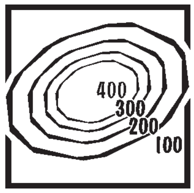

Chapter 4: Topography of the Southeastern US

Does your region have rolling hills? Mountainous areas? Flat land where you never have to bike up a hill? The answers to these questions can help others understand the basic topography of your region. The term **topography** is used to describe the changes in elevation over a particular area and is, generally speaking, the result of two processes: deposition and **erosion**. These processes can occur over an enormous range of timescales. For example, a flash flood can erode away tons of rock in a matter of hours, yet which rock is broken down and which remains can depend on how it was formed hundreds of millions of years ago. In the Southeast, topography is intimately tied to **weathering** and erosion as well as to the type and structure of the underlying bedrock, but it is also a story of **plate tectonics**, volcanoes, folding, **faulting**, **uplift**, and mountain building.

The Southeast's topographic zones are under the influence of the destructive surface processes of weathering and erosion. Weathering includes both the mechanical and chemical processes that break down a rock. There are two types of weathering: physical and chemical. Physical weathering describes the physical or mechanical breakdown of a rock, during which the rock is broken into smaller pieces but no chemical changes take place. **Wind**, water, temperature, and pressure are the main media by which physical weathering and erosion occur. Streams are constantly eroding their way down through bedrock to sea level, creating valleys in the process. Given sufficient time, streams can cut deeply and develop wide flat **floodplains** on valley floors. Streams, oceans, and ice also deposit the material they erode, creating new topographical features elsewhere. The pounding action of ocean waves on a coastline contributes to the erosion of coastal rocks and sediments, while the emptying of a river can lead to the formation of a **delta**.

Pressure release can cause rocks to crack. Growing plant roots can exert many pounds per square inch of pressure on rocks—think of **tree** roots uplifting and cracking a sidewalk. Additionally, since rocks buried miles beneath the surface are under considerable pressure, if those rocks become exposed at the Earth's surface (where the rock is under less pressure), the rock may expand and crack in a process called **exfoliation** (*Figure 4.1*). Ice can also change the landscape due to frequent episodes of freezing and thawing, causing both temperature and pressure differentials within a rock. On a small scale, as water trapped in **fractures** within the rock freezes and thaws, the fractures continue to widen (*Figure 4.2*). This alone can induce significant breakdown of large rock bodies.

topography • *the landscape of an area, including the presence or absence of hills and the slopes between high and low areas.*

erosion • *the transport of weathered materials.*

weathering • *the breakdown of rocks by physical or chemical means.*

plate tectonics • *the process by which the plates of the Earth's crust move and interact with one another at their boundaries.*

fault • *a fracture in the Earth's crust in which the rock on one side of the fracture moves measurably in relation to the rock on the other side.*

uplift • *upward movement of the crust due to compression, subduction, or mountain building.*

CHAPTER AUTHORS

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4 Topography

Review

mineral • *a naturally occurring solid with a specific chemical composition and crystalline structure.*

climate • *a description of the average temperature, range of temperature, humidity, precipitation, and other atmospheric/hydrospheric conditions a region experiences over a period of many years (usually more than 30).*

limestone • *a sedimentary rock composed of calcium carbonate ($CaCO_3$).*

marble • *a metamorphic rock composed of recrystallized carbonate minerals, most commonly calcite or dolomite.*

carbonate rocks • *rocks formed by accumulation of calcium carbonate, often made of the skeletons of aquatic organisms.*

cementation • *the precipitation of minerals that binds together particles of rock, bones, etc., to form a solid mass of sedimentary rock.*

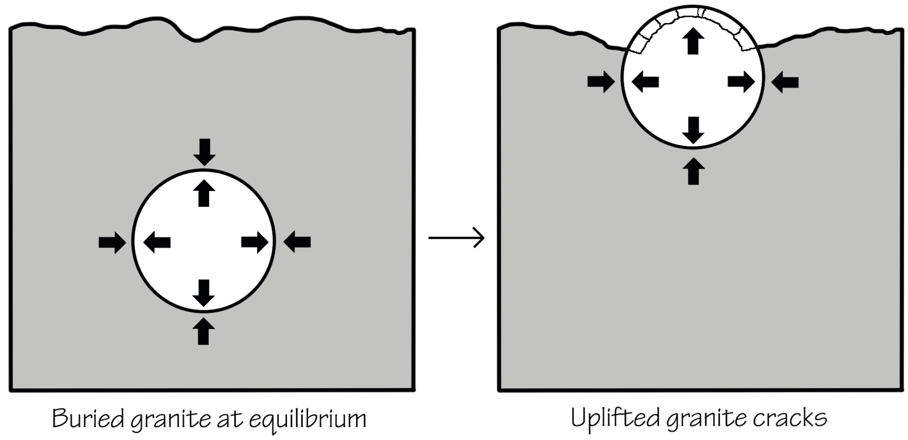


Figure 4.1: Exfoliation as a result of uplift and pressure release.

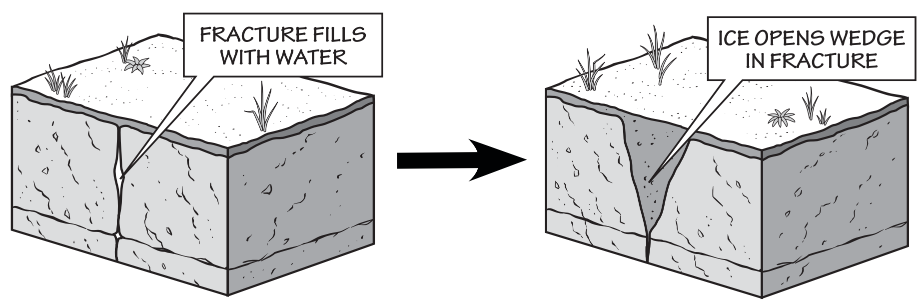


Figure 4.2: Physical weathering from a freeze-thaw cycle.

Working in conjunction with physical (mechanical) weathering, chemical weathering also helps to break down rocks through changes in the chemical composition of their constituent **minerals**. Some minerals contained in **igneous** and **metamorphic** rocks that are formed at high temperatures and pressures (far below the surface of the Earth) become unstable when they are exposed at the surface or placed in contact with water, where the temperature and pressure are considerably lower. unstable minerals transition into more stable minerals, resulting in the breakup of rock. Chemical weathering dominates in the Southeast due to its humid **climate**. Slightly acidic rainwater helps to form carbonic acid, promoting the disintegration of certain types of rocks. **Limestone** and **marble** may be chemically broken down as carbonic acid reacts with their **carbonate** mineral composition, forming cavities and caverns. Other **sedimentary rocks** held together by carbonate **cement** are also particularly susceptible to chemical weathering, which expedites the process of **soil** formation.

The specific rock type at the surface has an important influence on the topography of a region. Certain rocks are able to resist weathering and erosion more easily than are others; resistant rocks that overlie weaker layers act as caps and form ridges. The shallow **inland seas** that advanced across the face of the continent during the **Paleozoic** preserved sediments that became the sedimentary rocks seen today throughout the Inland Basin and Blue Ridge. Sedimentary rocks weather and erode differently than do crystalline (and generally harder) igneous and metamorphic rocks, such as those found throughout the Appalachian Mountains. **Silica**-rich igneous rocks have a crystalline nature and mineral composition that resists weathering far better than do the cemented grains of a sedimentary rock. The metamorphic equivalents of sedimentary and igneous rocks are often even more resistant due to **recrystallization**. There are exceptions, however, such as **schist**, which is much weaker than its pre-metamorphic limestone or **sandstone** state.

