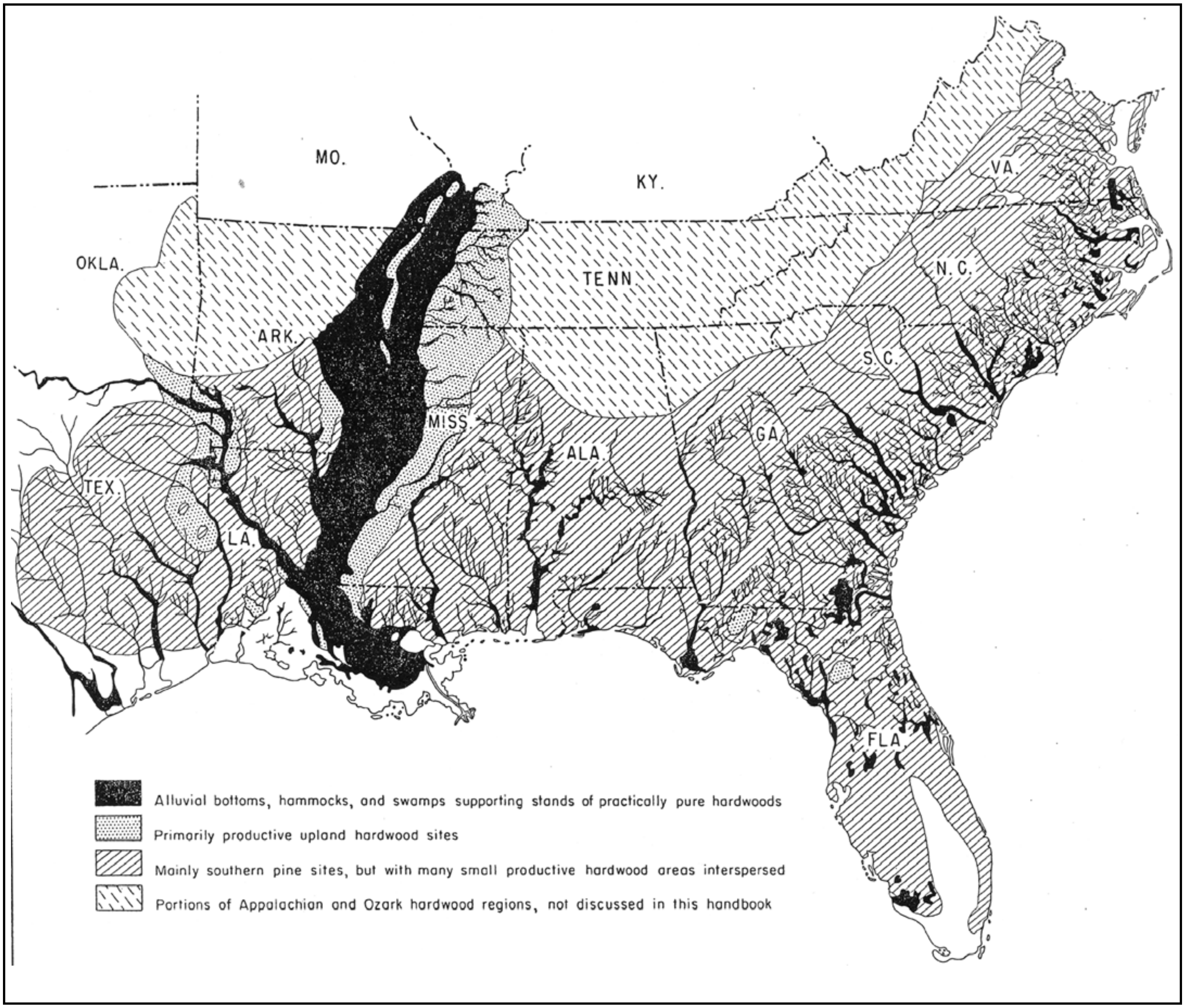

Figure 4.—*Streams and bottomlands of the Atlantic and Gulf Coastal Plain (Putnam and others 1960).*

their range coincides with the boundary between the Blue Ridge and the Piedmont provinces. The northwestern boundary in Michigan, Wisconsin, and Minnesota roughly follows the southern boundaries of white spruce (*Picea glauca* (moench) Voss), jack pine, and northern white-cedar (*Thuja occidentalis* L.), the latter with small scattered outliers in the CHF.

Eastern-Southeastern Boundary

From Long Island, NY, progressing southwest, the transition zone crosses a narrow area of the Atlantic Coastal Plain and then follows the physical boundary between the high rugged Blue Ridge Mountains and the low eroded rolling Piedmont Physiographic province (figs. 1, 2, and 4). The boundary and its associated provinces extend southwest into northern Georgia as delineated by Hicks (1998). This eastern-southeastern boundary has not only a physical/topographic distinction and separates the CHF from the Southeastern Pine-Hardwood Forest (Fralish and Franklin 2002), it also separates Entisols and Alfisols of the Blue Ridge province from the Ultisols of the Piedmont province. The Blue Ridge Mountains are vegetatively distinct from the Piedmont province because of the concentration of loblolly pine (*Pinus taeda* L.) and shortleaf pine forest mixed with oak in the latter. Both Braun (1950) and Waggoner (1975) indicate that the Piedmont coincides with the eastern oak-pine transition zone, which continues through Georgia and Alabama into Mississippi.

Southern Boundary

In northern Georgia, the boundary angles westward to encompass the southern extensions of the high Blue Ridge Mountains, Ridge and Valley, and Appalachian Plateau in north-central Alabama (figs. 1 and 2). From here, the boundary traditionally has been angled northwest to intersect the Brown Loam Hills region in northwest Mississippi. The actual transition zone of 50 percent pine and 50 percent oak-hickory across the northern sections of Georgia, Alabama, and Mississippi is relatively broad (80-120 miles); this transition zone is sufficiently large that it has been referred to as the "oak-pine region" (Braun 1950, Waggoner 1975). As delineated here, this area is considered outside the CHF although a strong argument to the contrary can be made since the headwaters of the major streams are generally located near or in the oak-pine transition zone (fig. 4). Concurrently, these headwaters also mark the northern extent of various southern bottomland species found on the terraces of these streams in the Gulf Coastal Plain; thus in addition to the oak-pine zone, there is a change in bottomland forest composition and physiographic provinces across the forested landscape that delimits the CHF southern boundary. The exception to this pattern is the Mississippi embayment (floodplain) that extends like a thumb north into southern Illinois and includes a narrow strip of west Kentucky and west Tennessee. A few southern bottomland species follow this floodplain north into the CHF.

In Georgia, Alabama, Mississippi, and Arkansas, the southern CHF boundary is also the northern boundaries of loblolly pine, bluejack oak (*Quercus incana* W. Bartrom), and laurel oak (*Q. hemisphaerica* Bartr.) of the upland Southeastern Pine-Hardwood Forest. Southern bottomland species that follow the CHF boundary include sweetbay (*Magnolia virginiana* L.), overcup oak (*Quercus lyrata* Walt.), swamp chestnut oak (*Q. michauxii* Nutt.), cherrybark oak (*Q. pogoda* Ell.), and water oak (*Q. nigra* L.).

