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Chapter 15. Appalachia and the Eastern Cordillera

David Shankman and L. Allan James

The uplands of eastern North America are commonly referred to as the Appalachian Highlands, based on the pre-eminence of the Appalachian Mountains within the region. However, the complex of Paleozoic fold belts found in the Appalachian Highlands also extented northeast, through Canada's Maritime Provinces to Newfoundland, and reappear in the Ouchita Mountains across the Mississippi River valley far to the southwest. For this larger region, the term Eastern Cordillera is appropriate in the present context. To the north and west, the region abuts to the narrow St. Lawerence Lowland along the margin of the Canadian Shield, the central lowlands of the Great lakes region, and the low platueas of western Kentucky and Tennessee (Fig. 15.1). To the south and east, the region extends to the Fall Line at the inner edge of the Coastal Plain. West of the Mississippi embayment are the Ouachita Mountains and Ozark pleateaus in Arkansas and southern Missouri. Whereas the later areas, together with the interior low plateaus are not formally recognized as part of the Appalachian Highlands, they are included here because of similarities in structure, relief, and vegetation. The Eastern Cordilliera thus defined, though dominated by the Appalachian Highlands, is not continuously mountainous but is sufficently elevated to generate a distinctive physical and biotic regionalism quite different from that of the adjacent lowlands.

15.1 Physical Regions of the Appalachians

Based on Fenneman's (1938) widely accepted physical divisions of the United States, six provinces are identified within the Appalachian Highlands, namely the Adirondack Mountains, Appalachian Plateaus, Ridge and Valley, Blue Ridge, Piedmont, and New England, (Fig. 1). Because these provinces differ in terms of tectonic evolution, they are distinguished from one another by structural and lithological differences that result in pronounced variations in topography (see Chapter 1). Most provinces are, however, characterized by northeast-southwest striking structures attributable to Paleozoic orogenies that give the region some uniformity over more than 3000 km from Newfoundland to Alabama.

Though structurally an extension of the Canadian Shield and underlain by Precambrian igneous and metomorphic rock, the relatively small Adirondack Province in New York State is a mountainous region more appropriately allied in terms of its surface features with the mountains of the Appalachian Fold Belt. Its peaks range between 1000-1500 m in elevation reaching 1629 m on Mt. Marcy. As elsewhere in the northern Appalanchians, the Adirondacks were repeatedly glaciated during Pleistocene times, leaving prominent erosional features.

The Adirodacks are bounded on the south by the Appalachian Plateaus that form the westernmost province of the Appalachian Highlands. The plateaus occupy much of New York, Pennsylvania, and West Virginia, and extend southward in a narrow strip to northern Alabama for a total distance of 1600 km. This region is underlain by nearly horizontal to deformed Paleozoic clastic sedimentary strata whose conglomerates, sandstones, and shales are variably resistant to erosion. Some areas are deeply dissected resulting in rugged terrain but of fairly low elevation. The highest summits range from 1300-1370 m in West Virginia; mountain peaks in other parts of the region are much lower. The Allegheny Front, a high east-facing escarpment of erosion resistant sandstones, separates the Appalachian Plateaus from the Ridge and Valley Province to the southeast.

The Ridge and Valley Province is a long narrow zone extending southward more than 1900 km from New York to northern Alabama, and linking northward with the St. Lawerence Lowland in eastern Canada. Unlike the Appalachian Plateaus, the Ridge and Valley Province consists of a belt of tightly folded and faulted Paleozoic sedimentary rocks. Alternating synclines and anticlines in much of the region result in a northeast-southwest alternation of parallel ridges and valleys. Older limestones and shales tend to erode and form valleys while younger Paleozoic sandstones and conglomerates form ridges. Folds and shallow thrust faults represent crustal warping and movement of rock toward the northwest. Along the eastern margin of the province is the Great Valley, a continuous lowland that includes Lebanon Valley in Pennsylvania, the Shenandoah Valley in Virginia, Hagarstown Valley in Maryland, and the Great Valley in eastern Tennessee.

To the east of the Ridge and Valley is the mountainous Blue Ridge Province. In contrast to the sedimentary rock underlying the Appalachian Plateaus and Ridge and Valley, the Blue Ridge consists largely of older Paleozoic and Precambrian metamorphic rock of a complex structure. The northern section of this 1000 km long province is narrow, only 15-20 km in some places, but it broadens southward to include the highest and most rugged mountains in the Appalachian region. In the southern

Blue Ridge along the North Carolina-Tennessee boundary are the Great Smokey Mountains named for the blue haze occurring at high elevation. Mountain peaks range from 1500 m to greater than 1800 m elevation. The highest peak in eastern North America is Mt. Mitchell (2027 m) in North Carolina. The Blue Ridge forms a natural barrier to transportation that long impeded the western expansion of European colonization.

To the east of these mountains is the Piedmont Province that extends 1500 km from New York to Alabama. Its northwestern boundary is the foot of the Blue Ridge and from there it slopes gently toward the Atlantic Coastal Plain. Its boundary with the Coastal Plain is most readily identified by the Fall Line, a series of rapids or falls in stream channels that occur where rivers flow from the more resistant rock of the Piedmont onto less resistant sediments of the Coastal Plain. The Piedmont is a non-mountainous region incised by southeast-trending river valleys and characterized by gentle rolling topography. It is highest in the south where it attains an elevation of 550 m on the Dahlonega Plateau in Georgia. The Piedmont is underlain by Precambrian metamorphic and igneous rocks that dip beneath Cretaceous and Cenozoic marine sediments of the Coastal Plain.

The New England Province has structural similarities with the Piedmont, Blue Ridge, and Ridge and Valley and was regarded by Fenneman (1938) as the northward continuation of these provinces. Indeed, the structural lineations and terranes of New England extend in turn northeast through the Maritime Provinces to Newfoundland and the adjacent continental shelf. The present geomorphic character of this province has been shaped largely by Pleistocene glaciation distinguishing it from less glaciated and unglaciated terrain farther south. During the major glacial advances, ice sheets covered all but the highest peaks in this region. Deep soils and weathered rock are almost entirely absent and much of the region is covered by a mantle of glacial and fluvioglacial deposits.