The underlying structure of rock layers also plays an important role in surface topography. Sedimentary rocks are originally deposited in flat-lying layers that rest on top of one another. The movement of tectonic **plates** creates stress and tension within the **crust**, especially at plate boundaries. **Intrusions** beneath the surface may also cause deformation of the crust. All these different sources of geological stress can deform the flat sediment layers through folding, faulting, or overturning. These terms are collectively used to describe rock structure, and they can also be used to determine which forces have affected rocks in the past. The folding of horizontal rock beds followed by erosion and uplift brings layers of rock to the surface. Tilted rocks expose underlying layers. Faulting likewise exposes layers at the surface to erosion, due to the movement and tilting of blocks of crust along the fault plane. For example, by the end of the Paleozoic, multiple phases of mountain building had produced the extensive Appalachian Mountain range, surrounded by folded and faulted strata that were deformed and wrinkled. For the last 200 million years, weathering has been dismantling the Appalachians and redistributing these sediments into extensive **clastic wedges** that form the wide Coastal Plain region. These sediment wedges are often over 15,000 meters (49,000 feet) thick and extend below current sea level to form the continental shelves. Above sea level, erosion continues to redistribute these sediments in multiple phases of **fluvial** erosion and deposition, ultimately depositing them along the coast to form barrier island complexes before ultimately transporting the sediment for final burial offshore; at least until the next tectonic phase of mountain building kick-starts the process all over again.

Just as we are able to make sense of the type of rocks in an area by knowing the geologic history of the Southeastern US, we are able to make sense of its topography (*Figure 4.3*) based on rocks and structures resulting from past geologic events. Topography is a central element of the broader concepts of geomorphology or **physiography**, which also include consideration of the shape (not just the height) of land forms, as well as the bedrock, soil, water, vegetation, and climate of an area, and how they interacted in the past to form the landscape we see today. A physiographic province is an area in which these features are similar, in which these features are significantly different from those found in adjacent regions, and/or is an area that is separated from adjacent regions by major geological features. The "regions" of the Southeast that we use in this book are examples of major physiographic provinces. The topography unique to each region thus provides a set of clues to its extensive geologic history.

Review

soil • *the collection of natural materials that collect on Earth's surface, above the bedrock.*

inland sea • *a shallow sea covering the central area of a continent during periods of high sea level.*

Paleozoic • *a geologic time interval that extends from 541 to 252 million years ago.*

silica • *a chemical compound also known as silicon dioxide (SiO_2).*

intrusive rock • *a plutonic igneous rock formed when magma from within the Earth's crust escapes into spaces in the overlying strata.*

fluvial • *see outwash plain: large sandy flats created by sediment-laden water deposited when a glacier melts.*

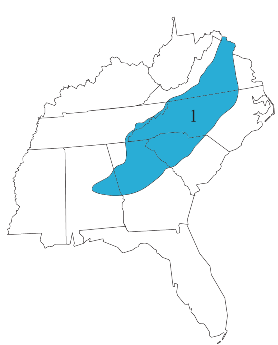
compression • *flattening or squeezing as a result of forces acting on an object from all or most directions.*

Pangaea • *supercontinent, meaning "all Earth," which formed over 300 million years ago and lasted for almost 150 million years.*

Pleistocene • *a subset of the Quaternary, lasting from 2.5 million to about 11,700 years ago.*

Figure 4.3: Digital shaded relief map of the Southeastern states.

Topography of the Blue Ridge and Piedmont
Region 1



The Blue Ridge and Piedmont represents a highly eroded ancient core of mountain building found along the spine of the Appalachians (*Figure 4.4*). Unlike the Southeast's other regions, which are dominated by sedimentary rocks, the Blue Ridge and Piedmont is underlain by crystalline metamorphic rock with localized igneous occurrences, including the remains of ancient volcanoes. Even though these mountains are highly eroded today, they can still top 1500 meters (4900 feet) in elevation. For example, Mount Rogers, an extinct volcano in Virginia, rises 1746 meters (5728 feet) above sea level.

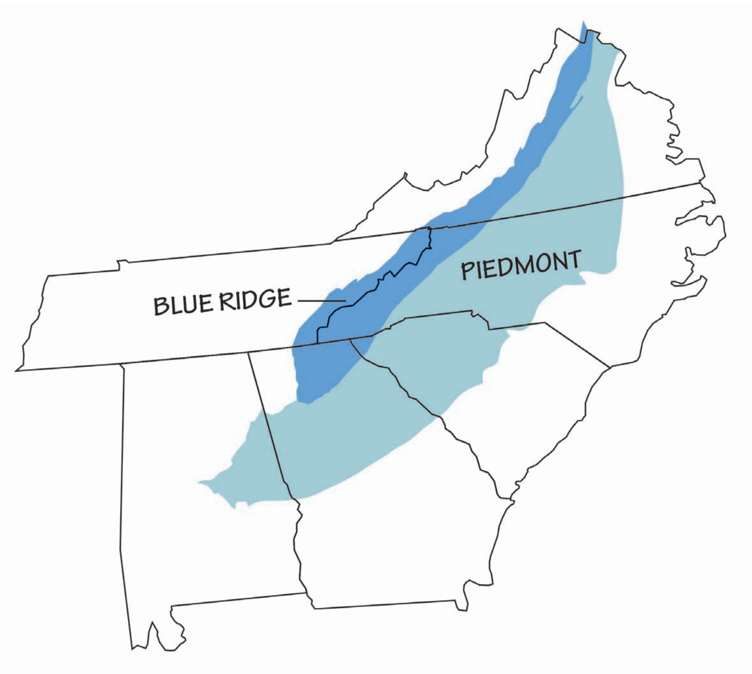


Figure 4.4: Physiographic divisions of the Blue Ridge and Piedmont.

Region 1

__periglacial zone__ • a region directly next to an ice sheet, which, although never covered or scoured by ice, has its own distinctive landscape and features.

__stratigraphy__ • the branch of geology specifically concerned with the arrangement and age of rock units.

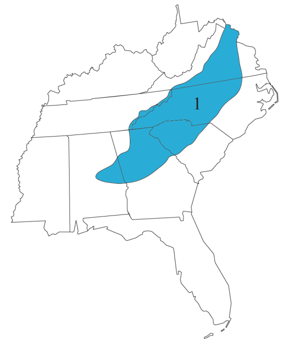
__anticline__ • a layer of rock folded (bent) along an axis, concave side down (i.e., in an upside down "u" or "v" shape).

The Blue Ridge

The elevated Blue Ridge formed from the **compressive** collision forces of several mountain-building episodes during the Paleozoic—essentially a block thrust northwest over the buried leading edge of the Valley and Ridge (directly west of the Blue Ridge). The boundary between the Valley and Ridge and Blue Ridge, the Great Appalachian Valley, is a major landform feature that stretches 1900 kilometers (1200 miles) from Quebec to Alabama. This gigantic trough, or chain of valley lowlands, reflects the late Paleozoic suturing of **Pangaea**. During this event, overthrusting juxtaposed contrasting lithologies, which have now been accentuated by subsequent erosion to produce the sharp boundary we use to divide the two physiographic regions. During glaciation in the **Pleistocene**, the Blue Ridge was also under the influence of **periglacial** processes, which further sculpted these landforms and influenced regional ecosystems.