An extension of the east-west boundary across the Brown Loam Hills and the Mississippi floodplain (both exclusively hardwood regions) into central Arkansas and Oklahoma essentially completes the southern boundary. The traditional dividing line between the CHF and the Southeastern Pine-Hardwood Forest is the Arkansas River Valley between the Boston Mountains to the south, and Ouachita Mountains to the north. The forest of the Boston Mountains of central Arkansas is oak-hickory with a mixture of southern pine while that of the Ouachita Mountains is mapped as pine-oak transition (Shantz and Zon 1924). Bruner (1931) as cited in Braun (1950) states that the pine stands of this area "represent the northwestern extension of the southern pine forest."

Western Transition Zone

The Western Transition Zone is formed from a mixture of two physionomically different plant communities: prairie (grassland) and oak-hickory savanna or woodland (trees). The cross-timbers area extends from northeast Texas east of the panhandle into a wide area covering much of Oklahoma, and terminates in a narrow section of southeast Kansas (Hoagland and others 1999). At its maximum width in Oklahoma, the Cross Timbers region is over 250 miles wide including disjunct areas. The primary species of the Cross Timbers are post oak (*Q. stellata* Wangenh.) and blackjack oak (*Q. marilandic*a Muenchh.) with black oak, and black hickory (*Carya texana* (Le Conte) DC) of secondary importance. However, a broad expanse of intermixed oak-hickory woodland (savanna) and prairie (the prairie-forest border region) continues northward along an area west of Missouri and Iowa into Kansas and Nebraska. Here most forested areas are along stream drainages (gallery forest). The ranges of a large number of species extend into the Western Transition Zone (Little 1971). The western range of bur oak (*Q. macrocarpa* Michx.) is most closely aligned with this zone from Texas to Minnesota (fig. 5).

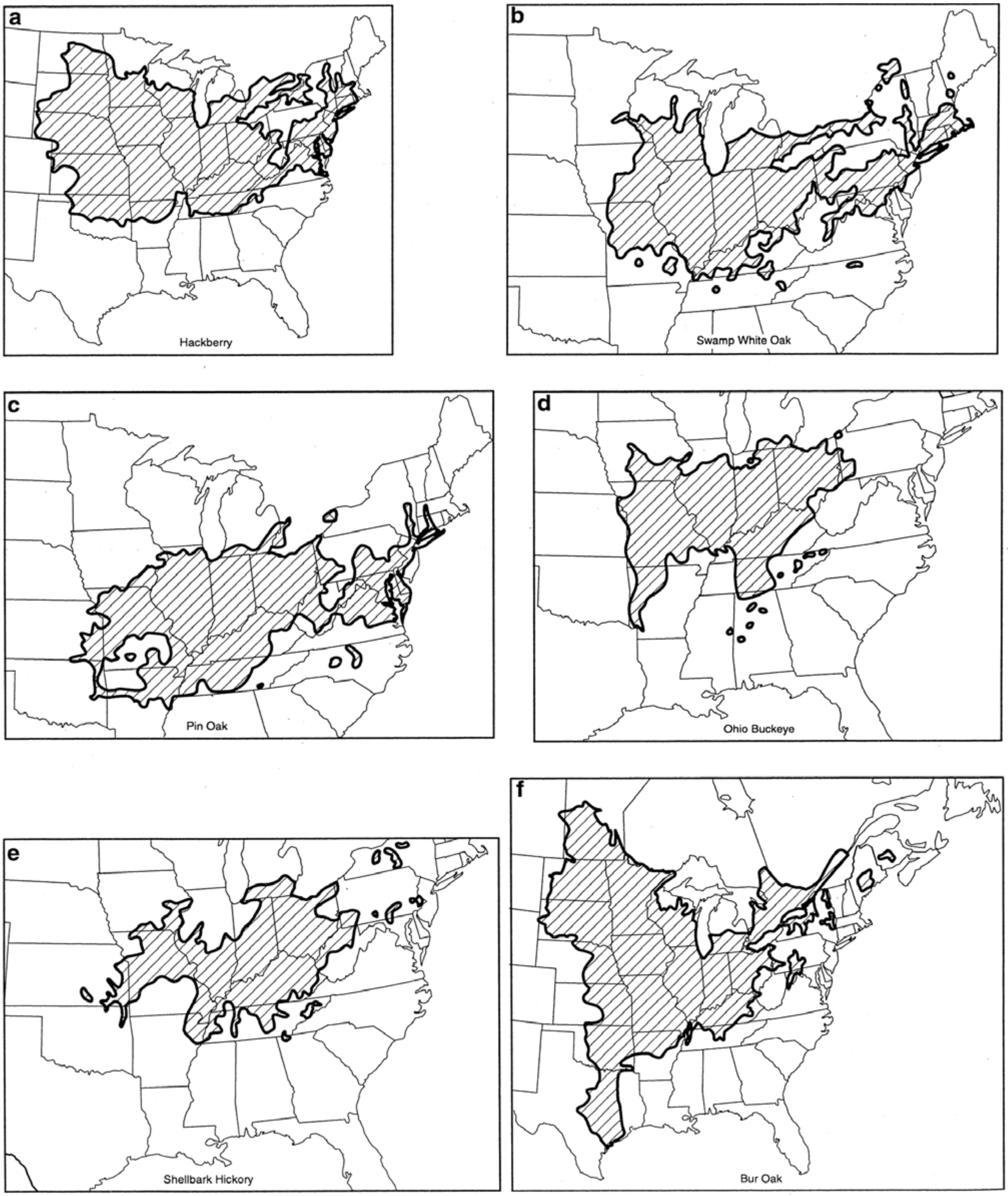

Figure 5.—*Hardwood species whose ranges are restricted to and collectively delineate the Central Hardwood Region (Little 1971).*

In northern Missouri, the zone broadens and extends eastward and across a large area of south-central, central, and northern Illinois. Early records indicate this transition zone, the "prairie-forest border region," extended through much of southern Wisconsin into north-central Indiana (Anderson 1982). Disjunct areas also once existed in southern Michigan, Ohio, and Kentucky. This zone also has been called the "prairie peninsula" (Transeau 1935). The zone continues as a narrow strip of oak-hickory savanna intermixed with maple-basswood forest that extends from the tri-state area (northwest Illinois, northeast Iowa, and southwest Wisconsin) into Minnesota (Kuchler 1964, Bailey 1976, 1994).

COMMONALITY OF COMMUNITY COMPOSITION AND SUCCESSIONAL PROCESSES

One general characteristic that connects most parts of the region outlined above (fig. 2) is the extensive distribution of high quality (i.e., site index 50-80) oak-hickory communities (stands) on xeric-mesic (intermediate dry-moist) and mesic (moist) sites (deep soil, north, northeast, and east slopes, low slopes, drainages, stream terraces). Nowhere else does a concentration of this magnitude occur. The Blue Ridge Mountains with their conifer component of hemlock and white pine in coves and Fraser fir (Abies fraseri (Pursh) Poir) at high elevations are integrated into the CHF due to the surrounding lower elevation oak-hickory zones. Similarly, oak-hickory dominated areas surround other concentrations of conifers such as pitch pine and Virginia pine. Also areas of poor quality (site index 35-50) oak-hickory stands on xeric (droughty) sites characterized by thin rocky soils, exposed south, southwest, and west slopes, and/or locations in the prairie-forest transition zone, but the strong domination by oak integrates these into the CHF region. The same argument applies to the bottomland forests that have a strong oak component.

