Chapter 2. GEOLOGY, PHYSIOGRAPHY, VEGETATION AND CLIMATE*

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The northeastern part of the United States encompasses a relatively small geographic area, about 62,232,000 hectares (153,779,000 acres) or about 7 percent of the United States area. Although relatively small, this area has a diverse array of geology, physiography, vegetation, and climate. The following sections of this chapter will briefly discuss these topics.

GEOLOGY

The geologic evolution of the northeastern United States is an extremely complex series of events (Cook et al., 1980; Eardley, 1951; King, 1969, 1977; King and Beikman, 1974; Isachsen, 1980). Most of these events can be best understood in terms of plate tectonics or, as it was called in its early stages of development, continental drift.

A complete and comprehensive discussion of this subject is available in the excellent summary texts by Wilson (1976) and Bird (1980). Briefly, the concept indicates that the earth's continental landmasses are not stationary, either with respect to a fixed reference point or with respect to each other. The continental areas are thought to be rigid blocks or plates (the lithosphere) of relatively light, sialic material (silica and aluminum-rich) that "float" and move over a denser mafic (iron and magnesium-rich), less rigid mantle material (the asthenosphere).

Figure 1 illustrates a general cross-section of the earth showing upwelling zones and relative motion of the plates. Material rises from the asthenosphere, cools and forms new lithosphere. The zone in which new lithosphere is created is an active "rift zone" and the Mid-Atlantic Ridge is a classic example of one such zone. Iceland is located astride the Mid-Atlantic Ridge and its pronounced volcanic activity results from its location on a rift zone. The lithosphere descends back into the asthenosphere along subduction zones in other areas of the globe, such as along the Pacific coast of North America. Numerous earthquakes and volcanic activity occur along these zones.

Plate tectonics provides a useful model to help explain the geologic history of the northeastern United States. For example, the periods of mountain building in the Northeast can be related directly to the collision of lithospheric plates. The sequential tectonic development of the Northeast is illustrated in Figures 2, 3, and 4. These figures should be referred to during the following discussion.

The geologic history of the northeastern United States begins with the Precambrian Grenville rocks (Figure 2). The major Grenville orogenic period ended about 950 million years ago. Igneous and metamorphic rocks of Grenville age are visible in the Adirondack Mountains of northern New York state and in the anticlinorial uplifts of the Green Mountains of Vermont, the Hudson and Jersey Highlands, the Reading Prong in eastern Pennsylvania,

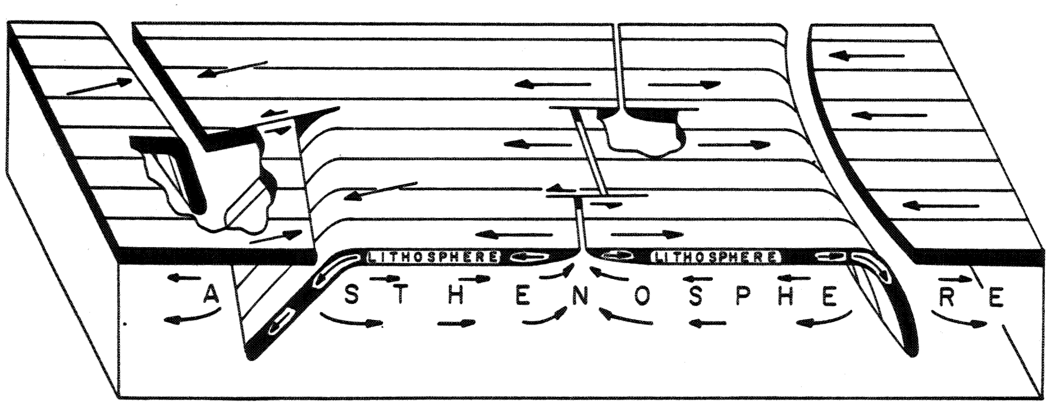

Figure 1. Generalized plate tectonic model illustrating the configuration, role, and sense of motion of the lithosphere and asthenosphere. Arrows on lithosphere indicate relative motion of adjoining blocks. Arrows in the asthenosphere show upwelling of new crust along a rift zone or active spreading center. From Isacks, Oliver and Sikes, Fig. 1, in Plate Tectonics, ed. J. M. Bird, 1980, reprinted with permission of the publisher.

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and are present as basement rocks beneath Paleozoic sediments throughout the area farther west. In Maryland and Virginia, Grenville age and late Precambrian rocks (extending to about 600 million years ago) are exposed in the Blue Ridge and Piedmont Provinces. They consist of metamorphic schists, gneisses, and intrusive igneous rocks of granitic to gabbroic composition. The Blue Ridge is composed of resistant granitic and gneissic rocks with a minor component of metamorphosed volcanic rocks (greenstones) and stands topographically above the Piedmont. In the Piedmont, a significant amount of less resistant metamorphosed Paleozoic rocks is contained within the gneissic basement. The Baltimore gneiss domes in the Piedmont of Maryland are a good example of a metamorphic basement complex upon which later Precambrian and Paleozoic sediments were deposited and subsequently metamorphosed during later orogenic events. The metamorphic and igneous rocks of the Piedmont have very complex structures indicating numerous periods of deformation.

Together, the rocks of the Piedmont and Blue Ridge record a long history which probably included repeated epochs of sedimentation, deformation, metamorphism, and intrusion. Several areas of these rocks produce economic deposits of metals. An example is the Franklin Mine in northern New Jersey which has been a major zinc producer.

The next major event in the late Precambrian history (about 750 million years ago) of the Northeast was the splitting of the continent that contained the Grenville belt, producing first a rift zone and then the proto-Atlantic ocean basin, with North America on its northwest side (Figure 3a). On the margin of the North American continent, sediments accumulated in the Appalachian geosyncline. The geosyncline is made up of a miogeosyncline which forms the continental shelf and a eugeosyncline which forms the ocean floor itself (Figure 3b). Sediments accumulated in the basin throughout Cambrian and Lower Ordovician time producing a thick accumulation of fossiliferous marine limestones and

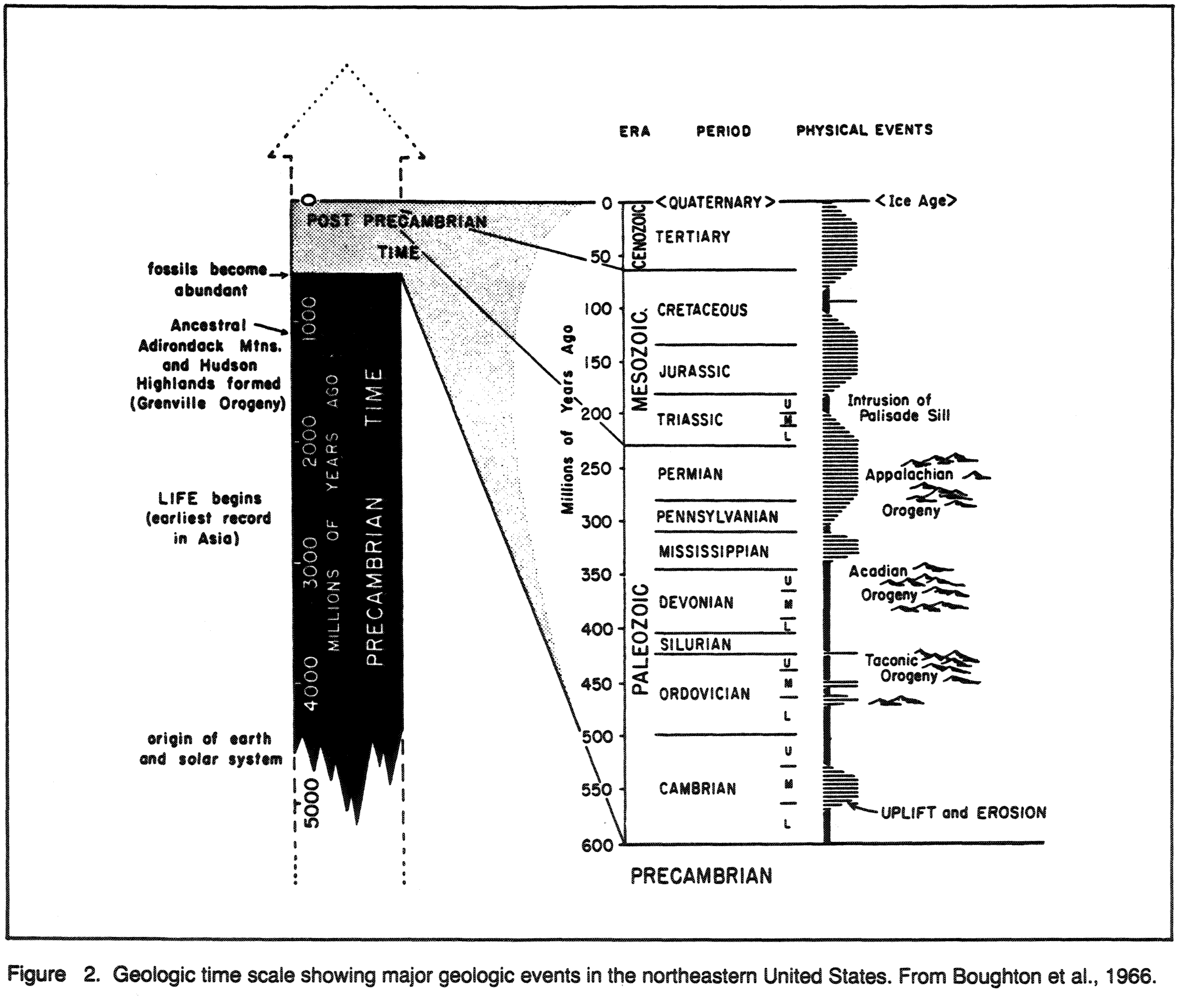

Figure 2. Geologic time scale showing major geologic events in the northeastern United States. From Boughton et al., 1966.