The tectonic forces that built the Blue Ridge uplifted the oldest rocks in the Southeast (dating back to the Mesoproterozoic) and exposures older than 1.2 billion years old are common here. The region was pushed over 160 kilometers (100 miles) west, telescoping into a series of folded, thrusted crustal sheets that carried older rocks atop younger rocks, overturning the **stratigraphic** sequence (*Figure 4.5*). The Blue Ridge is actually one giant upward fold, or **anticline**, with many smaller folds superimposed upon it. This is known as an anticlinorium (*Figure 4.6*). The Blue Ridge anticlinorium is overturned to the west. The Eastern Continental Divide runs along the crest

A *hydrological divide* is a boundary between two drainage basins or watersheds.



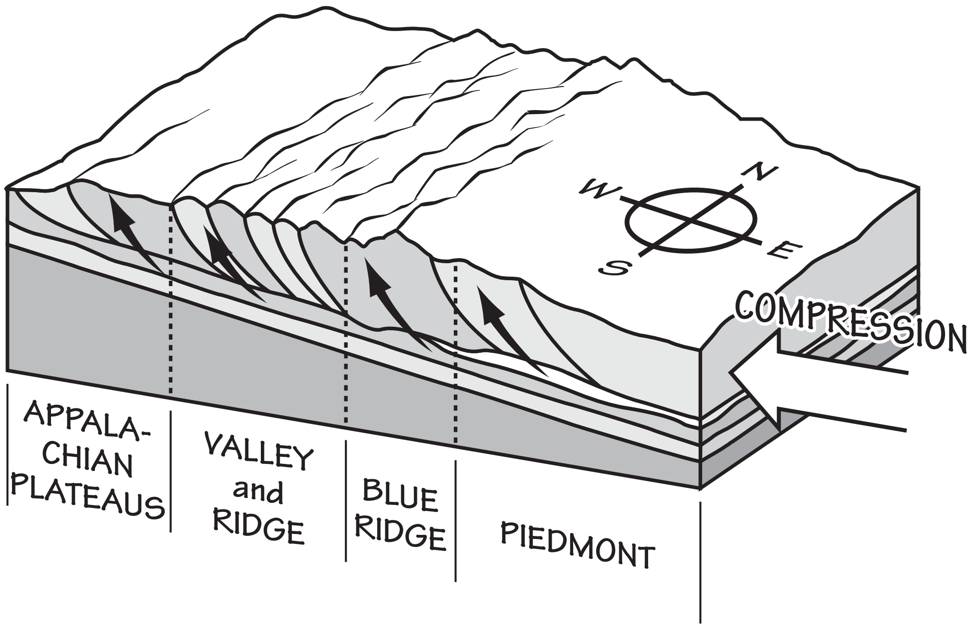


Figure 4.5: The crust of the Blue Ridge and Piedmont was "telescoped" by the compressional forces of Paleozoic mountain building. Slices of crust were thrust over top of each other, stacking like a deck of cards.

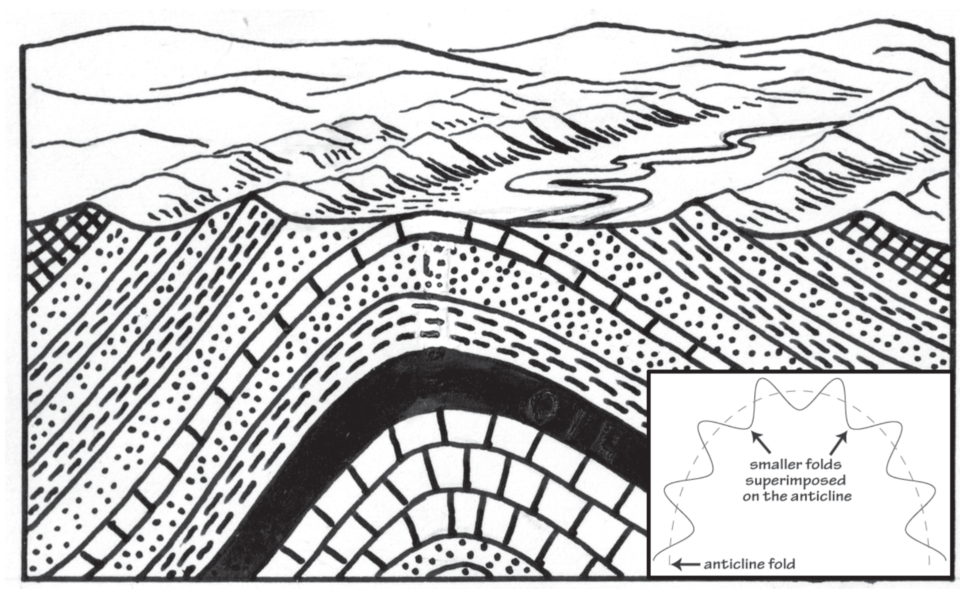
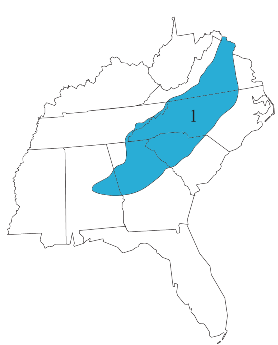


Figure 4.6: An anticline, an upward fold in layered rocks. Inset shows the structure of an anticlinorium.



Region 1

of the eastern Blue Ridge, and separates the North American **watersheds** that flow east into the Atlantic Ocean from those that flow west and south toward the Gulf of Mexico. The Black Mountains, a part of the Blue Ridge in western North Carolina, are the highest mountains in the eastern United States, and their southern tip intersects the Eastern Continental Divide.

Heat generated by mountain building transformed the area's original sedimentary rock into the metamorphic rocks of the Blue Ridge Mountains, and it also allowed igneous intrusions to punch their way up through the crust. In Virginia's Shenandoah Mountains, many of the highest peaks are capped by greenstones—metamorphosed **basalt** flows that spilled out of the Earth during a **rifting** event about 570 million years ago. Over several million years, these **lava** flows spread out over the landscape, blanketing over 6000 square kilometers (4000 square miles) with basalt ranging from 6 meters (20 feet) to over 30 meters (100 feet) thick. Although these flows were metamorphosed into greenstone during the formation of the Appalachian Mountains, the original shape of the layers remains and has a noticeable effect on the landscape. Flat "benches" separate jagged cliffs and create stairstepped textures (*Figure 4.7*), while other areas are broad and flat. Already a subdivision of the larger

Figure 4.7: Stony Man mountaintop in Shenandoah National Park, Virginia.

Appalachian Mountain chain, the Blue Ridge has been further divided into many smaller ranges throughout its expanse. The Shenandoah Mountains of Virginia, the Great Smoky Mountains of Tennessee and the Carolinas, and the Blue Ridge Mountains of northern Georgia are a few such subdivisions, accompanying many smaller ranges with local topographic peculiarities. The Great Smoky Mountains, along the border of Tennessee and North Carolina, encompass a rugged terrain containing 16 peaks with elevations over 1800

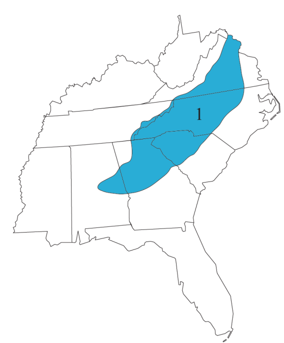
watershed *• an area of land from which all water under or on it drains to the same location.*

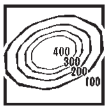
heat *• a form of energy transferred from one body to another as a result of a difference in temperature or a change in phase.*

basalt *• an extrusive igneous rock, and the most common rock type on the surface of the Earth.*

rift *• a break or crack in the crust that can be caused by tensional stress as a landmass breaks apart into separate plates.*

lava *• molten rock located on the Earth's surface.*





Topography

Region 1

quartzite • *a hard metamorphic rock that was originally sandstone.*

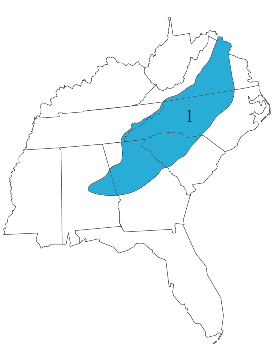
Precambrian • *a geologic time interval that spans from the formation of Earth (4.6 billion years ago) to the beginning of the Cambrian (541 million years ago).*

meters (6000 feet)—the highest elevations in the Southeast. The major peaks (Clingmans Dome is highest at 2025 meters [6644 feet], followed by Mount Guyot and Mount Le Conte) have smaller ridge spurs radiating from their central peaks, forming steep-sided, V-shaped valleys (*Figure 4.8*). Waterfalls are common throughout the steep valleys and gorges of the Blue Ridge.