15.2 Landform Evolution

15.2.1 Origin of the Appalachians

The Appalachians have a complex geologic history which, despite uncertainties, is best explained in a plate tectonic context (see Chapter 1). The evolutionary sequence began more than more than a billion years ago (>1Ga) when the late Precambrian Grenvillian orogeny shaped the highly deformed rocks now found in the crystalline core of the Blue Ridge Mountains and left a series of shallow faults (Fig. 2). Subsequent continental rifting, beginning about 700 Ma, eventually created the Iapetus Ocean along the eastern margin of the Laurentian craton (Hutton and Zullo, 1991). Throughout the Paleozoic, subduction and crustal accretion against this craton were associated with several orogenic events accompanied by granite plutonism, metamorphism, and island-arc volcanism (Rast, 1989; Hatcher, 1989). The Taconic orogeny (470-440 Ma) provided the framework for the Blue Ridge Mountains (Hatcher and Goldberg, 1991). The Acadian orogeny (400-350 Ma), generate by the crowding of several small plates against the Laurentian craton, is well represented in the folded terranes and post-orogenic granitics of the northern Appalachians. The final major mountain building episode, the Alleghenian orogreny (330-270 Ma) occurred as the West African plate moved against the Laurentian craton. Its effects are particularly well expressed in the central and southern Appalachians, mainly in the fold and thrust mountains of the Ridge and Valley Province (Horton and Zullo, 1991; Hatcher and Goldberg, 1991). Structures in the Appalachian Highlands are thought to involve a series of relatively shallow thrust faults that converge in a major horizontal fault zone upon which the Blue Ridge and Ridge and Valley crustal segments slid horizontally (Cook et al., 1979). During Triassic time (245-210 Ma), the enlarged North American plate began separating from Africa as Pangea broke up, with the Appalachian region forming the eastern mountainous margin of the new continent.

15.2.2 Cycles of Erosion and Denudation

The Appalachian Highlands have provided the setting for the development of a variety of influential geomorphic models (cf. Mills et al., 1987; Morisawa, 1989). William Morris Davis' concepts of landform evolution, which dominated geomorphology throughout the first half of the twentieth century, were largely derived from study of the central Appalachians (Davis, 1899a). His writings, however, predate plate tectonic concepts and assume long periods of crustal stability. While the theoretical framework of Davis' interpretations has fallen from favor, most modern concepts of denudation and drainage evolution draw heavily on observations he first applied to the region.

The concept of peneplain development, a fundamental assumption of Davis' cycle of erosion theory, was based largely on observations in the Ridge and Valley Province (Davis, 1899b; 1899c). In Pennsylvania and New Jersey, the highest accordant ridgetops were interpreted as remnants of a broad former erosional surface named the Schooley Peneplain, and attributed to a Jurassic-Cretaceous erosional cycle (Davis, 1890; 1899b). Broad lowlands in the region were believed to be a later erosional surface referred to variously as the Kittatinny or Harrisburg Peneplain or the Tertiary base-level lowlands (Davis 1890; 1899b; Morisawa, 1989). Davis interpreted narrow valleys cut into these Tertiary lowlands as the result of an on-going Quaternary erosion cycle. Davis's cycle of erosion theory was immensely popular. Peneplains were soon thought to be recognized by Davis' disciples throughout the Appalachian region and beyond.

Davisian concepts of the progressive and spatially uniform lowering of large areas and the development of peneplain surfaces have long been criticized (Tarr, 1898; Denny, 1956; Hack, 1976; 1980). The advent of modern tectonic ideas negated the Davisian assumption of long periods of crustal stability required for the completion of a cycle of erosion as did a growing appreciation of potentially rapid rates of geomorphic processes. Crustal activity has been substantial even on passive margins such as eastern North America and is characterized by high spatial and temporal variability. Stratigraphic evidence from marine sediments deposited after the opening of the Atlantic Ocean indicates differential uplift rates between the central Appalachians, the Adirondacks, and New England, events that do not support the classic Davisian model (Poag and Sevon, 1989).

15.2.3 Modern Models of Landform Development

The decline of Davisian concepts beginning in the 1940s paralleled developing interest in much different perspectives in geomorphology. For a while, attention turned to local-scale surficial processes as opposed to landscape-scale processes (Mills et al., 1987; Soller and Mills, 1991). In recent decades, the accordant ridges and other topographic features thought to represent former peneplains, have been reinterpreted in the context of improved landform models and erosion-resistant structures (Hack, 1960; 1976).

The Appalachian Piedmont was once considered one of the best examples of a peneplain because its underlying metamorphosed rocks had been worn down to a series of accordant drainage divides that were considered too flat-crested to have been caused by anything other than prolonged fluvial erosion (cf. Costa and Cleaves, 1984; Soller and Mills, 1991). Piedmont ridges are typically mantled by 10 to 20 m of saprolite overlain by a residual soil. Saprolite retains the underlying bedrock volume and structural features, although about one third of the rock mass has been lost to weathering. Compaction and loss of about 70 percent of the total saprolite mass occurs during its conversion to soil near the surface. Recent pedogenic analysis indicates that surface lowering procedes at the same average rate as the downward progression of the lower saprolite front. This suggests that the broad ridgetops resulted from pedogenesis and that the saprolite is Quaternary in age (Mills et al., 1987; Pavich, 1989; Mills and Delcourt, 1991). This interpretation contrasts with hold-held assumptions that the thick residuum is much older and implies that dynamic equilibruim theories explain Piedmont landscape evolution better than peneplanation (Mills et al., 1987). The predominance of weathering processes indicate that Piedmont bedrock outcrops, such as Stone Mountain, Georgia, are not monadnocks in the Davisian sense of an erosional remnant of a former erosion cycle (Bates and Jackson 1987), but survived because they were more resistant to weathering and erosion than the surrounding saprolite-covered surfaces (cf. Wahrhaftig, 1965).