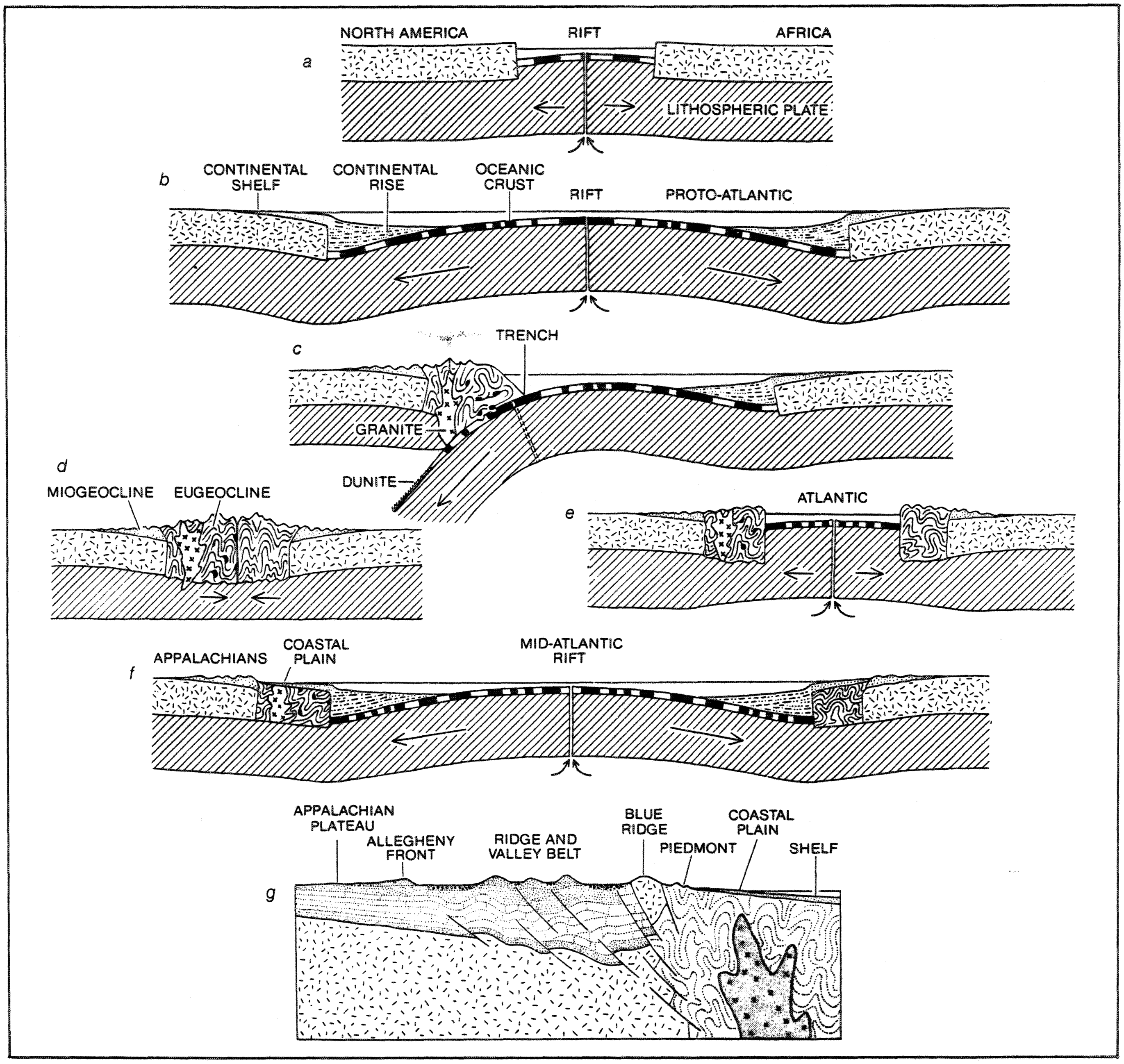

Figure 3. Mechanisms of crumpling that produced the Appalachian foldbelt based upon the hypothesis that the Atlantic Ocean has opened, closed, and reopened. In the late Precambrian (a), North America and Africa are split apart by a spreading rift, which inserts a new ocean basin. By the process of sea-floor spreading (b) the ancestral Atlantic Ocean opens. New oceanic crust is created as the plates on each side move apart. As the crust cools, its direction of magnetization takes the sign of the earth's magnetic field; the field periodically reverses, and the reversals are represented by the striped pattern. On the margin of each continent, sediments produce the geosynclinal couplet: miogeocline on the continental shelf, eugeocline on the ocean floor itself. The ancestral Atlantic now begins to close (c). The lithosphere breaks, forming a new plate boundary along the eastern portion of the present United States, and a trench is produced as the lithosphere descends into the earth's mantle and is resorbed. The consequent underthrusting collapses the eugeocline, creating the ancient Appalachians. The eugeocline is intruded with ascending magmas that create plutons of granite and volcanic mountains of andesite. The proto-Atlantic is now fully closed (d). The opposing continental masses, each carrying a geosyncline couplet, are sutured together, leaving only a transform fault (vertical black line). Sediments eroded from the mountain foldbelt create deltas and fluvial deposits collectively called molasse. North America and Africa were apparently joined in this way between 350 million and 225 million years ago (Mississippian through Permean periods). About 180 million years ago (e) the present Atlantic reopened near the old suture line (Triassic and Jurassic). Today (f) the central North Atlantic is opening at the rate of 3 centimeters per year, creating new geosynclines. An enlargement (g) of the left portion of (f) shows how the lithology and structure control the boundaries and position of the major physiographic provinces. From Wilson, 1976, reprinted with permission of the publisher.

shales, which pinch out against the stable interior platform to the west.

In Middle Ordovician time the ocean began to close and deformation occurred (Figure 3c). The deformation, called the Taconic orogeny (Figure 2), was expressed as folding, thrust faulting, uplift, gravity sliding, metamorphism, and granodioritic intrusion. The areas affected by mountain building were northern Maine, western New England and adjacent New York, northern New Jersey, and southeastern Pennsylvania. To the west in a shallow inland sea, a great delta (Queenston delta) was built reaching beyond Niagara Falls. Farther southeast in Maryland and Virginia, however, deposition was probably never interrupted. Thousands of feet of shallow-water limestones were deposited on a slowly subsiding continental shelf. These fossiliferous limestones and dolomites later would fold and erode to form much of the Great Valley of Pennsylvania, Maryland, and Virginia.

As the mountains wore down, the sea readvanced, reestablishing the continental shelf and slope in New England, probably somewhat farther east than before. During Silurian time in Pennsylvania, the Bloomsburg delta was constructed. The Bloomsburg delta is well known for its classic redbed sequence.

The Tuscarora Sandstone, which formed many prominent ridges in the Ridge and Valley area from Pennsylvania to Virginia, was deposited at the base of this thick deltaic sequence. It records a period of major tectonic uplift and clastic sandstone deposition. It is predominantly riverine in New Jersey and Pennsylvania, but becomes thin and more marine in Virginia. As with the Ordovician Taconic orogeny, this Silurian mountain-building episode was most active in the Northeast and decreased in intensity toward Virginia.