In northwestern North Carolina, several smaller ranges are isolated from the main body of the Blue Ridge Mountains. The Brushy Mountains are separated from the Blue Ridge Mountains by the Yadkin River Valley and divide the waters of the Yadkin and Catawba rivers. The Sauratown Mountains, located within Stokes and Surry counties, rise sharply 240 to 520 meters (800 to 1700 feet) above the surrounding landscape and are known for some of the best rock climbing in the state. The range is home to many prominent peaks, including Pilot Mountain, an isolated erosional remnant of metamorphic **quartzite** (*Figure 4.9*).

Figure 4.8: Ridges and valleys of the Great Smoky Mountains, straddling North Carolina and Tennessee. The mountains' heavy forests release water vapor and other compounds that hang in the air, giving the range its name.

The overthrust rocks of the Great Smoky Mountains have been subjected to erosional processes spanning more than 200 million years. Along the Smokies' western leading edge, erosion has cut numerous geologic "windows" through the older rocks that form the overthrust upper sheet, exposing younger rocks within window valleys (usually referred to as coves.) Cades Cove in Tennessee is a roughly circular window eroded in **Precambrian** sandstone to expose the Paleozoic limestone beneath. A fault at the bottom completely encircles the



Region 1

Figure 4.9: The bare rock walls of The Knob at Pilot Mountain, North Carolina, which rises about 430 meters (1400 feet) above the surrounding terrain.

karst topography • *a kind of landscape defined by bedrock that has been weathered by dissolution in water, forming features like sinkholes, caves, and cliffs.*

system • *a set of connected things or parts forming a complex whole.*

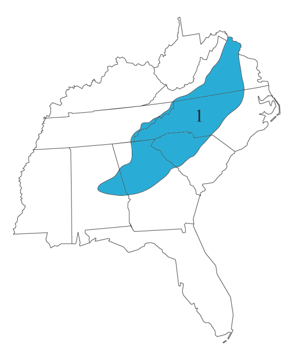
cove. Weathering of the carbonate rocks in this and other similar topographic lows (e.g., Tuckaleechee and Wear coves) exposes **karstic** limestone and produces rich soils that were used for agricultural purposes by 18th-century settlers. Dissolution of the limestone has led to the formation of several caves—Bull Cave in Cades Cove, 281 meters (924 feet) deep, is the deepest cave in Tennessee. Tuckaleechee Caverns, a mile-long cave **system** near Townsend, Tennessee that reaches depths of 46 meters (150 feet), is another karstic cave estimated to be between 20 and 30 million years old.

See Chapter 2: Rocks to learn about the formation of geologic windows and where they can be found in the Southeast.

The boundary between the Blue Ridge and Piedmont provinces is often considered to be the Brevard Fault Zone, a 600-kilometer-long (370-mile-long) zone stretching from Alabama to Virginia, where the rocks were crushed and ground by the tremendous pressure of thrusting during the formation of Pangaea.

The Piedmont

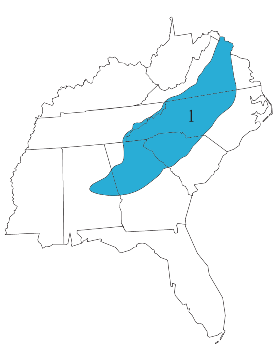
East of the Blue Ridge mountain belt lies the upland Piedmont region. Here, a more humid climate has resulted in extensive weathering of the Piedmont's overthrusted rocks, producing a more subdued topography of low rolling