For those unfamiliar with the CHF and its forests, the 12 major upland oak species include white, post, chestnut (*Q. prinus* L.), chinkapin (*Q. muehlenbergii* Engelm) in the "white oak" group, and in the "red oak" group, black, northern red (*Q, rubra* L.), southern red (*Q. falcata* Michx.), scarlet (*Q. coccinea* Muenchh), Hill's (*Q. ellipsoidalis* E.J. Hill), shingle (*Q. imbricaria* Michx.), blackjack, and bear oak. In the bottomland forests, there are six common species: swamp white (*Q. bicolor* Willd.), swamp chestnut, overcup, pin (*Q. palustris* Muenchh), willow (*Q. phellos* L.), and Shumard (*Q. shumardii* Buckl.), the first three are in the "white oak" group and the latter three in the "red oak" group. The 10 hickory species include shagbark (*C. ovata* (Mill) K. Koch), pignut, red (*C. ovalis* (Wangenh) Sarg.), bitternut, mockernut (*C. tomentosa* Nutt), sand (*C. pallida* (Mill) Engl.), and black hickory (*C. texana* (Le Conte) DC) in upland forest and water (*C. aquatica* Nutt), pecan (*C. illinoiensis*) Wangenh.) K. Koch, and shellbark hickory (*C. laciniosa* (Michx. F) Nutt) in bottomland forest. Stems of shagbark, shellbark, and mockernut hickory are occasionally found on both upland and bottomland sites.

In addition to composition, community succession also is a process unifying a forest region. In the Northern Conifer-Hardwood Forest (boreal forest, fig. 1) that is transcontinental across Canada, the species of the compositionally stable (climax) forest are white spruce (*Picea glauca* Michx.) and balsam fir. But after disturbance by fire or cutting and fire, the upland forest may be composed of trembling aspen (*Populus tremuloides*), black spruce, or jack pine. This replacement is a unifying process in the boreal forest.

In the Lake States Northern Hardwood-Conifer Forest, sugar maple, basswood, hemlock, white pine, and American beech in eastern Wisconsin and Michigan are dominant species on medium and fine textured soils. Although the severe timber harvesting and fire of the late 1800s and early 1900s cleared this forest, it was quickly replaced by trembling aspen and bigtooth aspen (*Populus grandidentata* L.), and to a lesser extent, white birch (*Betula papyrifera*) after fire control laws were enacted in the 1920s and 1930s. However, at present the northern hardwoods are rapidly replacing aspen and birch as the dominant community type unless silvicultural treatments reverse the process to maintain these shade intolerant species. On coarse sands, a mixture of white pine, northern red oak, and red maple appear destined to form compositionally stable stands, often replacing relatively pure stands of aspen, jack pine, or Hill's oak. These successional processes tend to unify the Northern Hardwood-Conifer Forest.

In the Southeastern Pine-Hardwood Forest, the major pine species are shade intolerant or extremely shade intolerant, and thus, are early-successional species that are easily and rapidly being replaced by a variety of oak and other shrubby species (e.g. holly (*Ilex* spp.). These species need a high level of disturbance for seedlings to become established and grow into mature overstory trees.

In the CHF, oak and hickory species have an unusual ecological role in that they form both compositionally stable and successional stands. Neither the aspens of the Northern Hardwood-Pine region nor the pines of the Southeastern Pine-Hardwood Forest are found in both conditions. Oak and hickory form compositionally stable (climax) woodlands on xeric sites and xeric-mesic sites while stands composed of many of the same species are successional on mesic sites. Thus, in the region outlined, oak is an ever-present unifying component over the landscape. Braun (1950) and Bryant and others (1993) describe the forest communities associated with the physiographic provinces described later.

The present oak forests on mesic sites apparently developed after a long period of continuous disturbance by fire and grazing, and later by timber harvesting. As with southern pine and aspen, the various oak species are shade intolerant or extremely intolerant and are early to mid-successional species. Seedlings require moderate light levels to become established, but as they grow they become more intolerant, thus high light levels must be maintained until oak-hickory stems reach the overstory canopy. In the western half of the CHF, forests composed of mesophytic species such as sugar maple, American beech, bitternut hickory, and red elm (*Ulmus rubra* Muhl.) form a dense shade and are rapidly replacing oak forest on mesic sites. In the eastern half of the region, red maple and white pine tend to be the late successional species. On xeric sites, oak and hickory often continue to dominate because of the lack of competition.

There is a seemingly paradoxical relationship between oak growth and its replacement pattern. Growth is slowest and site index lowest (35-50) on xeric sites and intermediate (site index 50-65) on xeric-mesic sites. Growth is fastest and site index highest (65-80) on mesic sites. Therefore, it would appear logical that with the rapid growth of oak on mesic sites, it would be relatively easy to manage for these species since they would outgrow nearly all other species. The problem is that the moist site conditions are also ideal for establishment of a dense understory canopy of mesophytic species that usually form a dense shade and prevent the establishment of oak seedlings. In the CHF, the most productive oak stands are being replaced by mesophytes, and this process is of major concern. Conversely, since mesophytic species do not survive on xeric and xeric-mesic sites, the oak stands on these sites remain relatively compositionally stable.

There is an interesting linkage between shade tolerance and drought tolerance (Fralish 1988). Shade intolerant (light demanding) species are usually drought tolerant and able to withstand stress associated with depleted soil water levels. Because of the severe environmental conditions, mesophytic species can not invade, forest density remains low, light levels at the forest floor remain high, and oak seedlings may grow and develop. Most mesophytic (moisture demanding) species are shade tolerant because on moist, deep soil sites, they must be able to survive at extremely low light levels in a dense forest composed of many species. Physiologically, the survival mechanisms between the two groups of species are quite different.

SPECIES RESTRICTED TO THE REGION

Although many of the oak and hickory species listed above have ranges that extend well beyond the CHF, there are a variety of both upland and bottomland species that are completely or largely restricted to within the delineated boundaries (fig. 5). No one single species has a range that perfectly matches the CHF boundaries. However, the ranges of a number of species are close to matching the boundaries west of the Appalachian Mountains and collectively their ranges can be used to delineate nearly all of the CHF. This list includes hackberry (*Celtis occidentalis* L.), bur oak, chinkapin oak, swamp white oak, shellbark hickory, and Ohio buckeye (*Aesculus glabra*). Individually, the ranges of hackberry, chinkapin oak, and bur oak come the closest to matching the CHF boundary but the range of hackberry extends into Vermont, New Hampshire, and northern New York, bur oak into the Northern Hardwood-Conifer Forest of southern Canada from Manitoba to Quebec, and chinkapin oak into the Southern Pine-Hardwood Forest from South Carolina to Mississippi.