In Middle Devonian time, all of New England and the edge of New York were intensely deformed by the Acadian orogeny (Figure 2). There was extensive metamorphism and granitic intrusion, and the sea retreated. Again mountains were produced and the Catskill delta was built to the west beyond the limits of the deformed area. The sea returned to western Pennsylvania, Virginia, and Maryland for a short time during the Mississippian period; but deformation was renewed in a belt passing from southernmost New England and southwestward through eastern New York, New Jersey, easternmost Pennsylvania, and Delaware. The nearshore portion of these deltaic deposits, in eastern New York and Pennsylvania, is composed of coarse grained sandstones and conglomerates. These quartz-rich rocks are very resistant to erosion and are the cause of the high relief in the Catskill Mountains and Pocono Plateau. In Maryland and Virginia this period was marked by pronounced intrusion of deep-seated igneous rocks and metamorphism in the Piedmont. West of the coarse deltaic sediments, deposition of finegrained sandstone, shales, and limestones continued throughout the Devonian time.

During the Pennsylvanian period, sedimentation rates varied markedly on the deltas. Periodic marine transgressions and regressions occurred and extensive peat swamps developed on the deltaic deposits. Much of the change in sea level that caused the transgressions was due to glaciation on adjacent land masses. The Carboniferous period takes its name from the numerous coal beds that formed from the peat swamps. Erosion has removed much of the Pennsylvanian record, but large areas of coal still occur in Pennsylvania, West Virginia, western Virginia, and Maryland, and to a lesser extent in Massachusetts and Rhode Island.

A major deformation occurred about the end of the Pennsylvanian time and in the Permian (Appalachian or Allegheny orogeny), producing the "typical Appalachian" folds of Pennsylvania, Virginia, and Maryland. The Allegheny orogeny also caused folding, metamorphism, and granite intrusion in New England. At this time the proto-Atlantic was completely closed (Figure 3d) by the collision of the North American, European, and African continents which were then welded (sutured) together to form the supercontinent, Pangea (Figure 4). This continental collision caused the igneous and metamorphic rocks of the Blue Ridge to be thrust westward up and over the sedimentary rocks of the Valley and Ridge. This area currently is called the Eastern Overthrust Belt and is a prime target for oil and gas exploration today.

The next well-documented event was one of mild warping and faulting accompanied by fluvial, alluvial fan, dark lacustrine sedimentation, and some volcanism in rift valleys from the Connecticut River basin in Massachusetts and Connecticut to the Culpepper and Richmond basins in Virginia (Figure 5). Tension in the earth's crust that resulted from the pulling apart of the North American, African, and European continents created the faults which bound these basins. Volcanic rocks were intruded along these tensional features. Though these deposits have long been called "Triassic," they are now known to range in age through Late Triassic and Early Jurassic.

At the same time or, more likely a little later in the Jurassic, the present Atlantic Ocean began to open (Figures 3e and 4). A large group of volcanic calderas, centered in the present area of the White Mountains of New Hampshire but with outliers in adjacent states, also were associated with the opening of the Atlantic. The associated igneous rocks, both intrusive and extrusive, are markedly alkalic. Marine waters eventually transgressed the eastern margin of the North American continent, and the present continental shelf, slope, and rise developed. The oldest dated rocks at the bottom of the pile of shelf sediments are Jurassic, and are a thick sequence of evaporated beds of salt. However, the oldest visible rocks on the present coastal plain are lower Cretaceous in age. Southern New Jersey, Delaware, eastern Maryland and eastern Virginia are underlain by undeformed, gently seaward-dipping, marine Cretaceous and Cenozoic shelf deposits (Figures 3f, 3g, and 7). In Cretaceous and early Tertiary (Eocene) time the present Coastal Plain area was

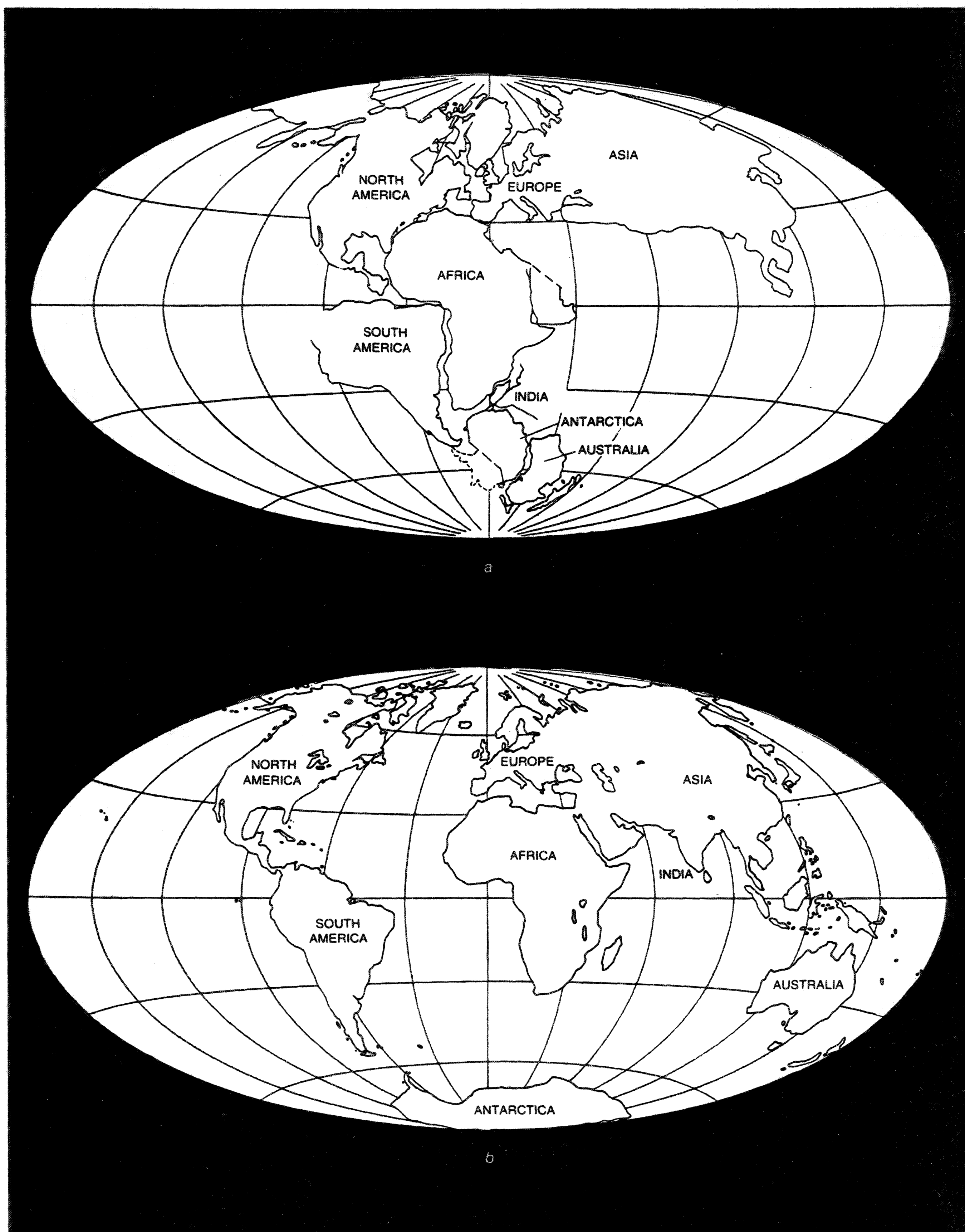

Figure 4. An ancient supercontinent called Pangea incorporated all the earth's large land masses at the end of the Paleozoic (a). For comparison, a map of the world as it appears today is shown (b). From Wilson, 1976, reprinted with permission of the publisher.

submerged and sediments accumulated. By late Tertiary (Miocene) time, about 20 million years ago, the Coastal Plain had been uplifted and was half its present width, and by the late Quaternary (Holocene) time the present shoreline had developed. Within the Coastal Plain many old beach ridges still can be recognized as long linear features with well-drained sandy soils, while the old offshore, finer-grained marine units tend to form valleys which control the present day drainage.

With the exception of the Coastal Plain, the northeast region was being eroded in late Mesozoic and Cenozoic times; yet the Appalachian region today stands moderately high and must have been differentially uplifted. Whether the region was ever completely worn down to a peneplain and then rejuventated (and, if so, how often) and whether the uplift was broadly continuous or spasmodic, are matters of debate.

The last major geologic event in the northeast region was the Pleistocene (early and middle Quaternary) continental glaciation. Much of the Pleistocene geology is summarized by Flint (1971). Continental ice covered a large part of the region and only central and southern New Jersey, the bulk of Pennsylvania, Virginia, and West Virginia were spared (Figure 5). The ice advanced and retreated many times, leaving terminal moraines which record two major Wisconsinan (late Pleistocene) advances and at least two older pre-Wisconsinan advances. The falling and rising of sea level, that accompanied the advance and retreat of the glaciers, alternately exposed the continental shelf and flooded the coastal areas from New Jersey to Virginia. The last ice retreat is well recorded by glacial till which was spread unevenly over the glaciated area, disrupting the drainage and producing the many lakes of New England and New York. Near the retreating ice, stratified drift was deposited in rivers, lakes, and the sea. Much of the constructional topography still is evident along the New England coastline where end moraines control the configuration of Long Island and Cape Cod (Figure 6). For a time during the Pleistocene, the sea covered much of coastal Maine and penetrated the St.