4 Topography

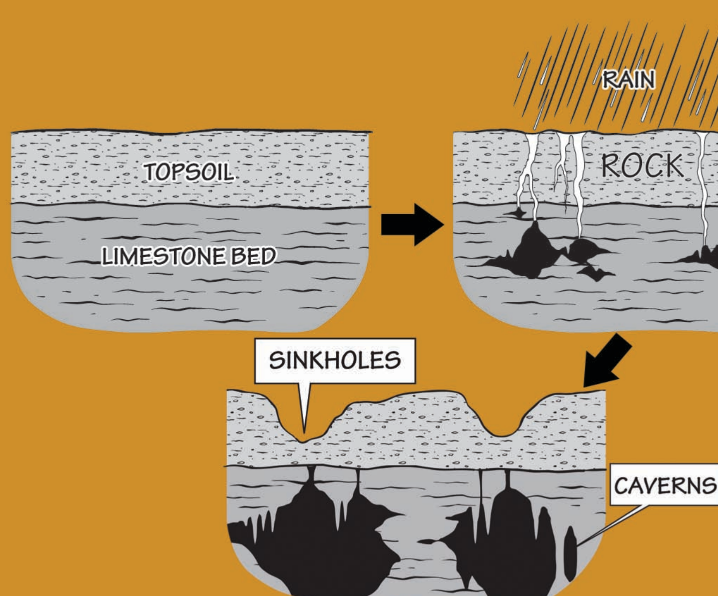
Region 1

atmosphere • *a layer of gases surrounding a planet.*

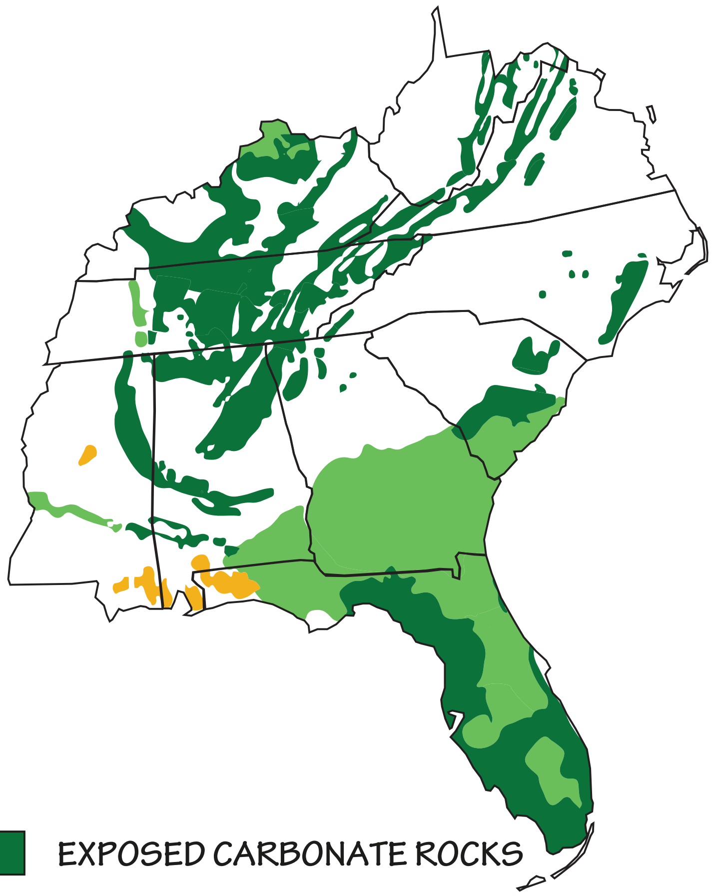


Karst Topography

Karst topography refers to a region where the landscape's features are largely the result of chemical weathering by water, resulting in caves, sinkholes, disappearing and reappearing streams, cliffs, and steep-sided hills called towers. These structures form when water picks up carbon dioxide from the *atmosphere* and ground to form carbonic acid. Even this fairly weak and dilute acid dissolves carbonate rocks (such as limestone) relatively easily, resulting in dramatic features while other rock is comparatively unaffected. Karst is found in every state except Hawaii, and as an aquifer it is the source of a significant amount of our drinking water. While common, karst is not always easily identifiable since it is often not expressed at the surface or its topography has been affected by other factors. Karst topography is a relatively mature type of landscape, taking many tens of thousands of years to develop, and it can indicate that a region has been free of other forms of erosion, or deposition, for an extended period. Karst topography in the Southeast is present wherever water has eroded the limestone bedrock, especially throughout the Inland Basin and across the Florida Platform.



Karst Topography (continued)

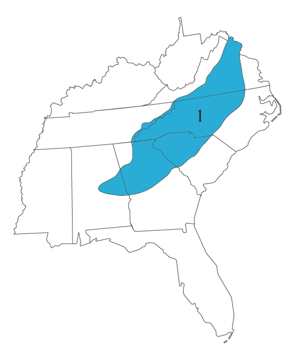


(See TFG website for full-color version.)

clay • *the common name for a number of very fine-grained, earthy materials that become plastic (flow or change shape) when wet.*

hills. Elevations can reach several hundred meters (particularly in Alabama's northern Piedmont, which contains the highest peaks in the state), and the entire Piedmont gently slopes toward the east, draining toward the Atlantic Ocean. The near surface of the Piedmont is composed of saprolite, the **clay**-rich remains of decomposed rock that produces a rich soil for farming. Sporadically peeking up through this blanket of weathered metamorphics are erosional remnants called

The word Piedmont comes from the French for "foot of the mountain" reflecting the area's low rolling hills.



4 Topography

Region 1

monadnocks—resistant rocks that contrast with their surroundings in terms of topography and composition. In Georgia, an igneous **pluton** conspicuously rises 514 meters (1686 feet) above the surrounding landscape to form Stone Mountain, a massive **granite** dome that covers 236 hectares (583 acres) and has a physical volume of over 210 million cubic meters (7.5 billion cubic feet) (*Figure 4.10*). Despite its size, the mountain occupies only a small portion of the area underlain by the granite, like the tip of an **iceberg**. All of this granite formed around 300 million years ago, during the **Alleghanian Orogeny**, when it was intruded into the preexisting rock at a depth of about 12–16 kilometers (8–10 miles) below the surface. The granite was more resistant to weathering than was the surrounding rock, and as the layers of overlying rock slowly eroded away, the granite was finally exposed at the surface about 15 million years ago. There is also a Stone Mountain in North Carolina—another granitic monadnock—that formed at around the same time! Other monadnocks in the Piedmont include Little Mountain and Table Rock in South Carolina, Arabia Mountain in Georgia, and Kings Pinnacle in North Carolina.

See Chapter 7: Soils to learn more about the types of soils formed from weathered rock.

Figure 4.10: An aerial view of Stone Mountain, DeKalb County, Georgia.

A series of irregular linear basins, collectively referred to as **Mesozoic** Rift Basins or **Triassic** Basins (e.g., Dan River-Danville and Culpeper basins in Virginia and Wadesboro Basin in North Carolina), are exposed sporadically within the Piedmont. Topographically, these basins are hard to distinguish from the surrounding and enclosing terrain; however, they tend to have tilted sedimentary strata of sandstone and **shale** that erode to form low linear ridges

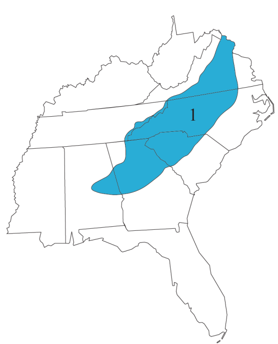
monadnock • *an isolated hill or small mountain on a plain, formed from rock more resistant to erosion than that of the surrounding landscape.*

pluton • *a body of intrusive igneous rock that formed under the Earth's surface through the slow crystallization of magma.*

granite • *a common and widely occurring type of igneous rock.*

iceberg • *a large chunk of ice, generally ranging in height from 1 to 75 meters (3 to 246 feet) above sea level, that has broken off of an ice sheet or glacier and floats freely in open water.*

Alleghanian Orogeny • *a Carboniferous to Permian mountain-building event involving the collision of the eastern coast of North America and the northwestern coast of Africa.*



on their eastern flanks. Where basalt flows occurred, these rocks are more resistant and form traceable topographic ridges.

See Chapter 1: Geologic History to learn about rifting during the Mesozoic.

At the westernmost edge of the Piedmont, called the Fall Line, the shift from crystalline rocks to loose sediment signals the beginning of the Atlantic Coastal Plain. A **fall line** (or fall zone) is a geomorphologic break between an upland region of relatively hard crystalline **basement rock** and a coastal plain of softer sedimentary rock (*Figure 4.11*). Rivers crossing such breaks typically display waterfalls and rapids, and were frequently sites of settlements that made use of water **power**. Numerous Southeastern cities are located on the Fall Line for this reason, including Great Falls, VA (on the Potomac River; *Figure 4.12*), Fredericksburg, VA (on the Rappahannock River), Richmond, VA (on the James River), Petersburg, VA (on the Appomattox River), Raleigh, NC (on the Neuse River), Columbia, SC (on the Congaree River), Augusta, GA (on the Savannah River), Macon, GA (on the Ocmulgee River), Columbus, GA (on the Chattahoochee River), and Belltown, AL (on the Tallapoosa River).

See Chapter 6: Energy for more information on the use of water as an energy source in the Southeast.

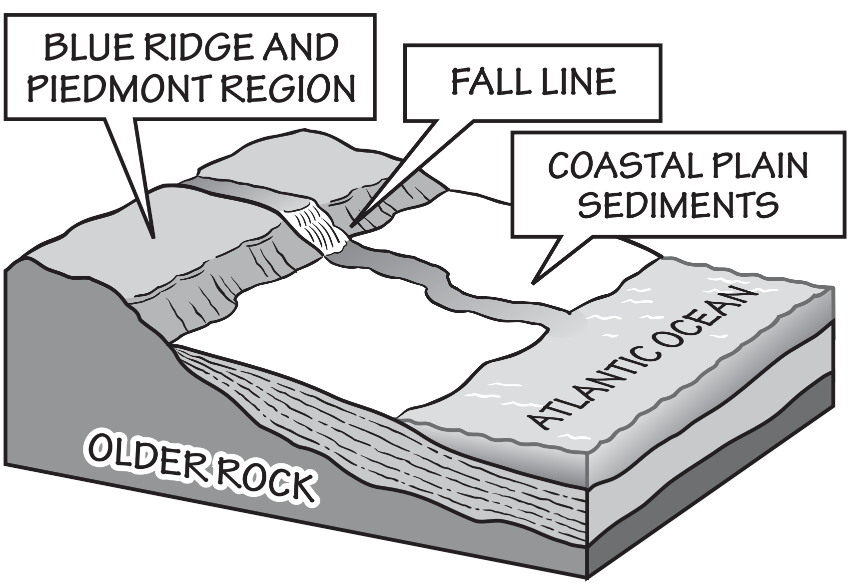


Figure 4.11: The Fall Line, between the Blue Ridge/Piedmont and Coastal Plain regions.