Species whose eastern range boundary follows the interface between the Blue Ridge Mountains and the Piedmont province include yellow buckeye (*Aesculus flava* Ait.), Fraser magnolia (*Magnolia fraseri* Walt.), and black locust (*Robinia pseudoacacia* L.).

The ranges of black maple (*A. nigrum* Michx.), dwarf chinkapin (*Q. prinoides* Willd.), and butternut (*Juglans cinerea* L.) also are closely aligned with the CHF boundary except these species extend into New York, Ontario, Quebec, and parts of New England. Scarlet oak and chestnut oak are CHF species including the Appalachians except that their distribution also includes the Piedmont. Most of the range of Hill's oak in Wisconsin and Minnesota is within the CHF. Shagbark hickory is primarily a CHF species although it can be found in New England and Quebec, on the Piedmont, and in sections of the Southern Pine-Hardwood Forest. The extension of the ranges of shagbark hickory, black maple, and northern red oak into southern Quebec may have been a factor in Leopold and others (1998) considering it as part of the CHF.

Other species with relatively small or restricted distributions inside the CHF that do not coincide with the boundary include northern catalpa (*Catalpa speciosa* Warder), blue ash (F*raxinus quadrangulata* Michx), Kentucky coffeetree (*Gymnocladus dioica* (L.) K. Koch), pin oak, shingle oak, bear oak, and yellowwood (*Cladrastris kentuckea*).

Midcanopy species of the CHF include pawpaw (*Asimina triloba* (L.) Dunal), roughleaf dogwood (*Cornus drummondii* C.A. Meyer), eastern wahoo (*Euonymus atropurpureus* Jacq.), sweet crabapple (*Malus coronaria*), Iowa crabapple (*M. ioensis*

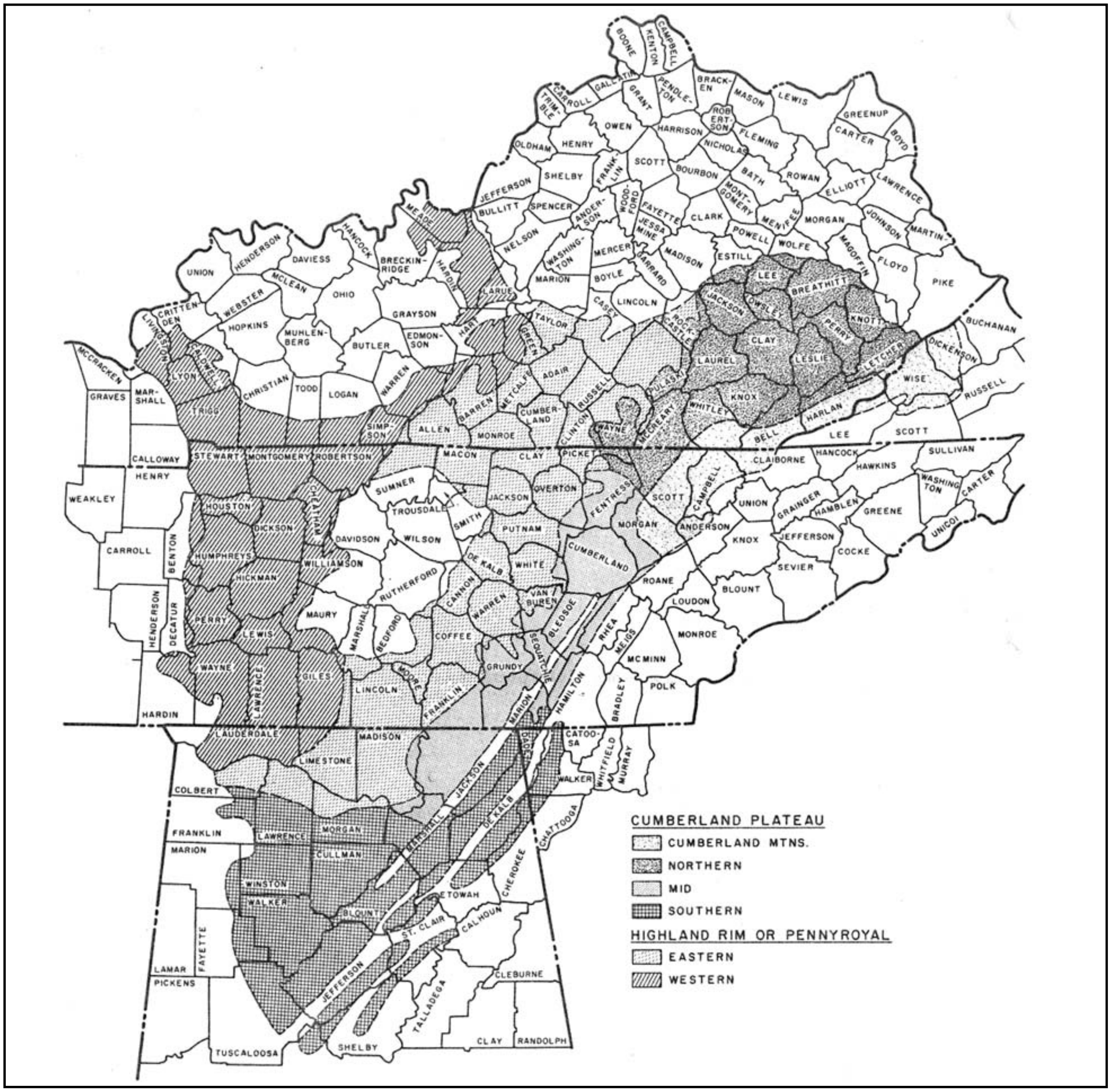

Figure 6.—*Location of the Cumberland Mountain and Plateau and Interior Low Plateau physiographic provinces (Smalley 1979).*

Marsh), American plum (*Prunus americana* Bailey), hortulan plum (*P. hortulana* Bailey), American bladdernut (*Staphylea trifolia*), and common prickly-ash (*Zanthoxylum americanum* Mill.). A number of rhododendron and azalea species and other endemics are found only in the Appalachian Mountains of the CHF.

PHYSIOGRAPHY OF THE CENTRAL HARDWOOD FOREST

Blue Ridge Mountains

The CHF boundaries described above enclose a diversity of bedrock types and soil orders. Beginning at the east boundary, the Blue Ridge physiographic region (fig. 1) extends from southeastern Pennsylvania to northeastern Georgia and has a width of from 5 miles (Northern Virginia) to about 70 miles near Asheville, North Carolina (Buol 1973). The Blue Ridge Mountain range is the eastern-most range of the Appalachian highlands and has the highest peaks. The province consists of various small ranges that are the oldest in the United States. Most peaks are worn to rounded tops and domes, thus, these mountains are referred to as “subdued” (Fenneman 1938). Probably the best known of the mountain complex is the Great Smoky Mountains (National Park) in Tennessee and North Carolina.

Rock types include Precambrian granite and gneiss, siltstone, sandstone, and conglomerate. Most of these rocks have weathered into acidic soils but a few rocks such as marble have weathered into basic soils. The soils are classed either as Ultisols (low base and high clay accumulation in the B horizons) or as Inceptisols (poorly developed profiles).