15.2.4 Drainage Reversal and Divide Migration

Two classic problems of Appalachian geomorphology concerns the long-term evolution of fluvial systems: (1) the question of drainage reversals and (2) explanations for transverse drainage. Some researchers have concluded that major streams originating in the Appalachian highlands once flowed westward or northwestward across the region toward the interior of the continent (reviewed by Mills et al. 1987). Although Hack (1982) acknowledged westward drainage divide migration occurred in some local valleys, he did not consider the process to be dominante in the Appalachians. Others have argued, however, for pronounced westward retreat of Blue Ridge escarpment in the southern Appalachians by headward erosion of Piedmont streams and piracy of Blue Ridge streams. Judson (1976) suggested that during the late Paleozoic following the breakup of Pangea many streams flowing northwest reversed and began to flow southeastward toward the Atlantic Ocean. According to Judson, during the break-up of Pangea beginning in the late Triassic the continental crust lowered as it migrated away from the mid-Atlantic rift zone. This ultimately resulted in the reversal of many streams that began flowing east into the rift zone (Fig. 2). These east-flowing streams had steeper gradients than channels flowing long distances westward which resulted in headward erosion of east-flowing streams, capture of previously west-flowing streams and their tributaries, and the westward migration of drainage divides.

Another classic geomorphic question has been the abundance of drainage systems that cut across transverse geologic structures. Incision of some of the major south-eastern-flowing streams in the central Appalachians created spectacular *water gaps* with cliffs up to several hundred meters high. For example, the Delaware River flows through several water gaps along the Pennsylvania-New Jersey border in the Ridge and Valley Province before reaching Chesapeake Bay. To the south, the Susquehanna River flows through plunging anticlines and synclines in central Pennsylvania, and the Potomac River, with headwaters in southern Pennsylvania, has cut water gaps in the Blue Ridge of West Virginia. In some cases, stream capture diverted streams and the abandoned water gaps, known as *wind gaps,* are common in the central part of the Ridge and Valley and Blue Ridge provinces. While water and wind gaps are not common in the southern or glaciated Appalachians, their prominence in the central Appalachians had considerable influence on geomorphic theory, and they have posed a geomorphic enigma for generations.

Concepts of superpositioning and antecedence have become increasingly sophisticated. Oberlander (1985) recognized several modes by which drainage can evolve transverse to structures, that a variety of both superpositioning and antecedent processes can operate concurrently, and that permeatations of both landform types may occur in the same region. He pointed out that thick, weak rock layers often lie conformably over erosion-resistant folded rocks in young orogenic zones such as the Zagros Mountains of Iran. If the weak rock layers are thick relative to fold amplitudes, there may be a complex evolution of drainage as anticlinal basins covered by weak rock elongate into valleys, enlarge, coalesce, and superpose channels onto competent rocks below (Oberlander, 1985). This process can result in the observed preferred location of water gaps in the high centers of broad anticlinoria.

A classic argument for transverse drainage in the Appalachians caused by superpositioning was based on stream incision of Coastal Plain sediments once extending much further west than their present Fall Line boundary (Johnson, 1931). Channels incising down through the former Coastal Plain overburden eventually cut into and across Piedmont structures (Staheli, 1976; cf. Hack, 1982; Battiau-Queney, 1989; Soller and Mills, 1991). Explanations of transverse drainge have also been based on transverse structural weakness (Epstein, 1966; cf. Mills et al. 1987; Clark, 1989). Clark (1989) presented a review of concepts concerning water gap and wind gap formation and their importance to geomorphic inquiry in the central Appalachians. He emphasized the importance of transverse structural weaknesses and described a process of *structural ensnarement* in which downplunge lateral channel migration around anticlinal noses proceeds until weak transverse zones are encountered that allow more rapid incision rates.

15.3 Late Quaternary Landscape Evolution

Repeated glacial episodes during the Pleistocene had a notable effect on the northern Appalachian Highlands. Ice sheets from Canada advanced southward into the northeastern United States several times during the Pleistocene (see Chapter 2). As a result of these ice sheets and local ice caps, glacial depositional and erosional landforms are common in the northern Appalachian Highlands. These features, however, commonly represent only the most recent glacial events of late Quaternary age, on which considerable research has been conducted. Successive scouring of the surface has left few remnants of previous glaciation, and therefore early Quaternary glacial episodes in the Appalachians are not well documented (Braun, 1989).

15.3.1 Glaciation

Over the last 200,000 years, there were at least three major glacial advances of ice sheets in much of eastern North America. Although dating of early events remains controversial, numeric ages given here are based on a commonly accepted method of combining marine oxygen isotope data and northern hemisphere solar energy receipts based on earth-sun orbital parameters (Mix, 1992). During the Illionisan glaciation in the Late Middle Pleistocene (Morrison, 1991; before 130 ka), ice apparently covered areas of the Ohio River Valley as far south as 36°40' N latitude, in New York and Pennsylvania well onto the Allegheny Plateau, and in New England out to Nantucket Island (Oldale et al., 1982; Oldale and Coleman, 1992). Continental ice presumably ablated completely during the last Interglacial (130-115 ka).

Major glacial advances occurred at least twice during the Wisconsinan glaciation (80-10 ka). In early Wisconsinan time (80-65 ka), Laurentide ice reached the St. Lawrence Lowland, retreated, and then readvanced to its maximum extent in Pennsylvania and New York (Dreimanis and Goldthwaite, 1973). In mid-Wisconsinan time (65-35 ka), Laurentide ice retreated to a position well north of the St. Lawrence Lowland. The late Wisconsinan advance, beginning about 30 ka, has been studied in greatest detail due to preservation of evidence.

There are two controversies regarding the source and the nature of the Late Wisconsinan glaciation. First, the source of the Laurentide ice sheet that came into the region has been disputed (see review in Dyke et al., 1989). It had long been assumed there was one original ice sheet that extended over eastern North America. However, evidence has mounted for multiple origins of the Laurentide ice (Shilts et al., 1987; Vincent, 1989; Wright, 1989). The second controversy envolves a debate about whether or not Laurentide ice crossed over the northeastern Appalachians to the Atlantic Ocean. Many researchers concluded that ice extended beyond the present coastline and occupied much of the continental shelf exposed by the lower sea level (Hughes et al., 1985; Braun, 1989). Clearly by 18 ka, possibly earlier, Laurentide ice extended across New England, northern Pennsylvania, New York, and New Jersey (Fig. 3). However, it is not clear if ice extended further to the northeast, in Maine and the Maritimes. The evidence for glaciation in this region is primarily based on off-shore sediments in addition to climate/ice flow models. In contrast, arguments for only partial ice coverage in this region are supported by the lack of terrestrial evidence of glaciation, most notably the absence of glacial erratics (e.g., Boulton et al., 1985). The absence of glacial have been explained by alternate means, however, such as dilution of till by local lithologies and thermal changes in the glacial bed (Newman et al., 1985).