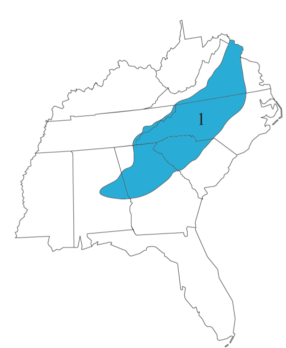
Mesozoic • *a geologic time period that spans from 252 to 66 million years ago.*

Triassic • *a geologic time period that spans from 252 to 201 million years ago.*

shale • *a dark, fine-grained, laminated sedimentary rock formed by the compression of successive layers of silt- and clay-rich sediment.*

basement rocks • *the foundation that underlies the surface geology of an area, generally composed of igneous or metamorphic crystalline rock.*

power • *the rate at which energy is transferred, usually measured in watts or, less frequently, horsepower.*



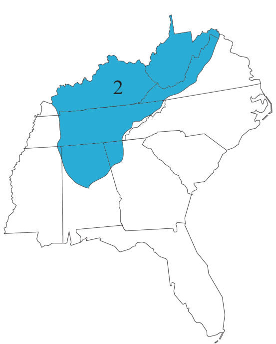
Mississippi Embayment • *a topographically low-lying basin in the south-central United States, stretching from Illinois to Louisiana.*

Figure 4.12: The Great Falls of the Potomac River, Virginia.

Topography of the Inland Basin
Region 2

The Inland Basin, occupying the landscape west of the Blue Ridge to the **Mississippi Embayment** and north of the Gulf Coastal Plain, can be thought of as the Southeast's geologically stable, ancient topographic nucleus. The Inland Basin is composed of a thick sequence of Paleozoic-aged carbonate sedimentary rock deposited during multiple ocean incursions into the continent's interior, punctuated by blankets of siliciclastic sediment from the erosion of newly uplifted mountains. This alternating stratigraphy of carbonates and clastics underlies the entire region, but it can be subdivided into several physiographic provinces based upon deformational characteristics associated with the formation of the Appalachian Mountains (*Figure 4.13*).

See Chapter 2: Rocks to learn how mountain building and erosion contributed to the Inland Basin's stratigraphy.



The Valley and Ridge

The easternmost part of the Inland Basin is a strip of linear, "wrinkled" ridges and valleys running northeast to southwest, adjacent to the Appalachians. This topography, characterized by long, even ridges with continuous valleys in between (*Figure 4.14*), is best developed in western Virginia and eastern Tennessee, but also extends into northeast Alabama and northwest Georgia. Individual ridge crests can run for extremely long distances—for example, Clinch Mountain in Tennessee is about 240 kilometers (150 miles) in length.

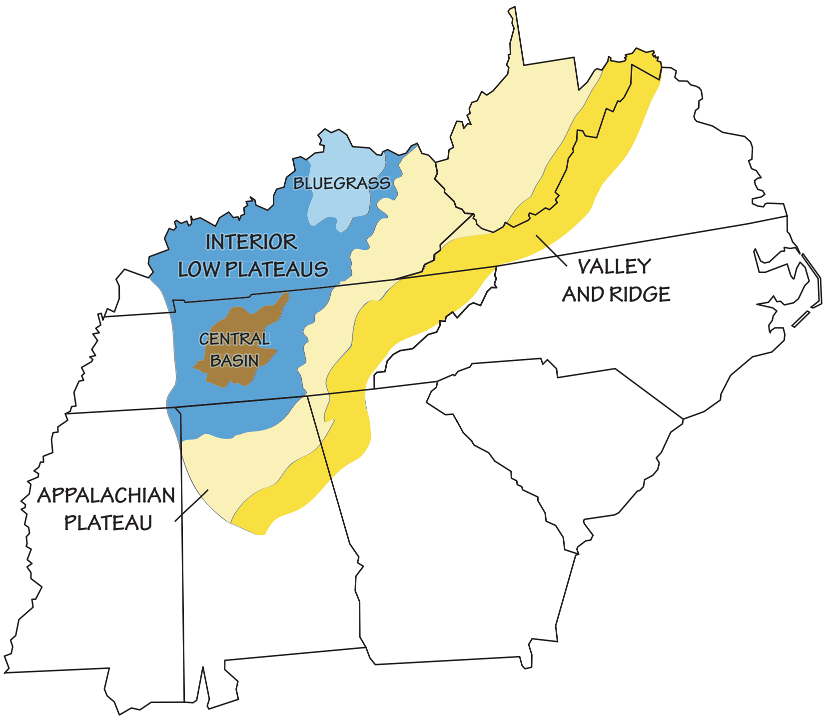
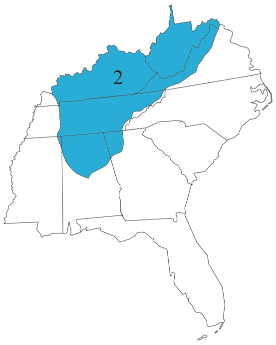


Figure 4.13: The physiographic regions of the Inland Basin. (See TFG website for full-color version.)

Figure 4.14: Linear ranges of the Valley and Ridge adjacent to the Shenandoah River, Virginia.



4 Topography

Region 2

relief *• the change in elevation over a distance.*

The **relief** of ridges in this area can range from 400 to over 1100 meters (1300 to over 4000 feet) in height. Before the days of motorized transportation, the length and height of these ridges presented a major obstacle to east-west land travel, and settlers were able to cross the Valley and Ridge only near its endpoints or at erosional "gaps" created by wind and water.

The elongate and folded sedimentary rocks of the Valley and Ridge were deformed by thrust faulting during the Alleghanian Orogeny, which created an accordion-like repetition of strata as sheets of rock folded and then broke to slide over adjacent areas. The ridges represent the edges of erosion-resistant strata, while valleys formed under softer and easily-eroded layers. Differential weathering and the erosion of alternating resistant sandstones and weaker shale and limestone sharpens the area's topography (*Figure 4.15*). Cemented sandstones hold up the ridges, and valleys tend to be floored by shale and karst limestone, the latter easily recognized by the numerous depressions and sinkholes that develop as surface drainage is diverted below ground. Nestled between adjacent highland areas, well-developed soils have formed thanks to the erosion of numerous sedimentary rock types, generating highly fertile farmland in the valleys.

See Chapter 10: Earth Hazards for more information about the dangers associated with karst topography.