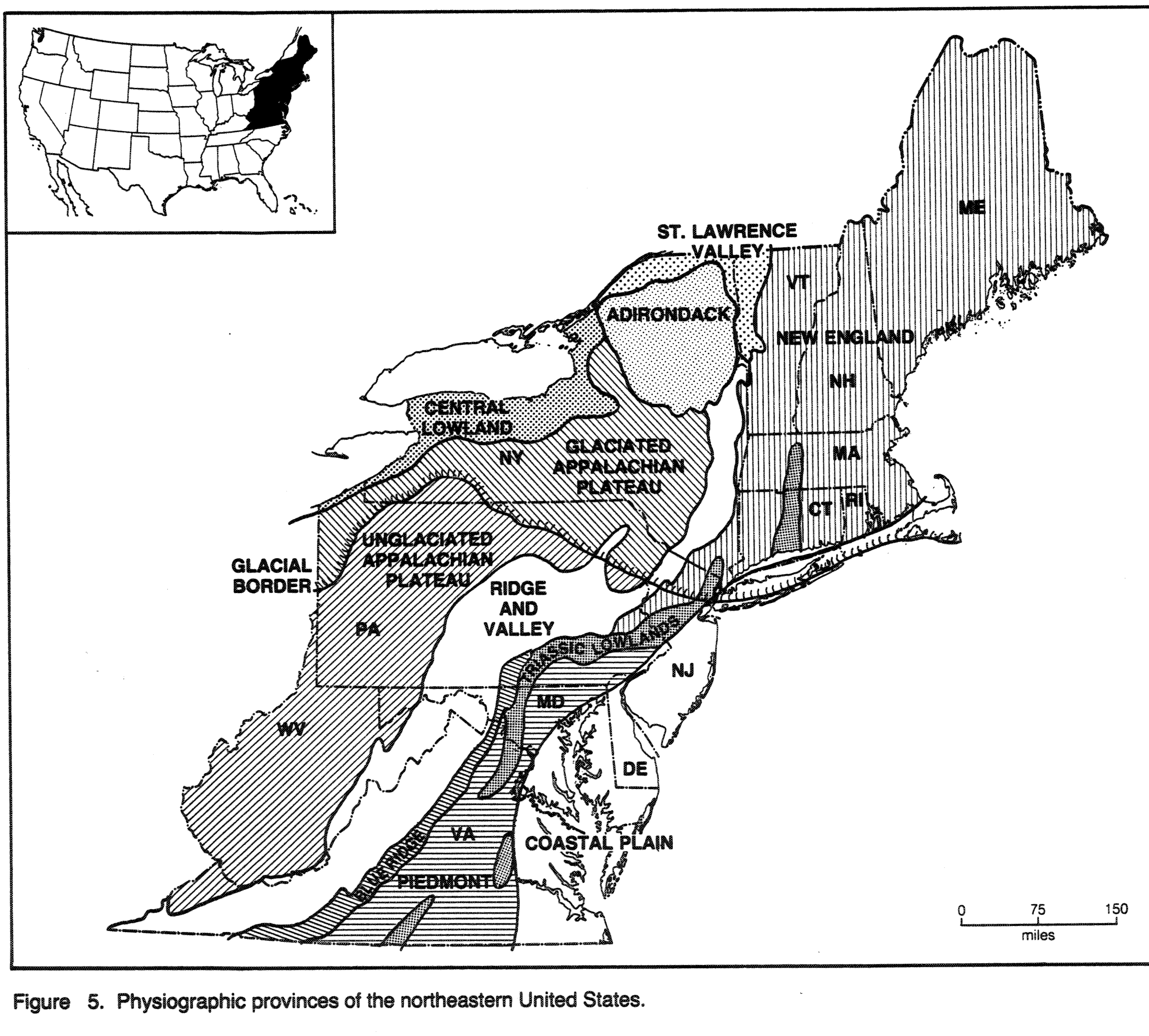

Figure 5. Physiographic provinces of the northeastern United States.

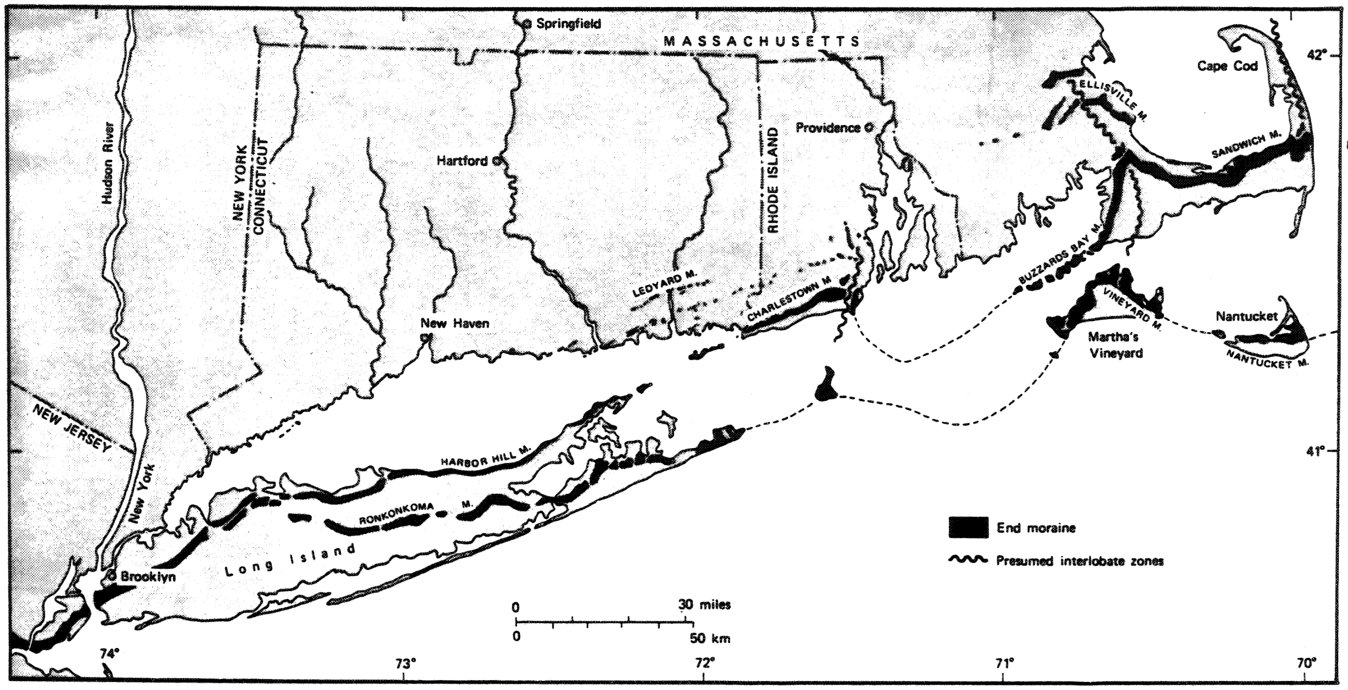

Figure 6. Map showing known end moraines between Hudson River and Cape Cod. From Flint, Fig. 22.2, 1971, reprinted with permission of the publisher.

Lawrence Valley to Lake Champlain and northern New York state, until glacial rebound caused its recession.

South of the glacial border, significant changes also were occurring during the Pleistocene. Periglacial conditions extended many hundreds of miles south of the glacial ice, particularly at higher elevations. Features produced by periglacial processes, such as patterned ground, involutions, ice wedge casts, grezes litees, and boulder fields, have been reported (Clark, 1968; Ciolkosz, 1978; Ciolkosz et al., 1979) to have formed during this time. Although these features are of interest, the occurrence of solifluction colluvial deposits over extensive areas (25 percent of an average county in the ridge and valley area of Pennsylvania) indicate that the surfaces of large areas were modified greatly during this time. In addition, these deposits indicate that a considerable amount of landscape modification occurred during the Pleistocene.

PHYSIOGRAPHY

When the North American, European, and African continents suffered the catastrophic collision about 250 million years ago, described in the previous section, sediments that had accumulated in the ancestral or proto-Atlantic were squeezed, folded, and thrust-faulted to create the Appalachian Mountain backbone of eastern North America. During the long intervening period up to the present, fluvial erosion and to a lesser extent glacial erosion, have etched out the zones of highly fractured rocks, faults, thrusts, and less resistant lithologies and have left the more resistant lithologies to stand as the accordant summits and monadnocks of the central and northern Appalachians.