15.3.2 Deglaciation

Deglaciation was not a simple retreat of the ice margin to the northwest. Warming and thinning of the Laurentide ice sheet occurred between 18 and 16 ka, although an extensive readvance occurred about 15.5 ka (Mickelson et al., 1983; Hughes et al., 1985). The Laurentide ice sheet in the northeastern region was strongly influenced by marine-based margins. Calving embayments developed off the coast of Maine and a calving margin advanced up the St. Lawrence Lowland between 14 and 12.8 ka (Hughes et al., 1985; Borns, 1985; Newman et al., 1985; Occhietti, 1989). Large ice streams accelerated into these calving margins enabling rapid thinning and ablation of the adjacent ice sheet (Borns, 1985). Thus, glacial ice persisted in and emanated from local ice caps in Maine, Gaspé, New Brunswick, Nova Scotia, and Newfoundland after it had disappeared from the St. Lawrence Lowland (Vincent, 1989; Occhietti, 1989). Ice was largely gone from the region by 11 ka, except for small remnants in the highlands of Nova Scotia and Newfoundland (Hughes et al., 1985).

15.3.3 Periglacial Activity

Evidence of periglacial activity in the Appalachians indicates the development of deep frozen ground during Wisconsinan time that may have been continuous near the glacial boundary in New York and Pennsylvania (Péwé, 1983; Mills and Delcourt, 1991) (Fig.3). Paleoperiglacial activity in the non-glaciated Appalachians was slow to be recognized relative to other regions, owing in part to thick forest cover and poor surface expression, but many periglacial features have now been identified in the central Appalachians and most are paleoclimatic relicts (Clark and Ciolkosz, 1988). In the central and southern Appalachians, small-scale features such as sorted polygons, circles, stripes, nets, and steps are common but tend to be active only where there is no ground cover. In contrast, unsorted patterned ground is relatively rare with the exception of ice wedge casts seen in vertical exposures. Mesoscale periglacial features such as block fields and block streams are common throughout the central Appalachians (Clark and Ciolkosz, 1988). No periglacial activity has been noted in the outer Piedmont or on the Coastal Plain more than 160 km from the late Wisconsinan limit (Mills et al., 1987).

15.3.4 **Fluvial and Colluvial Processes**

As is common in mountainous regions, the dominant long-term geomorphic action of most stream systems has been incision. Studies of multiple stream terraces in the central Appalachians, particularly in the Ridge and Valley Province, have been carried out along the New and Tennessee Rivers. Along the New River in southwest Virginia, upper terraces spans a wide range of time from early Pleistocene or older to Sangamon, while a low group of terraces is of Wisconsin age (Mills and Wagner, 1985; Mills and Delcourt, 1991). Young, low terraces along the lower Tennessee River suggest maximum aggradation rates occurred during glacial-to-interglacial transitions (Delcourt et al., 1986; Mills and Delcourt, 1991).

A debate over the importance of rare episodic events to the evolution of fluvial landforms was largely framed around central Appalachian rivers. Opposing views were presented by Wolman and Miller (1960) who believed long-term processes dominated landform evolution in contrast to Hack and Goodlett (1960) who believed episodic events were important in this region. Drastic effects of large floods on fluvial forms have been described by Clark (1987) and Miller (1995). Jacobson and others (1989) concluded that the magnitude and frequency of landslides in the central Appalachians varies with physiographic province. There has been little hillslope mass wasting in the Piedmont, but in the Blue Ridge and Ridge and Valley Provinces it can be quite active. At the local scale, landslide activity varies with precipitation characteristics and geologic materials. Slopes with colluvium and shale residuum may experience many shallow slides during protracted low-intensity storms that saturate the fine-grained soils. In contrast, quartzite ridges tend to have the greatest slope failures during shorter more intense storms due to more rapid drainage of the coarse materials (Jacobson et al., 1989). Clark (1987) documents several debris slides, debris slopes, and water blowouts in the central and southern Appalachians.

15.3.5 Climatic conditions and forested landscapes

During the Wisconsian glacial maximum, vegetation in eastern North America was displaced far to the south of its present latitudes (Delcourt et al., 1980; Delcourt and Delcourt, 1993; see also Chapter 3). Tundra vegetation occurred along the edge of the ice sheet and extended several hundred kilometers farther south along the crests of the Appalachian Mountains (Watts 1979). Boreal forest species, including black spruce (*Picea mariana*), red spruce (*P. rubens*), larch (*Larix larcina*), balsam fir (*Abies balsamea*), and jack pine (*Pinus banksiama*), now common in eastern Canada and northern New England, occupied large areas of the central eastern United States (Watts 1970; 1979). Deciduous forest vegetation occurred primarily in the lower Mississippi River valley and northern Florida, and may have also grown together with boreal species in some locations (Davis, 1981; Delcourt and Delcourt, 1977; 1993).

Between 15 and 11 ka the warmer climate and retreat of ice initiated widespread vegetation changes in eastern North America (Davis, 1981; Delcourt and Delcourt, 1993). Although northward migration of species may have begun as early as 15 ka, the most rapid changes occurred in the early Holocene between 11 and 7 ka (see also Chapter 4). New surfaces previously under ice were initially colonized by tundra vegetation. Davis' (1981) reconstruction of tree migration patterns during the late Pleistocene-early Holocene shows that boreal species rapidly migrated northward into New England and Canada, reaching their current range within the past 7-5 ka in most cases. Temperate deciduous species of oak (*Quercus*), hickory (*Carya*), and elm (*Ulmus*), among others, also moved northward during the late Pleistocene-early Holocene. Northern migration rates were highly variable. Boreal species tended to migrate rapidly, as much as 300 m/yr. Chestnut (*Castanea dentata*) moved more slowly northward and may have arrived in New England only 2000 yr BP before becoming one of the dominant species throughout much of the Appalachian mountain region (Davis, 1981).