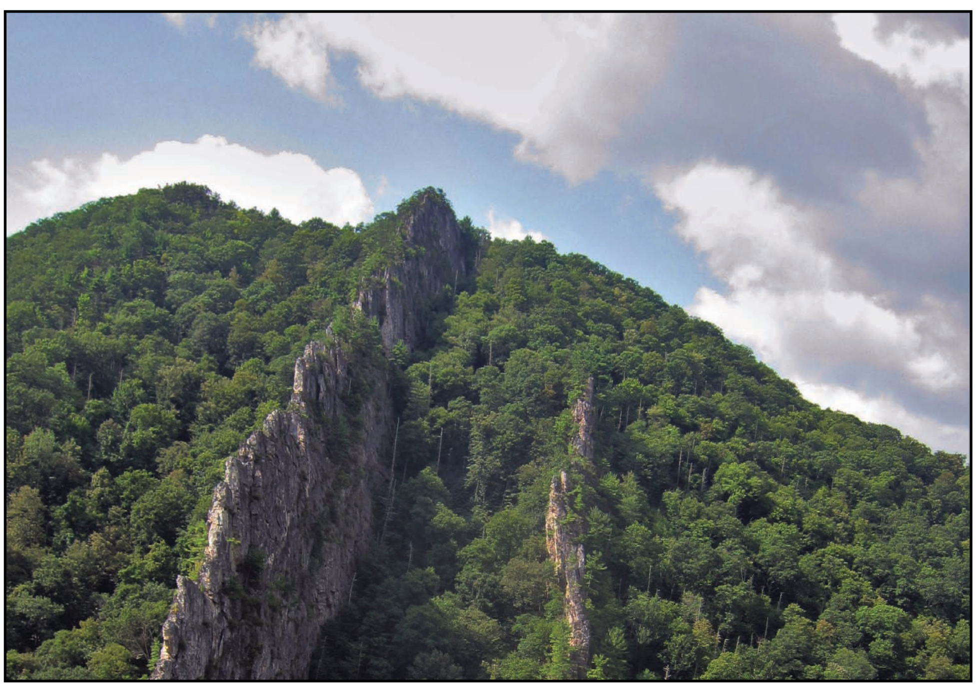
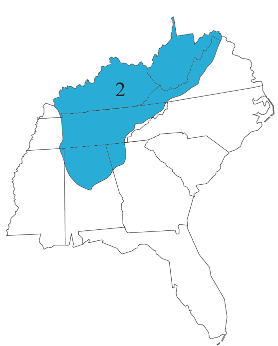
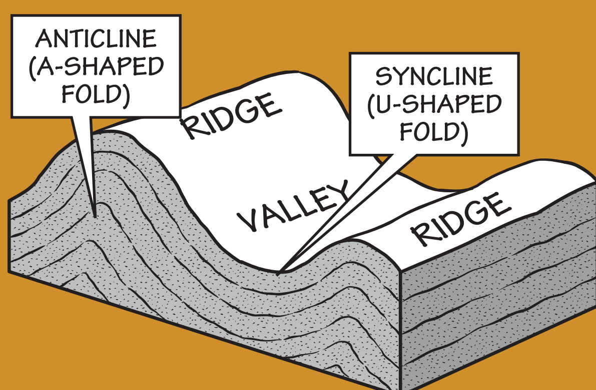


Figure 4.15: Sharp ridges of erosion-resistant sandstone are exposed in the Allegheny Mountains of Judy Gap, West Virginia, a popular rock-climbing destination.

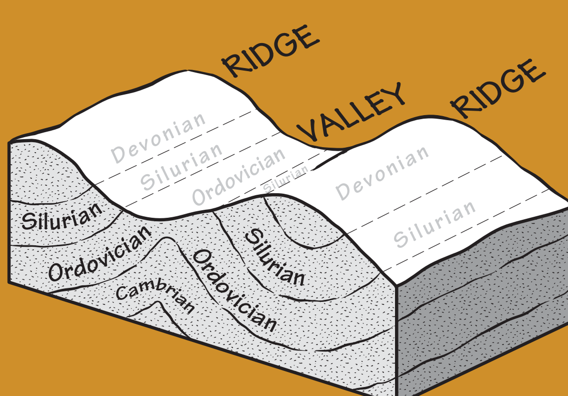


Topographic Inversions

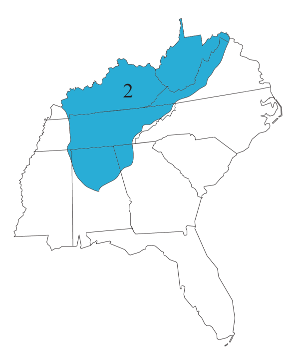
Typically, synclines (U-shaped folds) form valleys and anticlines (A-shaped folds) form ridges. However, the reverse is often true, especially in the Appalachians. In a phenomenon called topographic inversion, topographic lows (valleys) may form from the structural high (top of an anticline)—the term "structure" refers to the form of the rock layers. At the top of the anticline, a layer may erode away because of cracks caused by bending of the rock at the top of the fold. Fracturing at the top of the fold allows increased water penetration, and topographic highs are subjected to more severe weather. Once exposed, the less resistant layers below the eroded top quickly weather away to form a valley. The limbs of the resistant layer, however, are generally still intact. This leaves two ridges of resistant rock on either side of a valley floored by softer, less resistant layers.



Normal erosion of a fold.



Topographic inversion.



4 Topography

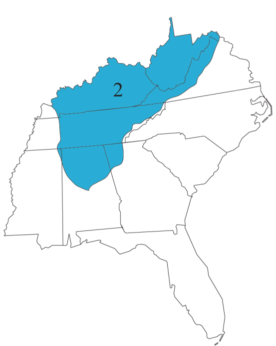
Region 2

iron • *a metallic chemical element (Fe).*

coal • *a combustible, compact black or dark-brown carbonaceous rock formed by the compaction of layers of partially decomposed vegetation.*

fuel • *a material substance possessing internal potential energy that can be transferred to the surroundings for specific uses.*

flux • *a mineral added to the metals in a furnace to promote fusing or to prevent the formation of oxides.*



Drainage within the Valley and Ridge typically follows the orientation of valleys, with most rivers meandering back and forth across valley floors in a northeast to southwest direction. Short tributaries flowing down the ridge slopes feed the rivers. This distinctive drainage pattern, controlled by the Valley and Ridge topography, is referred to as **trellis drainage** (*Figure 4.16*). Many small streams have developed in a manner consistent with the trellis pattern, but there are a few exceptions to this rule. The Tennessee River, for example, initially follows the Valley and Ridge, but abruptly doglegs westward through the Cumberland Plateau before heading west through northern Alabama. A few major rivers (including the Potomac and New rivers) have cut water gaps perpendicular to the ridges and are therefore thought to have been in place before the mountains were formed.

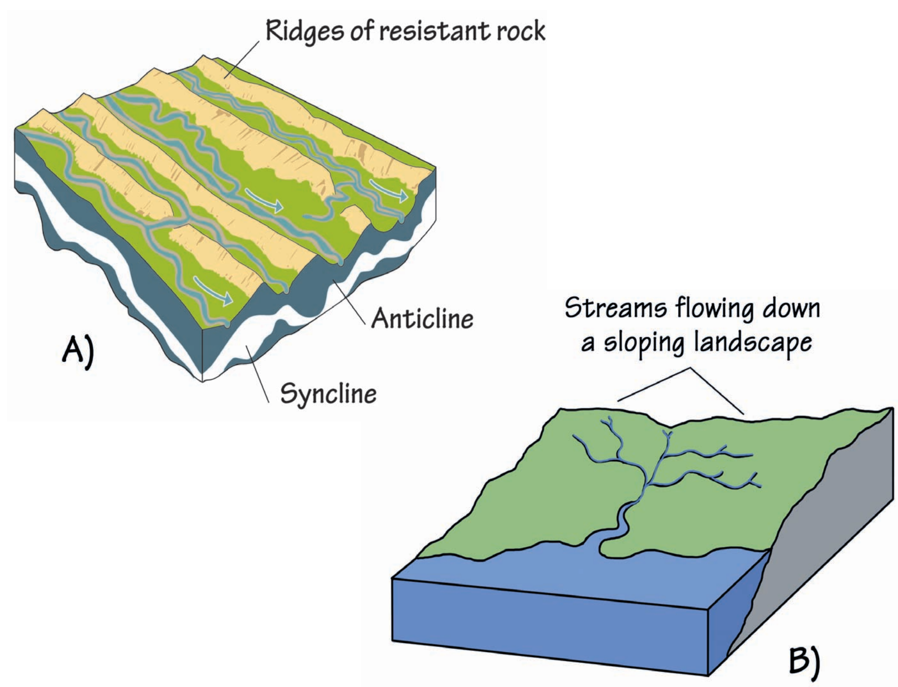


Figure 4.16: Common drainage patterns. A) Trellis drainage, in which tributaries feed into a river at right angles, forms between ridges of resistant rock. B) Dendritic drainage, in which many contributing streams join together like branches, follows the slope of the landscape.