The northeastern region has a wide variety of topographic forms. Some areas have similar characteristics or topography that tend to be elongated and subparallel to the Atlantic seaboard (Figure 5) and confined to zones of distinct structure and lithologic association (Figures 3g and 7). As a result of this unique relationship between topography, structure, and lithology, these regions have become known as physiographic provinces.

In the following sections a general discussion of the physiography (after Harrison, 1970; Hunt, 1967, 1974; Raisz, 1957; Thornbury, 1965; Denny, 1981) of the Northeast will be presented. The discussion will be limited to the features of these physiographic provinces found in the northeast region. Information on the character of these provinces in other regions should be obtained from the cited references.

Appalachian Plateau

The stable, interior region of the continent represented by the Appalachian Plateau Province extends from southern New York southwestward through West Virginia. The region is an elevated plateau that ranges from about 304 meters (1,000 feet) in elevation at its western edge to at places more than 912 meters (3,000 feet) at its eastern edge. The thickness of sedimentary rocks (predominantly interbedded sandstones, shales, conglomerates, and some coals) of Paleozoic age increases markedly from 3,950 meters (13,000 feet) near the western boundary to over 9,120 meters (30,000 feet) in central Pennsylvania. The plateau consists of a series of gently dipping rock units

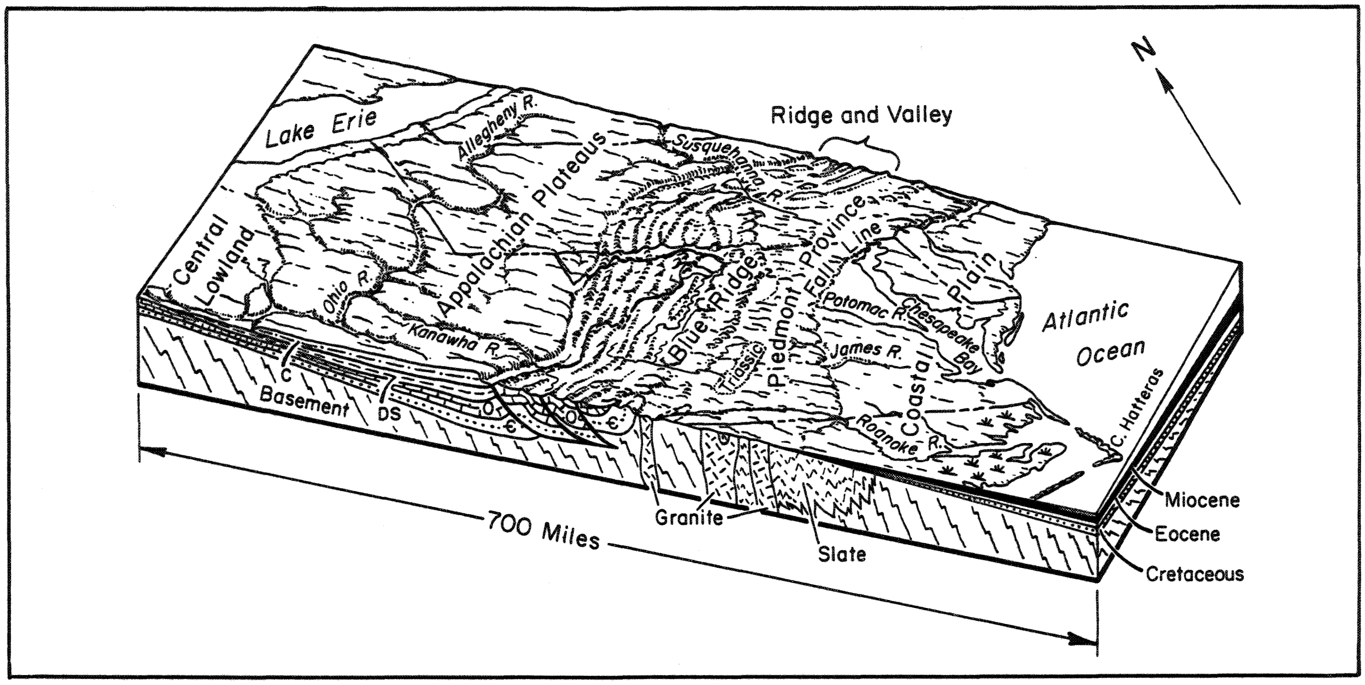

Figure 7. Structural and lithologic framework of the physiographic provinces in the central part of the northeastern United States. C, Cambrian; O, Ordovician; DS, Devonian Silurian; C, Carboniferous (Mississippian and Pennsylvanian). From Hunt, Fig. 11.3, 1974, reprinted with permission of the publisher.

arranged in the shape of a saucer. The deepest part of this structural basin, the Dunkard Basin, is centered in southwestern Pennsylvania and West Virginia. The rocks of the central basin mainly are thick red, montmorillonitic shales and interbedded sandstones that produce some of the most landslide-susceptible slopes in the Appalachians. In the eastern part of the plateau in southern New York, central Pennsylvania, and northern West Virginia, the formations are compressed into very gentle, northeast-trending folds which are the site of numerous oil and gas fields. These folds are a belt of transition from the plateau into the more intensely folded Ridge and Valley Province.

The plateau is bounded on all sides by outfacing escarpments which reflect its regional synclinal basin structure. The eastward facing escarpment, the Allegheny Front, forms the boundary between the Plateau and the Ridge and Valley area to the east. This feature forms one of the most persistent and striking topographic breaks in the United States (Hunt, 1967). The plateau has undergone considerable dissection, with the dissection generally being greater in the eastern area along faults, fractures, and zones of weakness. Although the greatest dissection is in the eastern area, along major rivers or streams in the central and western areas, the plateau also is deeply dissected.

Dendritic drainage patterns resembling the branches of a tree are typical of flat-lying sedimentary rocks and are well developed on the Appalachian Plateau. The drainage pattern is quite distinct from the trellis or rectangular pattern that has developed in the Ridge and Valley Province. In fact, maps showing only the drainage patterns of those two areas would provide sufficient information to distinguish the two provinces. The northern part of the Plateau in New York and Pennsylvania has been glaciated. The northern and western part of the glaciated plateau show the greatest amount of glacial erosion, deposition of till and valley filling, while the southcentral and southeastern areas show much less topographic modification.

Ridge and Valley Province

The folded and thrust-faulted Appalachian structural zone is the geomorphic Ridge and Valley Province. This zone is located just to the east of the Appalachian Plateau and extends from northern New York through Virginia. Its physiography is distinct from that of the plateau. It is the region of flat-topped, parallel or subparallel ridges and valleys that are carved out of anticlines, synclines, and thrust sheets. Local relief varies from 305 to 610 meters (1000 to 2000 feet). It often is termed the newer Appalachians, in contrast to the older Appalachians which include the Piedmont and Blue Ridge Provinces.

Most rocks of the Ridge and Valley Province are Paleozoic sediments ranging in age from Cambrian to Pennsylvanian. Their resistance to erosion varies greatly and has a major effect upon the topography. The Ridge and Valley area contains two levels of topography. The ridge crests appear to be accordant (at the same height), and are composed primarily of resistant sandstone and conglomerate bedrock. The valleys are underlain by less resistant shales and limestone. For example, the broad lowland of the Great Valley in Pennsylvania is composed of nonresistant Cambrian and Ordovician limestone and shales which characteristically produce fertile soils. The even-crested ridgetops and the uplands of the valley floors are thought to represent old erosional surfaces called peneplains (Johnson, 1931). It also has been proposed that different rock types produce surfaces of different elevations simply because of their differences in resistance, and therefore they do not record former peneplains (Hack, 1960). Regardless of their origin, the valley floors are not even plains. They are marked by significant stream dissection. Thus, most valley floors show a distinctive rolling topography with 30 to 90 meters (100 to 300 feet) of relief.

The topographic grain of the Ridge and Valley is predominantly northeast-southwest. Most streams and rivers follow this grain in the limestone and shale valleys. They break through the resistant sandstone ridges in spectacular water gaps, such as the Delaware Water Gap in eastern Pennsylvania. Many of the water gaps are located along zones of intense fracturing, termed lineaments. These short stretches through the ridges usually are oriented at right angles to the grain of the topography. This produces the trellis drainage pattern which is so characteristic of the Ridge and Valley.

The region is narrow in the north (22 kilometers, 14 miles, at the New York-New Jersey border) and it widens southward in Pennsylvania and Virginia (122 kilometers, 75 miles). One small area in Pennsylvania, New York, and New Jersey has been glaciated. In this area, in addition to the deposition of glacial till and outwash, lacustrine and marine materials were deposited, particularly in the section in northern New York.