A few of the tree species that migrated northward during the Holocene have small populations that persist in isolated stands far to the south of their continuous ranges. For example, eastern hemlock (*Tsuga canadensis*) is common in New England and the high elevations of the Appalachians but also occurs in isolated stands on cool, moist north-facing river bluffs and ravines as far south as central Alabama and Georgia (Harper, 1943; Bormann and Platt, 1958). Balsam fir is common in the boreal forest in Labrador and northern Ontario, yet a few isolated stands also grow at high elevations in Virginia. Also, red spruce, that grows in Nova Scotia, occurs in extensive, noncontinuous stands at high elevations in the southern Appalachians (Oosting and Billings, 1951; Whittaker 1956).

15.4 Changing Landscapes in Historical Times

15.4.1 Old growth forests

Forests dominated the pre-European landscape of eastern North America.
Many early explorers' descriptions of a pristine landscape helped develop the concept of the forest primeval with unbroken, undisturbed stands of ancient trees (e.g., Baird, 1832; Bartrum, 1958; Trautman, 1977). Whitney (1994) summarized the more prominent features of several early accounts of forests in eastern North America in terms of large, ancient trees with abundant woody debris and decayed organic matter on the forest floor, an abundance of epiphytes covering the trees and mosses in the understory, and consisting of dense stands with luxuriant growth in the understory.

The many descriptions of these primeval forests indicate an abundance of old-growth stands. Yet, it is unlikely that massive, old-age trees dominated the entire landscape. Both natural and human-induced disturbances were common to this region, destroying forests stands covering areas ranging from less than a hectare to many square kilometers. A more accurate description of many of these forests would invoke stands at different stages of recovery depending on the period of time since they were disturbed. The New England coastal region, for example, is regularly hit by hurricanes that historically have leveled thousands of hectares of forest. Futhermore, tornadoes and other extreme climatic events have caused catastrophic windthrow across many parts of eastern North America. Also, periodic insect infestation caused wide spread destruction of the forests. In the central Appalachian region, however, catastrophic disturbance is less common and the primarily deciduous forests here naturally occur at later stages of successional development.

15.4.2 Forest fire in eastern North America

The forested areas in eastern North America have long been affected by fire, as shown by charcoal in lake sediments and alluvial deposits (Winkler, 1985; Patterson et al., 1987). Fire was probably most common in the extreme southern region of the Appalachians where fire-dependent species commonly occur and lightning causes fires on xeric sites. Fires set by Indians, however, were likely more important compared to naturally occurring fires in the pre-European landscape (Harmon, 1982; Delcourt and Delcourt, 1997). In contrast to the southern Appalachians, lightning-caused fires were probably not as common in most of the colder, humid regions to the north, although fire remains an important ecological process even in the boreal forest beyond the Appalachian region (see Chapter 14).

There are many historical accounts of Indians who regularly burned forests (Whitney, 1994). Early explorers in eastern North America noted that fire was used to drive game, enhance wildlife habitat, clear land for cultivation, and improve travel by reducing undergrowth. The extent and frequency of Indian burning, however, is not entirely clear and no doubt varied considerably in different regions. Indian and natural fires created openings in the forest as did Indian agricultural practices. Early explorer accounts indicate there were extensive areas of cleared land throughout much of the Appalachian region. During the sixteenth and seventeenth centuries there was a massive decline in Indian populations as a result of diseases spread by European explorers. This resulted in rapid and widespread abandonment of large tracts of cleared land (Cowdrey,1983). Some of these tracts in the coastal areas were reclaimed by early European colonists. Most abandoned farmland in the interior, however, began succeeding to forest as early as the sixteenth century.

15.4.3 Agricultural Settlement

Large-scale European colonization of eastern North America resulted in massive deforestation and conversion of cleared land to agriculture. The moist, typically fertile bottomland sites were usually the first areas to be cleared and settled. Because of steep slopes and poor soils, many areas within the Appalachians were not well suited for agriculture and were initially bypassed by settlers. As productive land became less available, settlers started farming on lower ridges and eventually on the flat rocky ridgetops. Industrial logging after the Civil War further contributed to the loss of forests and by the early twentieth century only small fragments of the region's old-growth virgin forests remained (Davis, 1996).

Poor farming practices in the Appalachians resulted in accelerated soil erosion and a decline in fertility that in many cases led to the abandonment of farmland. The most serious soil depletion typically occurred on upland sites that were too infertile or on slopes too steep for sustainable agriculture. Declining productivity led to abandonment of marginal agricultural sites and, in some areas of the Appalachians, to out-migration. Abandonment of farmland accelerated during the late nineteeth century, facilitated by increased mechanization and extensive development of more productive farmland towards midcontinent. The alluvial valleys in the eastern United States continue to be intensively cultivated. These are areas of fertile soils and low relief and therefore contain the most productive farmland in the region. These sites, however, represent only a small percentage of the land surface.