Ridge and Valley Province

The Ridge and Valley physiographic province (fig. 1) parallels and lies west of the high Blue Ridge Mountains; it parallels and lies east of the eroded Appalachian Plateau. The area is world famous for its fold mountains. As the name indicates, the province consists of a group of long, narrow, usually wooded steep mountain ridges separated by level valley floors. The resistant sandstone bedrock forms the ridges and the weaker shale and limestone the valley floors, the latter eroded to a common level (Buol 1973). In Tennessee, the broad valleys and narrow ridges of the eastern section are called the “Great Valley.” The soils of the Ridge and Valley are classed as Ultisols and Inceptisols with some Alfisols in more northern regions.

Appalachian or Cumberland Plateau

Directly west of the Ridge and Valley is the Appalachian Plateau (fig. 1). Along its western boundary are the Interior Low Plateau and the Eastern Central Lowlands. The area has been divided into the Southern Cumberland Plateau (Smalley 1979), Mid-Cumberland Plateau (Smalley 1982), Cumberland Mountains (Smalley 1984), and Northern Cumberland Plateau (Smalley 1986). The area is underlain in many places by horizontal sandstone and the highly dissected topography is characterized by dendritic drainage with winding narrow-topped ridges and deep narrow valleys. In some areas the sandstone bedrock creates upland flats (Buol 1973). Collectively, the four subregions are oriented southwest to northeast and parallel the Ridge and Valley province. The soils of the Plateaus are primarily Ultisols (Hapludults) with Inceptisols (Dystrochrepts) found in the eastern area. The soils of the Cumberland Mountains are primarily Inceptisols (Dystrochrepts) and Ultisols (Hapludults), along with rockland (Buol 1973).

Interior Low Plateaus

The Interior Low Plateaus physiographic province has been intensively studied by Smalley (1980, 1983), DeSelm and Schmalzer (1982), and Quarterman and Powell (1978). The Appalachian Plateau bound the province to the east and south (fig. 6). The western boundary in Kentucky and Tennessee follows the Tennes-see River and interfaces with the Coastal Plain sediments of the Mississippi Embayment. The northern boundary is considered to generally follow the southern limit of glaciation through southern sections of Ohio, Indiana, and Illinois (Hunt 1978).

Within the province, a number of different regions are delineated. In the southern part of the triangle are the Eastern Highland Rim and Western Highland Rim enclosing the Central (Nashville) Basin. The northern part of the triangle encompasses the Inner Bluegrass and Outer Bluegrass regions of north central Kentucky. The Western Coal Field along with the Shawnee Hills section and parts of the Western Highland Rim and Pennyroyal form the west section of the triangle that extends into southern Illinois. The Pennyroyal is situated between the Western Highland Rim and the Western Coal Fields. Quarterman and Powell (1978) describe additional subdivisions for each of these regions. Both the Bluegrass subregion and the Nashville Basin are underlain by Ordovician limestone that is often exposed at the surface. Because of weathering, caves are common and the land surface is pitted with sinkholes (Karst topography). The soils of the Interior Low Plateaus are classed as Alfisols (primarily Paleudalfs) and Ultisols (primarily Hapludults).

Central Lowland Physiographic Province

The Central Lowlands was delineated by Fenneman (1938) and includes the northern midwest from North Dakota east into northeast Ohio and New York and south into central Texas. Vegetatively, this province includes the beech-maple, oak-hickory, Maple-Basswood regions (Braun 1950) and the zone known as the prairie-forest transition (Anderson 1982). The vegetation of the zone west of the prairie-forest border is mid-grass prairie and outside the area of CHF. Although not reviewed here, the Central Lowlands is subdivided into a variety of natural divisions (Lindsey 1966, Schwegman 1973, Homoya and others 1985, Albert and others 1986, Nelson 1987, Bailey 1994, Hole and Germain 1994, Albert 1995). Most states have developed a system of natural divisions.

East Central Lowlands

In the United States, the boundaries of the Eastern Central Lowland Physiographic province are based on those established by Fenneman (1938). Some sections of the boundary are physiographically well defined while others are more or less arbitrary. For convenience, the Mississippi River has been defined as the western boundary. The surface of the Eastern Central Lowlands was predominately formed by erosional and depositional processes, primarily glaciation combined with surface water movement. The glaciers scoured lake basins and lowlands but deposited material that created various formations such as till plains, end and ground moraines, outwash, eskers, drumlins, and kames. These deposits substantially reduced the importance of underlying bedrock.

Older glacial deposits cover most of northern, southern, and western Illinois; northern, central, southwestern, and southeastern Indiana; and the northern and western half of Ohio (Harris and others 1982). Many of these deposits are covered by Wisconsinan age material. The Wisconsinan age ice covered the northeastern half of Illinois (Schwegman 1973) and the northern two-thirds of Indiana (Lindsey 1966) thus leaving older deposits to the south undisturbed. In Ohio, material from the Wisconsinan glacier covered nearly all of that deposited by older glaciers. Capping the surface of the Driftless Area and glacial deposits is loess, a silt or silt loam material blown out of the floodplains of the major river valleys such as the Mississippi, Ohio, and Wabash Rivers. Because of the westerly wind, the deepest loess deposits are found directly east of the rivers and become progressively thinner with distance from the floodplain. In large areas of the East Central Lowlands, the soils are classed as Alfisols but in western, south central, north central, and northern Illinois and in the southeastern Wisconsin area, the soils are a mixture of Alfisols and Mollisols (prairie-forest transition), and Entisols in the lake bed of the old glacial Lake Wisconsin (Hole 1976, Fehrenbacher and others 1984).

The “Driftless Area” of southwestern Wisconsin (fig. 7), northwestern Illinois and northeastern Iowa (West Central Lowland) is the only unglaciated part of the Eastern Central Lowland. Apparently the deep troughs of Lake Superior and Lake Michigan directed the glaciers to the west and east, respectively. One other interesting area in the Eastern Central Lowlands is the lake bed of extinct glacial Lake Wisconsin. During the last glacial advance, the Wisconsin River in central Wisconsin was flooded and backed up resulting in a deposit of deep sand from glacial melt water.

Western Central Lowlands

Near the end of the Mesozoic era, erosion from the Rocky Mountains resulted in the deposition of material that formed a huge east-sloping plain that stretched to the Mississippi River (Risser 1981). The second major influence on this region was glaciation. There is a gradient of vegetation change from east to west with the concentration of hardwood forest in the prairie-forest transition zone of eastern Missouri, Iowa, and central Minnesota decreasing to the west and becoming essentially non-existent except for gallery forests in eastern Kansas and Nebraska. Concurrently, there was an increase in prairie vegetation from east to west; most of the prairie land has been plowed for agricultural crops. The proportion of forest and prairie soils, Alfisols, and Mollisols, respectively, follow the same pattern.