Blue Ridge Province

The Blue Ridge Province extends from southern Pennsylvania through Virginia. The province gets its name from the Blue Ridge in Virginia which is a narrow mountainous ridge extending from the Potomac River to Roanoke. The famous Skyline Drive in Virginia is situated on the Blue Ridge. The Blue Ridge begins in southern Pennsylvania as the Carlisle prong, and ranges in width from 8 to 48 kilometers (5 to 30 miles). It is composed of primarily Precambrian granite, gneiss, and metamorphic volcanic rocks older than the folded Appalachians to the west, and often is referred to as the older Appalachians or Appalachian Highlands. The rocks are deformed intensely. Along its western edge the sedimentary rocks of the Ridge and Valley are turned up steeply, often along a fault contact which forms a sharp structural boundary between the two provinces. The rocks of the Blue Ridge are very resistant to erosion and have conspicuous relief, rising 305 to 610 meters (1,000 to 2,000 feet) above the Great Valley to the west and the Piedmont to the east.

Piedmont Province

The Piedmont Province extends from the Hudson River in the north through Virginia. It is composed primarily of Paleozoic metamorphic (schists and gneisses) and plutonic rocks (granites). Locally, belts of quartzite and pure marble are well developed. A belt of basic rocks containing talc and soapstone is present near the western boundary.

The Piedmont widens from about 16 kilometers (10 miles) in New York to about 190 kilometers (125 miles) at the Virginia-North Carolina border. Its topography is rolling, with relatively low relief varying from 15 to 90 meters (50 to 300 feet). Numerous hills or monadnocks rise 61 to 305 meters (200 to 1,000 feet) above the general surface. The rocks are intensely folded but beveled by an undulating erosional plain.

Within the Piedmont, various places in New Jersey, Pennsylvania, and Virginia have low lying areas of Triassic age sedimentary and intrusive, basic (high content of magnesium and calcium), igneous rocks. These Triassic basins are distinct from the other Piedmont rocks. The Triassic rocks exhibit gentle dipping in contradistinction to the gneisses and schists, and are cut by numerous faults. The sedimentary rocks are primarily red shales and sandstones which are intruded by diabase dikes and sills. The diabase is more resistant to erosion and tends to form ridges and higher areas surrounded by the sedimentary rocks. The outcome of the historic battle at Gettysburg was determined by the position of the Union Army on the high ground of one of the diabase sills. The diabase often is referred to as trap rock, from the German *treppen,* meaning step; and is used as an aggregate in road construction.

To the east, the Piedmont gives way to the Atlantic coastal plain where the crystalline rocks are overlapped by the flat-laying Cretaceous and Tertiary sediments. The boundary between the Piedmont and Coastal Plain is marked by the Fall Line, the location of falls along all major rivers crossing the Piedmont. The boundary also is a zone of mild earthquakes.

New England Province

The New England Province is essentially a northward extension of the Blue Ridge and the Piedmont. The geology of the Blue Ridge extends into the New England region through the Reading Prong (the Precambrian rocks extending from New England through New Jersey and into eastern Pennsylvania), the Berkshire Hills, and Green Mountains. The remainder of the New England area is composed of gneiss, schist, slates, and plutonic granites of an age similar to that of the Piedmont.

The major difference between the Piedmont and the New England area is that the New England area has been extensively glaciated. The effects of the glacial erosion are conspicuous. Much smoothing of the bedrock occurred during glaciation, but because of the hard crystalline nature of the bedrock, only thin patchy tills with many boulders were deposited. Also, as in the Northern Ridge and Valley area, there were extensive lacustrine materials deposited in the Connecticut River Valley as well as marine deposits along the coast of Maine. The topography of the New England area varies from a low relief of rolling glacial plain in its southern areas near the coast to more rugged areas of higher relief inland from the coast.

Like the Piedmont to the south, the New England Province has Triassic age basins. The largest basin is found in the Connecticut River Valley of Connecticut and Massachusetts (Figure 8). The glacial deposits derived from these deposits are much different than those derived from the gneisses, schists, and granites that are the bedrock in most of the New England area. The deposits tend to have more coloring and to have a different mineralogical composition.

Coastal Plain Province

The Coastal Plain, extending from Cape Cod in Massachusetts through Virginia, is a low-lying seaward-sloping plain found just east of the Piedmont. Relief generally is less than 150 meters (500 feet). North of Cape Cod the plain is submerged and is a part of the continental shelf. The geologic formations forming the surface of the Coastal Plain are Cretaceous, Tertiary, and Quaternary in age. The formations dip gently seaward (Figure 7) and outcrop as belts forming crests and valleys roughly parallel to the inner and outer edges of the Coastal Plain. The Cretaceous system forms an inland belt, the Tertiary an intermediate belt, and the Quaternary a coastal belt. These sediments are primarily sandy, but many silty and clayey sediments also occur. The Coastal Plain of the eastern United States has been subdivided into sections and within the Northeast region the Coastal Plain has been named the Embayed section. The most outstanding geomorphic feature of this section is the bays formed due to submergence of the Northern Coastal Plain area. The submergence reaches as far south as the James River in Virginia, where tidewater reaches the Fall Line. The submergence was the combined result of the depression of northeastern North America under the Pleistocene glacial ice, and the postglacial rise in sea level as the glaciers melted. Submergence was greater at the north than at the south, as evidenced by a decrease northward in the width of the Coastal Plain. This submergence created the Chesapeake and Delaware embayments by drowning the lower ends of the Susquehanna and Delaware rivers.

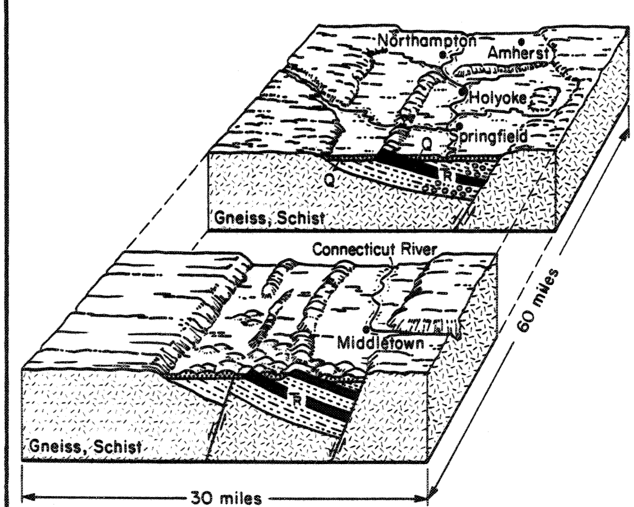

Figure 8. Block diagram illustrating the structure of the Triassic basin of the Connecticut River Valley. The basin is a half-graben because only one side is fault-bounded. Cross-hatched units are diabase, circles are conglomerates, dots are sandstones, and dashes are shales. From Hunt, Fig. 11.19, 1974, reprinted with permission of the publisher.

There are many distinctive levels, called terraces, on the Coastal Plain. The older levels adjacent to the Fall Line stand higher in elevation than the younger levels nearer the coast. The older levels also show a much greater degree of dissection and erosion. There tends to be a progression from the higher older levels to the lower younger levels of less dissection and flatter landscapes. The very lowest levels that are near sea level are characterized by many swamps and large areas of poorly drained soils.

Adirondack Province

The Adirondack Province is found in northern New York and is one of the two extensions of Canadian Shield geology found in the United States; the other extension is the Superior Upland in Wisconsin. The Adirondack Province is a nearly circular structural dome more than 160 kilometers (100 miles) in diameter. The center of the dome has been uplifted more than 3.2 kilometers (2 miles). The bedrock of the Adirondacks is made up primarily of Precambrian igneous (granite) and metamorphic (quartzites, schists, and gneisses) rocks. Topographically, the Adirondacks are divided into central highlands and northwest lowlands. Many peaks in the highlands exceed 1,200 meters (4,000 feet) in elevation and local relief may be as much as 915 meters (3,000 feet). Like the remainder of New York, the Adirondacks were glaciated and glacial cirques are present on many of the higher peaks.

Central Lowland Province

The Central Lowlands encompass the relatively flat areas north of the Appalachian Plateau and west of the Adirondacks. From the lake level of Lake Erie, 175 meters (570 feet), and Ontario, 64 meters (244 feet), the land rises gently eastward and southward to an elevation of 305 to 450 meters (1,000 to 1,500 feet) at the Appalachian Plateau. The preglacial surface topography of this area has been modified greatly by the deposition of glacial till in the form of drumlins, moraines, and shoreline deposits.

St. Lawrence Valley Province

The St. Lawrence Valley is a small lowland area with some low hills (relief of about 30 meters, 100 feet) found north and east of the Adirondacks. It, like the central lowland area, has been greatly affected by lacustrine deposits as well as marine deposits caused by glaciation. The marine deposits accumulated in late glacial time and are a part of a much larger accumulation that was deposited from an arm of the ocean that flooded the St.