15.4.4 Invasion and Spread of Alien Species

Widespread deforestation and the abandonment of farmland favored expansion of aggressive colonizing, weedy species. These include introduced species that in many cases are now common throughout much of eastern North America, such as Japanese honeysuckle (*Lonicera japonica)* and privet (*Ligustrum vulgare*). Both were brought in as ornamentals that later escaped cultivation and now grow in dense thickets from New England southward. Kudzu (*Pueraria lobata*) was introduced from southeast Asia for erosion control and now occupies large areas throughout the southern Appalachians, growing typically in dense layers that preclude regeneration of almost all native species. Exotic trees are also now common in eastern North America, including Lombardy poplar (*Populus nigra*), weeping willow (*Salix babylonica*), black locust (*Robinia pseudoacacia*), catalpa (*Catalp speciosa*), Chinese mulberry (*Morus multicaulis*), scots pine (*Pinus sylvestris*), and Norway spruce (*Picea abies*)

One of the most notable introductions to eastern North America was a fungal plant pathogen. Until the introduction of the chestnut blight (*Endothia parasitica*) at the beginning of the twentieth century, American chestnut (*Castanea dentata*) was one of the most common trees in many parts of eastern North America. American chestnut occurred throughout much of the central and southern Appalachian Mountain region and in some mature forests may have accounted for 40 percent or more of the large trees (Keever, 1953). It was most abundant on moist, well-drained soils on mountain sides (Russell, 1987), and usually occurred in association with the most common oak species such as white oak (*Quercus alba*), red oak (*Quercus rubra*), and scarlet oak (*Quercus coccinea*). The chestnut blight was first discovered in North America in 1904 in New York City and quickly spread. In the 1920s, infections occurred as far south as Georgia and South Carolina. By the late 1940s, the chestnut blight had killed most of the mature chestnut trees throughout its range.

The chestnut blight had dramatic consequences for the forest landscape of the Appalachians. Many of the oaks formally found in association with chestnut increased in dominance. Hickory (*Carya*) species have increased in abundance and in many areas the former chestnut-oak forests have been replaced by oak-hickory forests (Keever, 1953; Woods and Shanks, 1959; McCormick and Platt, 1980). Only a few mature individuals of the once dominant tree can still be found. The root systems of many individuals have survived and root sprouting is common. But the large stems in almost all cases are killed by the blight. Chestnut now survives primarily as an understory tree (Paillet, 1984).

Other alien pathogens have also significantly affected forest community composition and structure. The American elm (*Ulmus americana*) is a common tree throughout the mesic and lowland forests of eastern North America, but many of the largest individuals were killed after the introduction the of Dutch elm disease (*Ceratocystis ulmi*) from Europe about 1930 (Karnosky, 1979; Huenneke, 1983). Also, many of the large American beech (*Fagus grandifolia*) in some areas of the northeastern US have been killed by beech bark disease that is caused by the interaction of insects and fungi (*Nectria*). The long-term effects of this disease on American beech throughout its broader range in eastern North America is not clear (Twey and Patterson, 1984).

15.5 Forest Regions

Today, the forest vegetation of the Appalachian region is highly complex. Forest communities include spruce-fir stands in the north and hardwood and mixed pine-hardwood communities farther south. Distinctive forest regions developed largely in response to climatic conditions. The severity of winters decreases and the length of the growing season increases significantly from north to south (Figure 4). The northern Appalachians, including New Brunswick, Nova Scotia, and much of New England, have cold, continental climates. The short growing season of only 3-4 months and the cold winters favor coniferous forest species. In contrast, hardwood forest communities dominate the central Appalachians because of milder winters and longer growing seasons. The southern Appalachians of the western Carolina’s, northern

Georgia, and Alabama have a subtropical climate with a growing season of 7-8 months, which favor hardwood and mixed hardwood-pine forest communities.

The entire region is humid, and although some areas of the Appalachians have noticaby less summer-fall precipitation, there is not a distinct dry season. The summer-time Bermuda High drives warm, humid air across much of eastern North America. Summer convection occurs throughout most the region, although it is much more common in southern Appalachians. During the winter the polar jet stream is displaced southward. Mid-latitude cyclones and fronts are most common during the winter and spring, but are the dominant precipitation mechanisms throughtout the year for most of the region.

The classic works of Braun (1950) and Kuchler (1964) provide the basis for the forest classification throughout the Appalachian region. Within the Appalachian mountains are three distinctive forest regions (Fig. 5). The northern most is the **Northern Transitional Forest**, extending from southeast Canada and New England southward into central Pennsylvania. As its name states, this is transitional region between the conifer dominated Boreal forest to the north and deciduous forests to the south. The **Central Hardwood Forest** occupies much of the unglaciated Appalachian region of West Virginia, Kentucky, and Tennessee, in addition to the westernmost parts of Virginia and North Carolina. The term **Central Hardwood Forest** refers to three of Braun's centrally located forest regions, the oak-chestnut (OC), mixed mesophytic (MM), and western mesophytic (WM) forests (Fig. 5). In this region, conifers are only occasionally dominant, except at the highest elevations of the Blue Ridge and Ridge and Valley. The **Southern Transitional Forest** occupies most of the Piedmont and the southernmost mountain provinces, including the uplands west of the Mississippi River valley This is a transitional forest region between the decidous forest region to the north and pine-dominated regions of the Coastal Plain farther south.

15.5.1 Northern Transitional Forests

The forest vegetation of the northern Appalachians is characterized as a large-scale mosaic of coniferous, hardwood, and mixed forest communities. The Maritime provinces and Maine, the northernmost areas of the Appalachians are occupied by spruce-hardwood stands that include, white spruce (*Picea glauca*), red spruce (*P. rubens*), American beech (*Fagus grandifolia*), yellow birch (*Betula allagheniensis*), and sugar maple (*Acer saccharum*). Hardwoods are more abundant on the favorable sites and generally decrease in dominance with distance north because of the harsher climate. Hardwood and mixed hardwood-hemlock (*tsuga canadensis*) communities dominate the more southerly part of New England, in addition to lower elevations in the north.

There is a distinct altitudinal zonation of forest communities in the mountainous regions of the northern Appalachians. The Catskills and Green Mountains in New York and Vermont reach over 1200 m above sea level, the White Mountians in New Hampshire to more than 1800 m, and Mt. Katahdin in Maine to 1605 m. The general altitudinal sequence of these mountains, in addition to mountains of lower elevation farther north begins on the lower slopes with hardwoods that in some cases are mixed with spruce, followed by predominantely spruce forests, then spruce-fir forests at the highest altitudes. These high altitude forest communities are southern extensions of the spruce-fir, boreal forest that extend unbroken from the northern margins the Appalachians across to Alaska (Oosting and Billings, 1951; see also Chapter 14). Lowland spruce-fir forest occurs below the hardwood forest in some areas because of cold air drainage. Alpine treeline in the high mountains of the northern Appalachians is reached between 1100-1300 m. Growing season temperatures seem to be an important control on the altitude of treeline. In the northern Appalachians, treeline corresponds fairly well to the 13^{o}C mean July isotherm (Cogbill and White, 1991).