Interior Highlands

The Interior Highlands consists of two unglaciated regions: the Ozark Plateau and the Ouachita Mountains (fig. 8). As noted earlier, the forest of the Ouachita Mountains is a mixture of southern pine and oak-hickory; it is part of the transition forest between the Southeastern

Pine-Hardwood region and the CHF. The Ozark Plateau (often called the Ozark Hills) covers the northwest half of Arkansas, southern half of Missouri, and an eastern section of Oklahoma. The region consists of rugged hills, steep slopes, and deep valleys (Hunt 1974). Along the southern edge of the Plateau are a series of hills widely known as the Boston Mountains. In Missouri, there are a number of subregions (Nelson 1987). The Ozark Plateaus are underlain by several formations of limestone and dolomite of Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian age; these strata vary with the subregion. The soils are classed as Ultisols, more specifically, Hapludults, Fragiudults, and Paleudults. Soils of steep slopes are Incep-tisols, primarily Dystrochepts (Buol 1973). Some Mollisols (prairie soils) are interspersed.

OTHER RELATED HARDWOOD AREAS

Mississippi Embayment

The Mississippi Embayment (Gulf Coastal Plain) extends from the Delta of the Mississippi River

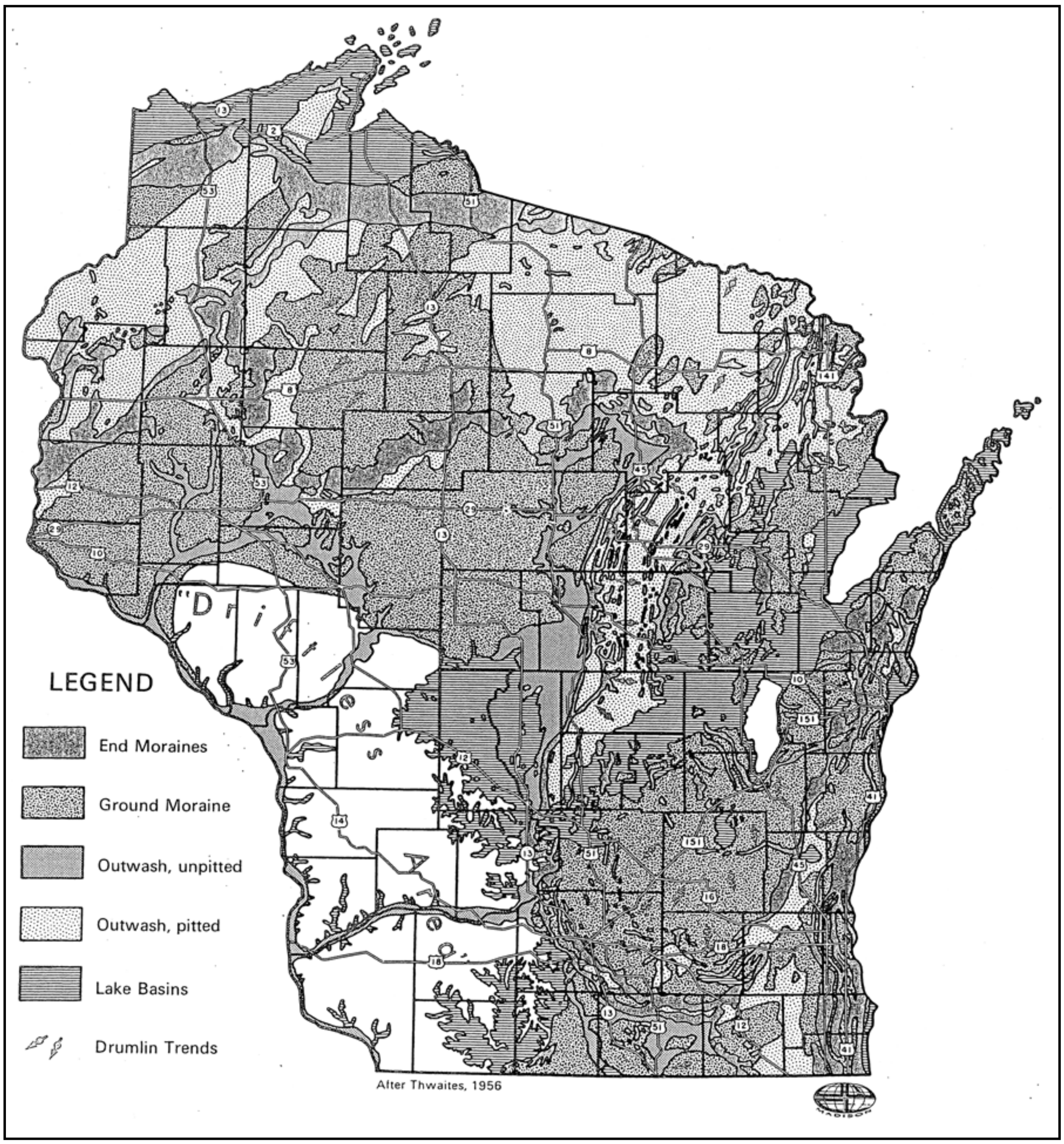

Figure 7.—*Glacial deposits and the Driftless Area of Wisconsin. The lake basin of ancient Lake Wisconsin in the center of the state was created when the glacier blocked the Wisconsin River (Hole 1976). Reprinted with permission of the University of Wisconsin Press.*

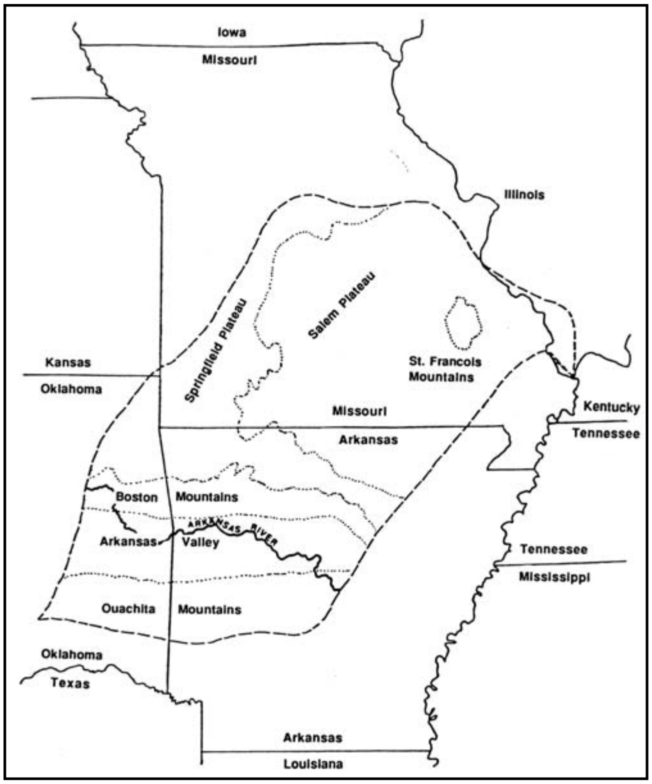

Figure 8.—*Subdivisions of the Interior Highland physiographic province (Zachry and others 1979).*

northward along the floodplain into southern Missouri, Illinois, and Indiana (figs. 4 and 5). A number of bottomland species of the Coastal Plain region grow north of the Arkansas River, the southern boundary of the CHF. This list of species includes willow oak, water oak, cherrybark oak, Nuttall oak (*Quercus nuttallii* Palmer), swamp chestnut oak, overcup oak, swamp tupelo (*Nyssa aquatica* L.), and baldcypress (*Taxodium distichum* (L.) Rich.). The soils are classed as Inceptisols, primarily Haplaquepts. In presettlement time, most of this area was covered by bottomland forest, but because of the deep soil and high fertility most of the forest was cleared for agriculture. One major feature of the floodplain is Crowley's Ridge that stretches south from the Missouri border into central Arkansas (Fenneman 1938, Waggoner 1975).