Lawrence Valley. Much of the earthquake activity of the northeastern United States is located in this province.

VEGETATION

The natural vegetation of the northeastern area is predominantly forest. Broadly speaking, there are five forest regions: spruce-fir, beech-birch-maple, white pine-hemlock-hardwood, oak-yellow poplar, and yellow pine-hardwood (Figure 9).

The spruce-fir region occurs in the coolest parts of the Northeast: central and northern Maine, the White and Green Mountains, the Adirondacks, and on mountain tops in West Virginia. This region is a dense evergreen forest with a few deciduous trees. Red, white, and black spruces and balsam fir predominate. Sugar maple, yellow birch, and beech prevail in some areas where changes in land use have modified the forest composition. White cedar may predominate in swamps, and white pine is common on many sandy sites.

The northern hardwood region (beech-birch-maple) has tall, broad-leaf, deciduous forest stands with a mixture of needleleaf evergreens. Predominant hardwoods are beech, yellow birch, and sugar maple. Also found in the region are stands of hemlock, sweet birch, red maple, basswood, white ash, northern red oak, and black cherry. Aspen, pin cherry, or paper birch may take over after a stand cutting and/or a fire. Spruce and fir intrude on poorer, colder sites and white pines and oaks may prevail on sandy soils. Black spruce and Northern white-cedar are common in swamps.

Northern red oak probably is the most widely distributed hardwood in the white pine-hemlock-hardwood region. Other oaks, hickory, and yellow poplar are found in the southern part of this zone. In the northern and higher areas, hardwoods typical of the beech-birch-maple region are common. White pines may occur in old fields or pastures, hemlock in ravines, and pitch pine on sandy areas. Swamp composition consists of red maple, black ash, elm, spruce, or Atlantic white-cedar in coastal sections.

Characteristic stands within the oak-yellow poplar region vary greatly because of differences in elevation, latitude, and soil properties. In the hills of West Virginia, Virginia, Pennsylvania, or Maryland, the characteristic oak species are black, white, chestnut, scarlet, and

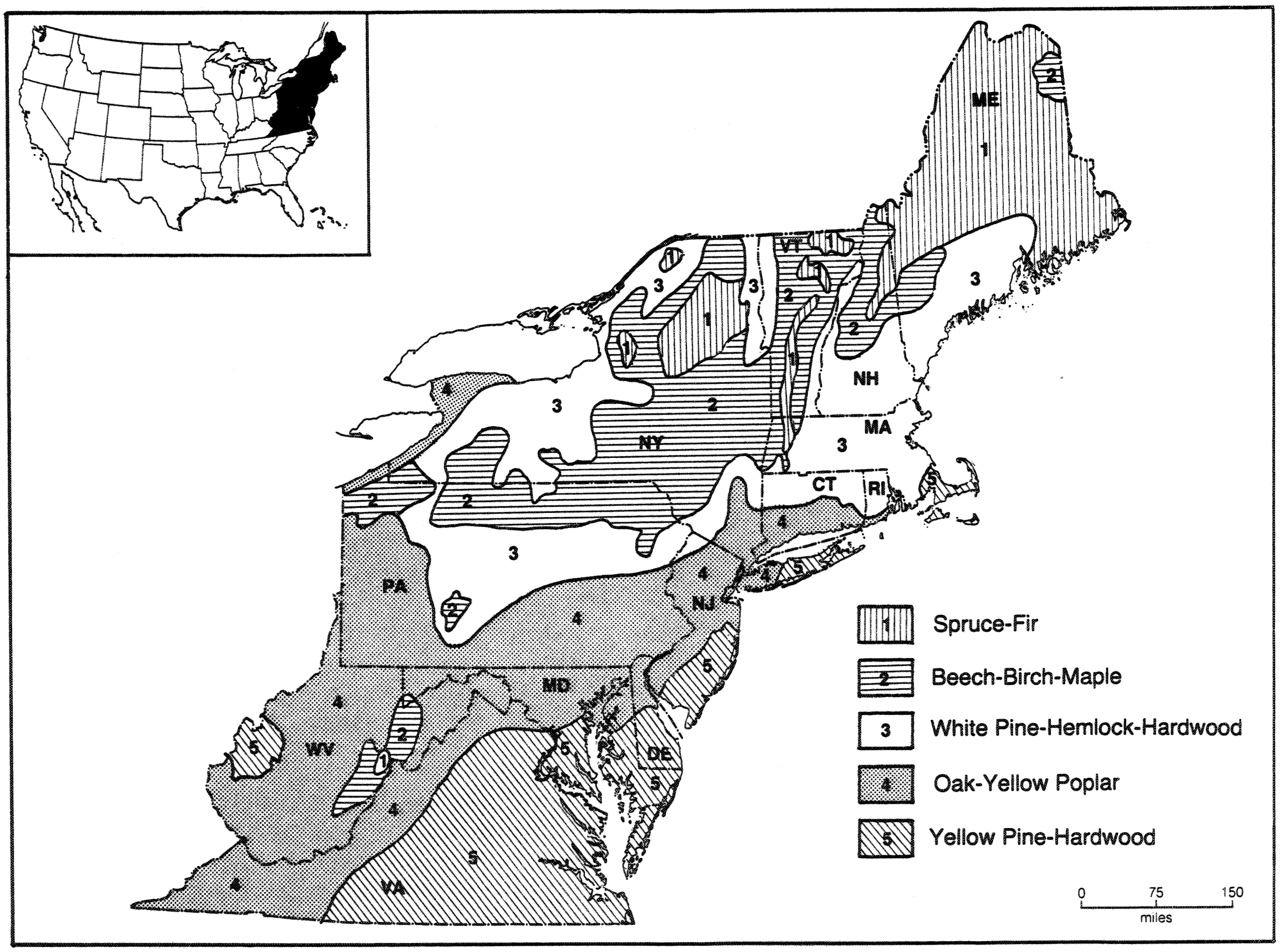

Figure 9. Major vegetation regions of the northeastern United States. From Kuchler, 1964; Lull, 1968.

northern red. In some sections of the lower Piedmont of Maryland or sections of northern New Jersey, nearly pure stands of yellow poplar are common. The pin, swamp, chestnut, and willow oaks, and sweetgum are characteristic on clayey soils of the upper Coastal Plain. Intrusions from other regions also can be found in localized areas and on the borders of this region.

The yellow pine-hardwood region has stands of medium tall to tall needleleaf evergreen as well as broadleaf deciduous forest stands. The characteristic pines of the region are pitch, loblolly, shortleaf, Virginia, and pond. Except for a small region in West Virginia, the yellow pine-hardwood region closely approximates the coastal plain areas and the Piedmont of Virginia. Yellow pines include pitch, loblolly, shortleaf, Virginia, and pond. Virginia and pitch pines predominate in West Virginia, as do pitch and shortleaf pines in New Jersey. In southern Maryland the major species is Virginia pine.

A wide range of hardwood species is found in association with the yellow pine. Species that commonly occur are hickory, white oak, post oak, red maple, and blackgum. Atlantic white cedar is common in the coastal swamps. Tupelo and bald cypress also are common on floodplains and in swamps in lower Delaware, eastern Maryland, and southeastern Virginia.

The forest species discussed in the previous paragraphs are the major species growing in the Northeast. However, variations can be noted throughout the region. Forest fires, clear cutting operations, and land-use histories have changed the composition of some forest stands.

CLIMATE

The climate of the northeastern states is extremely varied because of the differences in elevation, topography, and nearness to large bodies of water. The Appalachian Mountains have a major effect on the climate of the region. The Atlantic Ocean also has a modifying effect but it does not dominate the climate. Cold fronts moving in from the west are forced upward along the western slopes of the mountains. This orographic lifting is sufficient to cause a considerable amount of rainfall during the warm months and heavy snowfall during the winter (Baldwin, 1973). A similar effect occurs on the eastern slopes when fronts or storms move northward or westward from the Atlantic Ocean.