The spruce-fir forests fairly common in eastern Canada and northern New England extend southward along the crests of the Appalachian Mountains, but at progressively higher elevation with distance south because of the warmer climate. There is a fairly abrupt transition between the lower spruce-fir forests and the highest hardwood dominated communities. The elevational zone where these forest communities meet is about 500-600 m in northern New England although it is somewhat lower on cooler north-facing slopes and sheltered sites. The lower elevation of spruce-fir forests increases about 80 m for every 1^{o} latitude to the south. The decrease in the spruce-fir/hardwood ecotone corresponds closely to the 17^{o}C mean July isotherm (Cogbill and White, 1991).

As noted earlier, forests of eastern North America are subject to a variety of natural and human disturbances. For example, New England forests have been much affected by hurricanes that strike the New England coast on average once every one or two decades (Simpson and Riehl, 1981). Although damage by hurricanes is greatest in the coastal regions, vegetation in the interior of New Hampshire, Vermont, Massachusetts and Connecticut has also been significantly affected (Whitney, 1994). Hurricanes can level forests over thousands of hectares. Mature stands in which trees are less densely spaced and those on the more exposed sites are most vulnerable. Extensive blowdowns favor early colonizing species including white birch (*Betula papyrifera*) and quaking aspen (*Populus tremuloides*) which are uncommon in mature stands. The existence of different aged forest stands in response to windthrow has in some areas of New England created a landscape scale mosaic of distinctive forest communities (Foster, 1988).

New England was the first part of North America heavily settled by European colonists. Almost all forests at low elevations were logged. The remaining old-growth forests consist mostly of subalpine spruce and spruce-fir stands at high elevations. Large areas of high altitude old-growth forests occur in the Catskills, New Hampshire's White Mountain National Forest, Baxter State Park in Maine, which includes Mt. Katadin, and the Adirondack State Park in New York. The largest area of low elevation old-growth is the Big Reed Forest Preserve in Maine. There are, however, many other smaller parcels of unlogged stands scattered throughout the Northern Transitional Forest (Davis, 1996).

15.5.2 Central Hardwood Forests

A large portion of the central and southern Appalachian region is occupied by hardwood forest communities. These are diverse forests that contain many wide-ranging species. Oak (*Quercus*) is the largest genus in North America with 42 species, many of which occur throughout a large part of the Central Hardwood Forest region (White and White, 1996). Drier sites within this region are occupied by post oak (*Q. stellata*), chestnut oak (*Q. prinus*), and scarlet oak (*Q. coccinea*). In addition to other oaks, upland sites are also occupied by several wide-ranging hickories such as mockernut hickory (*Carya tomentosa*) and pignut hickory (*C. glabra*). Another dozen or so species can be added to the list. Among the dominant tree species on mesic sites are white oak (*Q. alba*), northern red oak (*Q. rubra*), and black oak (*Q. veluntina*), and on the most favorable sites tulip poplar (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), sugar maple (Acer saccharum), and hemlock**,** (*Tsuga candensis*). Because of the range of environmental conditions related to slope aspect and soil conditions, fine-scale forest community composition and structure are highly variable.

Plant community patterns across most forested landscapes are largely a consequence of natural disturbance (White, 1979; Pickett and White,1985). Major disturbances (including hurricanes, fire, insect infestation, avalanches) often destroy stands covering areas ranging from less than a hectare to hundreds of square kilometers. Forest communities at early stages of recovery are dominated by early successional species. The Central Hardwood Forests, however, are affected less frequently by large scale disturbance compared to the other forest regions in eastern North America (Runkle, 1990; 1996). Therefore, the hardwood stands in this region often reach a later stage of stand development during which older trees occupy the forest canopy.

Trees are typically closely spaced during early forest succession. At this stage of vegatation development, space created by the death of an individual is quickly filled by its neighbors. Progressively older stands have fewer and more widely spaced trees. The death of a dominant individual in mature stands creates a well defined, and in some cases a long-lived canopy gap. These gaps are less likely to be filled by adjacent trees than in young stands (Oliver, 1981; Oliver and Larson, 1990). Instead, large canopy gaps facilitate the growth of individuals in the understory that can eventually occupy a canopy position. It is through this process that some species incapable of surviving long in dense shade in the central hardwood region will remain a component of the forest canopy. One of the best examples is tulip poplar which is a canopy dominant in many mexic sites in the central Appalachians.

Although much of the Central Hardwood Forest lacks major disturbances common to other regions, the forest vegetation here has have been strongly modified by human impact, to some extent by native Americans, but mostly since European settlement. Most forests have been logged, but there are surviving old-growth stands. Up to one-third of the Great Smokey Mountains National Park in North Carolina and Tennessee is covered with old-growth forest, including mixed mesic hardwoods, hemlock dominated, and high elevation spruce-fir stands. Smaller, but substantial areas of old-growth forest are in The Joyce Kilmer Memorial Forest in the Nantahala National Forest in North Carolina with mesic hardwoods and hemlock dominated stands, the Lilley-Cornett Woods in eastern Kentucky with oak-hickory and beech-hemlock stands, and the Chattahoochee National Forest in north Georgia with oak dominated communities (White and White, 1996).

Some of the most interesting areas of the Central Hardwood Forest region are the cove forests in and around the Great Smoky Mountains and the loess hills of western Tennessee and northern Mississippi. Cove forests occur on concave topography that has created cool, mesic sites. The number of species in coves is largely determined by soil type. Sites with rich calcareous soils support some the most diverse forest communities in eastern North America. Dominant species include sugar maple, buckeye (*Aesculus octandra*), basswood (*Tilia heterophylla*), and tulip poplar. In contrast, coves with more acidic soils support much less diverse forest communities often dominated by hemlock. The loess hills in western Tennessee and northwest Mississippi, adjacent to the lower Mississippi River alluvial valley, are also occupied by diverse forest communities. The loess is greater than 20 m thick in places at its western limits and rapidly thins with distance to the east. In contrast to the cove forests, the loess hills have less precipitation. This region, however, consist of deep calcareous soils that support luxuriant hardwood stands of American beech, tulip poplar, hickory, and white oak.