Loess Bluffs

The Mississippi alluvial plain is bordered on the east by Loess Hills (also called Brown Loam, or Loessial Hills) that are 5 to 15 miles wide extending from Mississippi (Tunica Hills) to Kentucky (Cane Hills) (figs. 4 and 5). They rise 125 to 250 ft above the floodplain and are dissected with ravines particularly along the western margin. The mantle of loess is up 100 ft thick in places. The silt loam material of the bluffs blew out of the floodplain during dry periods, usually during the winter months. Loess thickness on the west bluffs is thinner because the prevailing wind direction is west to east. These deep, fertile, moist soils are classed as Alfisols (Fragiudalfs). They are yellowish-brown in color and contrast with the nearby red-yellow Ultisols. The forest is strongly dominated by mesophytic hardwoods (Braun 1950, Waggoner 1975).

SUMMARY

Although the location of the boundary for the CHF is going to be interpreted somewhat differently depending on the objectives of independent researchers, the region is ecologically distinct and there is considerable commonality in forest community types, successional patterns, and to a lesser extent, physiographic provinces and soil. Although done at different times and working with different base factors (climatic, vegetative, physiographic), there is considerable correspondence among the maps of Braun (1950), Kuchler (1964), Keys and Carpenter (1995), Bailey (1976, 1994), and Fralish and Franklin (2002). The eastern boundary of the CHF reported by Fralish (1994) does not coincide with these maps because only the region of CHF bottomlands was considered thus leaving out the Appalachian provinces.

ACKNOWLEDGMENTS

Sincere thanks to Dr. Scott Franklin in the Department of Biology at the University of Memphis, TN; and Dr. Susan Will-Wolf in the Department of Botany at the University of Wisconsin, Madison; for their reviews of the manuscript.

LITERATURE CITED

Albert, D.A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin. Gen. Tech. Rep. NC-178. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 259 p.

Albert, D.A.; Denton, S.R.; Barnes, B.V. 1986. Regional landscape ecosystems of Michigan. Ann Arbor, MI: University of Michigan, School of Natural Resources.

Albert, J.D.; Mellilo, J.M. 1991. Terrestrial ecology. Philadelphia, PA: Saunders College Publishing.

Anderson, R.C. 1982. An evolutionary model summarizing the role of fire, climate, and grazing animals in the origin and maintenance of grasslands. In: Estes, J.R.; Tyrl, R.J.; Brunken, J.N., eds. Grasslands: systematics and ecology. Norman, OK: University of Oklahoma Press: 297-308.

Bailey, R.G. 1976. Ecosystems of the United States. (RARE II map).

Bailey, R.G. 1980. Descriptions of the ecoregions of the United States. Misc. Publ. 1391. Washington, DC: U.S. Department of Agriculture, Forest Service.

Bailey, R.G. 1994. Ecoregions and subregions of the United States. Washington, DC: U.S. Department of Agriculture, Forest Service. (Map)

Bailey, R.G. 1995. Description of the ecoregions of the United States. 2d ed. Washington, DC: U.S. Department of Agriculture, Forest Service. 176 p. + map.

Bailey, R.G. 1996. Ecosystem geography. New York, NY: Springer-Verlag. 204 p.

Braun, E.L. 1950. Deciduous forests of Eastern North America. New York, NY: Hafner Publishing Company. 596 p.

Brunner, W.E. 1931. The vegetation of Oklahoma. Ecological Monographs. 1: 99-188.

Buol, S.W., ed. 1973. Soils of the southern States and Puerto Rico. South. Coop. Ser. Bull. 174. Agricultural Experiment Stations of the Southern States and Puerto Rico Land-Grant Universities.

Clark, F.B. 1976. The Central Hardwood forest. In: Fralish, J.S.; Weaver, G.T.; Schlesinger, R.C., eds. Proceedings, 1st Central Hardwood Forest conference. Carbondale, IL: Department of Forestry, Southern Illinois University: 1-8.

Clayton, J.S.; Ehrlich, W.A.; Cann, D.B.; Day, J.H.; Marshall, I.B. 1977. Soils of Canada: soil report, vol. 1. Ottawa, ON: Canada Department of Agriculture. 243 p. + maps.

Clements, F.E. 1928. Plant succession and indicators. New York, NY: H.W. Wilson Company.

Curtis, J.T. 1959. The vegetation of Wisconsin: an ordination of plant communities. Madison, WI: The University of Wisconsin Press. 657 p.

DeSelm, H.R.; Schmalzer, P.A. 1982. Classification and description of the ecological themes of the Interior Low Plateau. Washington, DC: U.S. Department of Interior, Park Service. 118 p.

Farrar, J.L. 1995. Trees of the northern United States and Canada. Ames, IA: Iowa State University Press. 502 p.

Fehrenbacher, J.B.; Alexander, J.D.; Jansen, I.J.; Darmody, R.G.; Pope, P.A.; Flock, M.A.; Voss, W.F.; Scott, J.W.; Andrews, W.F.; Bushue, L.J. 1984. Soils of Illinois. Bull. 778. Urbana, IL: University of Illinois, College of Agriculture, 85 p.

Fenneman, N.M. 1938. Physiography of the United States. New York, NY: McGraw-Hill Book Co., Inc. 714 p.

Fralish, J.S. 1988. Predicting potential stand composition from site characteristics in the Shawnee Hills forest of Illinois. The American Midland Naturalist. 120: 79-101.

Fralish, J.S. 1994. Composition, diversity, and environmental relationships of the Central Hardwood bottomland forest. In: Roberts S.D.; Rathfon, R.A., eds. Publ. No. FRN 151. West Lafayette, IN: Purdue University, Department of Forestry and Natural Resources: 39-49.

Fralish, J.S., ed, comp. 2002. The Central Hardwood Forest conference 1976-1999: title, subject, author, and species indexes for the proceedings. Gen. Tech. Rep. NC-225. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 227 p.

Fralish, J.S.; Franklin, S.B. 2002. Taxonomy and ecology of woody plants in North American forests. New York, NY: John Wiley and Sons. 612 p.

Harris, S.E., Jr.; Fralish, J.S.; Weaver, G.T. 1982. A survey of potential national natural landmarks of the Eastern Central Lowlands Physiographic Province of the United States. Washington, DC: U.S. Department of Interior, Park Service. 879 p.

Hicks, R.R., Jr. 1998. Ecology and management of Central Hardwood Forests. New York, NY: John Wiley & Sons, Inc. 412 p.