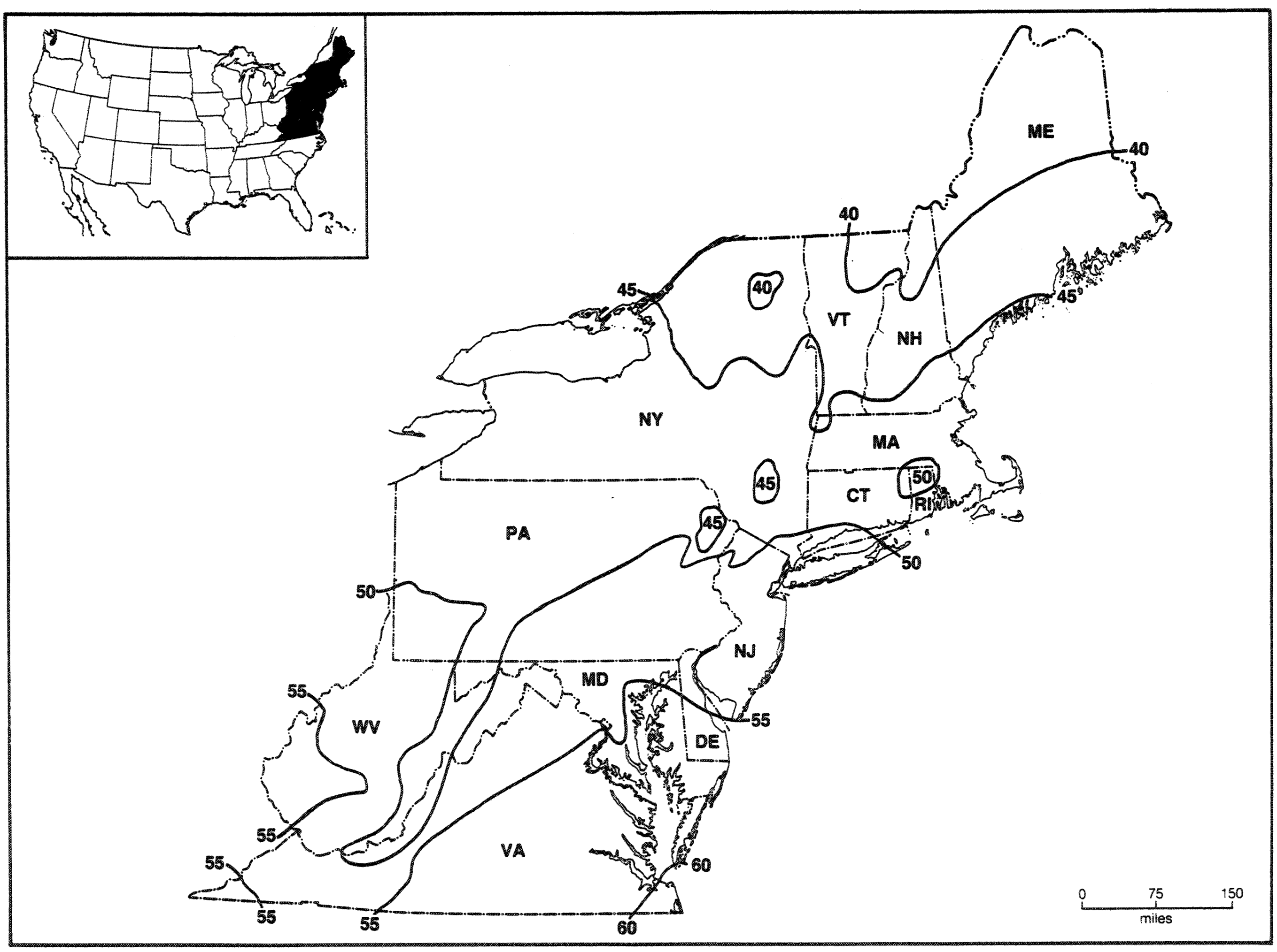

Figure 10. Average annual air temperatures of the northeastern United States. Presented in degrees Fahrenheit, convert to degrees centigrade by subtracting 32 then multiplying by 0.555. From USDA, 1941.

The climate of the region generally is characterized by the following statements (Ruffner, 1978):

1. An equal distribution of precipitation among the four seasons.
2. Large ranges in both daily and annual temperatures.
3. Great differences during the same season or same month of different years.
4. Considerable diversity of the weather over short periods of time.

The growing season, based on the number of freeze-free days (temperatures above 0°C, 32°F), ranges from less than 100 days in extreme northern Maine, New Hampshire, Vermont, and New York to over 220 days in southern Maryland and parts of Virginia (Ruffner, 1978). Because of the modifying effects of the ocean, coastal regions have longer growing seasons than the interiors of the states. The growing season for the coastal area of Maine ranges from 140 to 160 days. All other states along the coast have maximum growing seasons ranging from 180 to 200 days. Average annual air temperature of the region is shown in Figure 10.

Mean annual precipitation varies widely because of factors already mentioned (Figure 11). Snowfall also is quite variable within each of the states. In West Virginia, the average snowfall ranges from 50 centimeters (20 inches) at some of the lower elevations to over 254 centimeters (100 inches) at the highest. Snowfall in New Hampshire varies from 127 centimeters (50 inches) near the coast to 470 centimeters (185 inches) on Mt. Washington.

Cryic, frigid, and mesic soil temperature regimes are recognized in the Northeast (Smith, 1984). Recent data (Carter and Ciolkosz, 1980) show some central Appalachian regions probably have areas of frigid soils where none has been mapped.

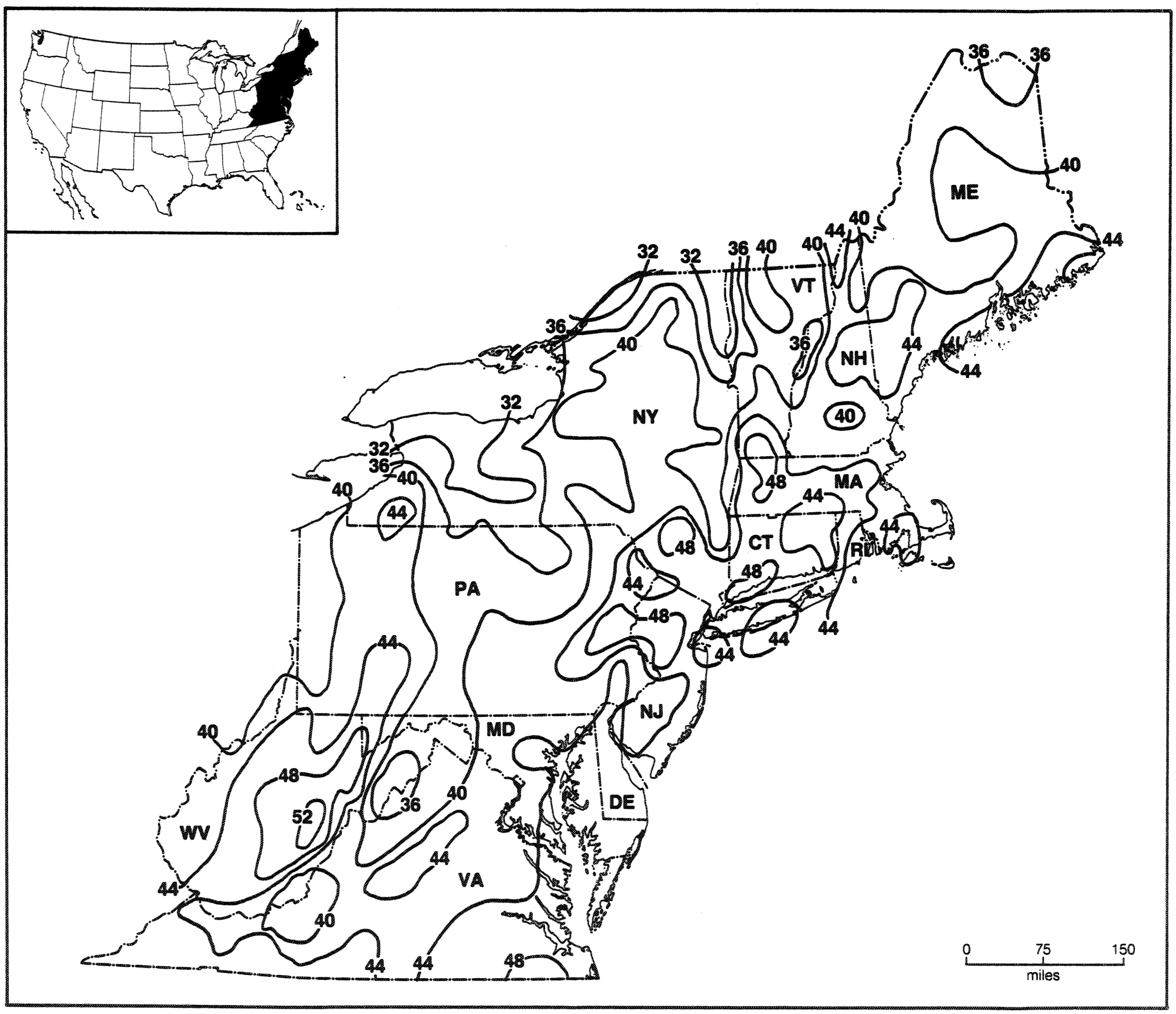

Figure 11. Mean annual total precipitation of the northeastern United States. Presented in inches, multiply by 2.54 to obtain centimeters. From Lull, 1968; Ruffner, 1978.

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