In contrast to hardwood dominance throughout most of this region, forests of red spruce and Fraser fir (*Abies fraseri*) occur in the high mountains of Virginia, West Virginia, Tennessee, and North Carolina. These conifer forests generally occur above 1500 m but are also present at lower elevations on the cooler north-facing slopes. Red spruce is one of the most common species in the northern Appalachians, but farther south it occurs within a fairly narrow altitudinal range (1400-1800 m) and typically is most abundant on well drained sites. In contrast, Fraser fir, which is endemic to the southern Appalachians, increases in dominance with higher elevation and forms almost pure stands on ridges and near mountain summits (Whittaker, 1956). During the 1980s and 1990s, almost all of the mature Fraser fir in the Great Smoky Mountains were killed by the balsam woolly adelgid (*Adelges piceae*), an insect introduced from Europe into the eastern United States early in the century (Busing et al., 1988).

15.5.3 Southern Transitional Forests

The Southern Transitional Forest extends from New Jersey to central Georgia and westward to the lower Mississippi River alluvial valley where it is interrupted before reappearing in Arkansas, northern Louisiana, and east Texas (Fig. 5). This includes much of the Piedmont, the southernmost sections of the Appalachian mountain provinces, and the Ozark Plateau and Ouachita Mountains. The southernmost portion of the Appalachians is a humid subtropical region with a long growing season and abundant precipitation throughout the year. This region supports hardwoods and mixed hardwood-pine forest communities. It contains many of the same hardwoods occurring in the Central Hardwood Forest region, but unlike that region, pines are common. Pine-dominated communities occur on dry upper slopes and ridgetops, sites generally less favorable for most hardwoods. Also, they rapidly colonize recently disturbed sites. This region does not reach high elevation and the distinctive altitudinal vegetation zonation occuring in the mountains to the north is generally lacking.

Most of the Southern Transitional Forest region was heavily settled during the ninteenth century and large areas were cleared for cultivation. Much of the area has poor soils for agriculture and early settlers gave little thought to soil conservation practices. Site productivity typically declined after several years of cultivation, and it was common practice for fields to be abandoned and new land cleared (Oosting, 1942). During the early 1900s, agriculture in the Piedmont declined and large cultivated tracts were abandoned. This resulted in a patchwork of second-growth forest communities of various ages and composition (Braun, 1950). There are few large areas of old-growth forest remaining in this region.

Young pine stands dominate much of the region. Pines aggressively colonize abandoned fields and sites disturbed by fire. Many sites that can potentially support hardwood stands are now occupied by pine and in some cases mixed hardwood-pine forest communities. (Billings, 1938; Coile, 1940; Oosting, 1942). Loblolly pine (*Pinus taeda*) and shortleaf pine (*Pinus echinata*) are common throughout most of the region. Shortleaf pine is more abundant on the drier upland sites, whereas loblolly pine is more common on lower slopes and valley bottoms because of its high tolerance for poor soil aeration. Both species, however, occur in a variety of topographic and soil conditions. Young pine forests are interrupted by narrow stream valleys supporting bottomland forest communities. River birch (*Betula nigra*), cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*) occur on areas subject to frequent flooding. Other common bottomland species are willow oak (*Quercus phellos*), water oak (*Quercus nigra*), and sugarberry (*Celtis laevigata*).

The southern Transitional Forests extend beyond the Appalachian and Ozark-Ouchita region into in eastern Oklahoma and Texas, but forest vegetation becomes less luxuriant in reponse to lower precipitation. With increasing aridity and more frequent droughts westward, trees are smaller and there are progressively fewer species. Forest cover decreases and there is a gradual transition from forest vegetation to forest scrub and grassland, and eventually to continuous grassland (Bruner, 1931). Because of the drier conditions at the western extremes of the Southern Transitional Forest, continuous forest vegetation occurs mostly in river bottomlands with the adjacent uplands occupied by grasslands. Farther west, bottomland trees also decrease in size and become more widely spaced.

15.6 Concluding Perspectives

Ranging through nearly 20º of latitude, the Appalachian region includes considerable diversity of climate, vegetation, and physical landscapes. It is an amalgam of sturctural terranes involving Precambrian and Paleozoic rocks that were shaped by several orogenic episodes and seperated collectively from Africa during the breakup of Pangea in early Mesozoic times. The region was subsequently subject to prolonged weathering, erosion, and drainage reversal, and exposed to the rigors of frequent climate change during the Quaternary glaciation in the north and periglacial conditions throughout the latitudinal range at higher elevations. Eastern North America was strongly influenced by human activity in historic times and it is not possible to understand the diverse physical landscapes of this region without considering human impacts. The vegetation was modified by Indians who burned the forests and in some areas cleared land for cultivation. Europeans had a much greater affect through land conversion to agriculture, industrial logging, and introduction of alien species, including now widely destructive insects and plant pathogens. Vegetation change has inevitably modified the variety of earth surface processes, most notably through the accelerated erosion of abandoned agricultural lands that were formerly forested (see Chapter 23). Other direct impacts have resulted from dam construction and river flood control projects, surface mining, extensive urbanization, and growth of the rural population. The physical geography of the Appalachians will continue to change, probably in more dramatic ways in the near future as the population in eastern North America and the concomitant demand for resources increase.

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Figure Captions

Figure 15.1. Physiographic regions of eastern North America.

Figure 15.2. Cross-section of the central Appalachians from the Piedmont westward to the Appalachian Plateaus.

Figure 15.3. Extent of continental glaciation, areas of permafrost, and periglacial features in eastern North America during late Wisconsin times. Source: Michelson et al., 1983.

Figure 15.4. Climate diagrams showing monthly average temperature and precipitation for representative areas in the Appalachians.

Figure 15.5. Major forest associations in the Appalachian region. Abbreviations for the Central Hardwood Forest region are: WM, western mesophytic; MM, mixed mesophytic; OC, oak-chestnut. Source: Braun, 1950.