Hoagland, B.W.; Butler, I.H.; Johnson, F.L.; Glenn, S. 1999. The Cross Timbers. In: Anderson, R.C.; Fralish, J.S.; Baskin, J.M., eds. Savannas, barrens, and rock outcrop plant communities of North America. Cambridge, UK: Cambridge University Press: 231-245.

Hole, F.D. 1976. The soils of Wisconsin. Madison, WI: University of Wisconsin Press. 223 p.

Hole, F.D.; Germain, C.E. 1994. Natural Divisions of Wisconsin. Madison, WI: Wisconsin Department of Natural Resources. (Map)

Homoya, M.A.; Abrell, D.B.; Aldrich, J.R.; Post, T.W. 1985. The natural regions of Indiana. Proceedings, Indiana Academy of Science. 94: 245-268.

Hunt, C.B. 1974. Natural regions of the United States. San Francisco, CA: W. H. Freeman and Co. 725 p.

Keys, J.E., Jr.; Carpenter, C.A., eds. 1995. Ecological units of eastern United States (with map). Atlanta, GA: U.S. Department of Agriculture, Forest Service. 80 p.

Kingsley, N.P. 1985. A forester's atlas of the northeast. Gen. Tech. Rep. NE-95. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

Kuchler, A.W. 1964. Potential natural vegetation of the conterminous United States. Spec. Publ. 36. New York, NY: American Geographical Society. 116 p. + map.

Leopold, D.J.; McComb, W.C.; Muller, R.N. 1998. Trees of the Central Hardwood Forests of North America. Portland, OR: Timber Press. 469 p.

Lindsey, A.S., ed. 1966. Natural features of Indiana. Indianapolis, IN: Indiana Academy of Science. 597 p.

Little, A.E. 1971. Atlas of United States trees. Vol. 1. Misc. Publ. 1146. Washington, DC: U.S. Department of Agriculture.

Lull, H.W. 1968. A forest atlas of the Northeast. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

Merz, R.W. 1978. Forest atlas of the Midwest. St. Paul, MN. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 48 p.

Nelson, P.W. 1987. The terrestrial natural communities of Missouri. Jefferson City, MO: Missouri Department of Conservation. 197 p.

Patton, D.R. 1997. Wildlife habitat relationships in forested ecosystems. Portland, OR: Timber Press. 502 p.

Putnam, J.A.; Furnival, G.M.; McKnight, J.S. 1960. Management and inventory of southern hardwoods. Agric. Handb. 181. Washington, DC: U.S. Department of Agriculture, Forest Service. 102 p.

Quarterman, E.; Powell, R.L. 1978. Potential ecological/geological natural landmarks of the Interior Low Plateaus. Washington, DC: U.S. Department of Interior, Park Service. 738 p.

Risser, P.G. 1981. A survey of potential national natural landmarks, biotic themes, of the Western Central Lowlands. Washington, DC: U.S. Department of Interior, Park Service. 261 p.

Rowe, J.S. 1972. Forest Regions of Canada. Can. For. Publ. No. 1300. Ottawa, ON: Department of Environment.

Schwegman, J.E. 1973. The natural divisions of Illinois. Rockford, IL: Illinois Nature Preserves Commission. 32 p.

Scott, A.A.J. 1995. Canada's vegetation: a world perspective. London, ON: McGill-Queen's University Press. 361 p.

Shantz, H.L.; Zon, R. 1924. Natural vegetation: atlas of American agriculture. Part I, Section E. Washington, DC: U.S. Department of Agriculture.

Smalley, G.W. 1979. Classification and evaluation of forest sites on the Southern Cumberland Plateau. Gen. Tech. Rep. SO-23. New Orleans, LA: U.S. Department of Agriculture, Forest Service. Southern Forest Experiment Station. 59 p.

Smalley, G.W. 1980. Classification and evaluation of forest sites on the Western Highland Rim and Pennyroyal. Gen. Tech. Rep. SO-30. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 120 p.

Smalley, G.W. 1982. Classification and evaluation of forest sites on the Mid-Cumberland Plateau. Gen. Tech. Rep. SO-38. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 58 p.

Smalley, G.W. 1983. Classification and evaluation of forest sites on the Eastern Highland Rim and Pennyroyal. Gen. Tech. Rep. SO-43. New Orleans, LA: U.S. Department of Agriculture, Forest Service. Southern Forest Experiment Station. 123 p.

Smalley, G.W. 1984. Classification and evaluation of forest sites in the Cumberland Mountains. Gen. Tech. Rep. SO-50. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 84 p.

Smalley, G.W. 1986. Classification and evaluation of forest sites on the Northern Cumberland Plateau. Gen. Tech. Rep. SO-60. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 74 p.

Soil Survey Staff. 1975. Soil taxonomy. Agric. Handb. 436. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service. 754 p.

Spencer, J.S., Jr.; Bones, J.T. 1987. Forest statistics and information needs in the Central Hardwood Region. In: Hay, R.L.; Woods, F.W.; DeSelm, H.R., eds. Proceedings, 6th Central Hardwood Forest conference; Knoxville, TN: The University of Tennessee: 457-465.

Transeau, E.N. 1935. The Prairie Peninsula. Ecology. 16: 423-437.

Veach, J.O. 1953. Soils and land of Michigan. East Lansing, MI: Michigan State College Press. 241 p.

Veach, J.O. 1959. Presettlement forest in Michigan. East Lansing, MI: Michigan State University, Department of Resource Development. (Map based on soil surveys, General Land Office survey records, and other historical information)

von Althen, F.W. 1987. Site preparation and weed control in hardwood afforestation in Ontario. In: Hay, R.L.; Woods, F.W.; DeSelm, H.R., eds. Proceedings, 6th Central Hardwood Forest conference. Knoxville, TN: University of Tennessee: 75-80.

von Althen, F.W. 1989. Early height growth increased in black walnut-silver maple intermixtures. In: Rink, G.; Budelsky, C.A., eds. Proceedings, 7th Central Hardwood Forest conference; Carbondale, IL. Gen. Tech. Rep. NC-132. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 170-174.

von Althen, F.W.; Webb, D.P. 1978. Effects of root regeneration and time of planting on sugar maple plantation establishment. In: Pope, P.E., ed. Proceedings, 2nd Central Hardwood Forest conference. West Lafayette, IN: Purdue University: 401-411.

von Althen, F.W.; Webb, D.P. 1980. Planting of sugar maple on abandoned farmland in southern Ontario. In: Garrett, H.E.; Cox, G.S., eds. Procedings, 3rd Central Hardwood Forest conference. Columbia, MO: University of Missouri: 354-373.

Waggoner, G.S. 1975. Eastern deciduous forest: Southeastern Evergreen and Oak-Pine Region. Volume 1. Inventory of natural areas and sites recommended as potential natural landmarks. Washington, DC: U.S. Department of Interior, Park Service. 206 p.

Zachry, D.L.; Dale, E.E., Jr.; Berry, R.A.; Davis R.H. 1979. Potential national natural landmarks of the Interior Highlands natural regions, Central United States. Washington, DC: U.S. Department of Interior, Park Service. 272 p.