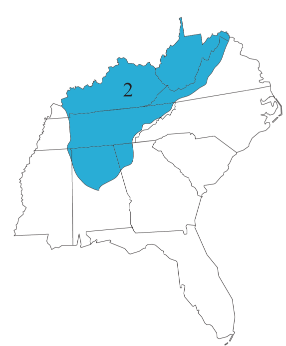
At its southernmost extent, the Valley and Ridge enters Alabama with several major ridges and their associated valleys: Birmingham-Big Canoe Valley and Cahaba, Coosa, Weisner, and Armuchee ridges (*Figure 4.17*). In the Birmingham area, Red Mountain towers above the city, exposing **iron**-rich sedimentary red beds that once gave the city the name "Iron and Steel Capital of the South" due to the proximity of **coal** for **fuel** and limestone for **flux**. In central Alabama, the entire Valley and Ridge terminates against the younger sediments of the Gulf Coastal Plain.

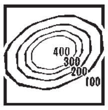
See Chapter 5: Mineral Resources to learn about Alabama's iron and steel industry.

The Contrary River

Most southeastern rivers follow a more or less direct path of least resistance from their headwaters downslope to the ocean. However, the Tennessee River seems to have a mind of its own. Its headwaters are in northeastern Tennessee on the west side of the Appalachians, which impede a direct eastern flow to the Atlantic Ocean. Rather, the Valley and Ridge trellis drainage pattern governs the Upper Tennessee, forcing it to follow valleys to the southwest. Instead of continuing its trek directly to the Gulf of Mexico, the Tennessee abruptly doglegs to the west at Chattanooga, forcing it to incise a deep canyon into Walden Ridge ("the Grand Canyon of Tennessee") before finally resuming a southwestward course. This is only temporary, however, for the Tennessee again changes course to head west through northern Alabama, forming rapids referred to as Muscle Shoals, then onward toward the Mississippi River. Here, the river once again confounds shortest-distance convention by turning at Pickwick to flow north across Tennessee and Kentucky before emptying into the Ohio River. The Tennessee River's circuitous course has proven useful to the Tennessee Valley Authority—damming the river allowed control of floods, and the construction of hydroelectric plants helped transform the south from poverty to riches after the Great Depression.

The Tennessee River and its tributaries.
(See TFG website for full-color version.)





Topography

Region 2

foreland bulge *• an area of uplift on the far side of an inland basin.*

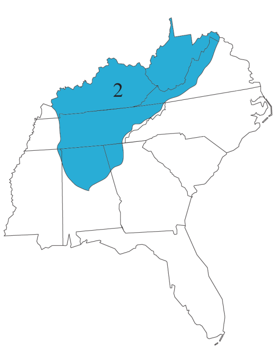
conglomerate *• a sedimentary rock composed of multiple large and rounded fragments that have been cemented together in a fine-grained matrix.*

Figure 4.17: The Coosa River flows through the Coosa Valley, part of Alabama's Valley and Ridge.

The eastern margin of the Valley and Ridge is a structural trough—a series of valley lowlands—called the Great Appalachian Valley, and it has been used as an important north-south route of travel since prehistoric times (today, it is occupied by Interstate 81 as well as portions of I-40 and I-75). The valley, which extends from Canada all the way south to Alabama, is bounded by the Blue Ridge Mountains along its eastern edge. Regional names for the Great Appalachian Valley in the Southeastern states include the Shenandoah and James River valleys in Virginia, the Tennessee and Holston River valleys in Tennessee, and the Coosa Valley in Alabama.

The Appalachian Plateau

Westward of the Valley and Ridge, the highland rims rise and top out in a broad, high, flat plateau or "tableland" called the Appalachian Plateau. Although not as elevated as the Appalachian Mountains, these tablelands were slightly deformed into a broad, open fold, indicating their proximity to the "wrinkled carpet" deformation that made up the **foreland bulge** of the Appalachians. Southward, more extensive erosion has narrowed the plateaus, and the influence of underlying faulting and folding becomes more evident. The plateau's caprock is dominated by clastic Paleozoic rocks (e.g., **conglomerate**, sandstone, shale, and coal) formed in extensive swamps and coastal plains while the Appalachians rose. These relatively horizontal and undeformed caprocks lessened the rate of erosion, allowing the area to lag behind the more extensively eroded carbonates exposed in the Interior Low Plateaus to the west and creating the high tableland topography we see today. Erosion continues to eat away at the area from both sides, causing it to narrow as time passes.



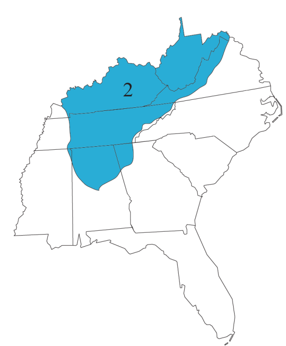
The eastern side of the Appalachian Plateau is a major southeast-facing escarpment, the Appalachian Structural Front, formed in part by northeast- to southwest-trending thrust faults. The relief along this structure is steep, and rockfalls and **landslides** are common environmental hazards. In West Virginia, the escarpment is called the Allegheny Front, and its highest point is Mt. Porte Crayon (1400 meters or 4700 feet). In Kentucky, it is the Pottsville Escarpment, a rugged sandstone belt of cliffs and valleys (*Figure 4.18*). In Tennessee, it is called the Cumberland Escarpment, and rises over 300 meters (980 feet), with grand vistas of the Valley and Ridge to the east.

***Escarpments*, or "scarps," form when faulting or erosion acts to create a cliff or steep slope that separates two level or gently sloping topographical surfaces.**

landslide* • *the rapid slipping of a mass of earth or rock from a higher elevation to a lower level under the influence of gravity and water lubrication.

Figure 4.18: A natural arch in the sandstone of the Pottsville Escarpment, Daniel Boone National Forest, Kentucky.

In West Virginia, the Appalachian Plateau is divided into the Parkersburg, Logan, and Allegheny plateaus. The highest tableland in Virginia is High Knob, which rises 1287 meters (4223 feet) above sea level and contains a mixture of topographical features common to the Valley and Ridge as well as the Appalachian Plateau. The southern portion of the tableland, stretching from Kentucky and Tennessee to Alabama, is called the Cumberland Plateau. In Kentucky, the Cumberland Plateau is dominated by forested hills and dissected by V-shaped valleys. A 201-kilometer-long (125-mile-long) thrusted ridge, Pine Mountain, extends across the area. In the northern part of the Tennessee Plateau, an unusual pattern of late Paleozoic thrust faults has created a raised and tilted uplift called the Wartburg Basin, deforming the strata into the



topographically higher Cumberland Mountains—a mountain range that lies on top of the plateau. In southern Tennessee, the Cumberland Plateau is bisected by a breached anticline, the Sequatchie Anticline, that later eroded to form Sequatchie Valley—also an example of **topographic inversion** (*see box on p. 167*). This northeast-trending valley resembles a deep knife slice into the southern Cumberland Plateau extending into Alabama (*Figure 4.19*).

topographic inversion • *a landscape with features that have reversed their elevation relative to other features, most often occurring when low areas become filled with lava or sediment that hardens into material that is more resistant to erosion than the material that surrounds it.*

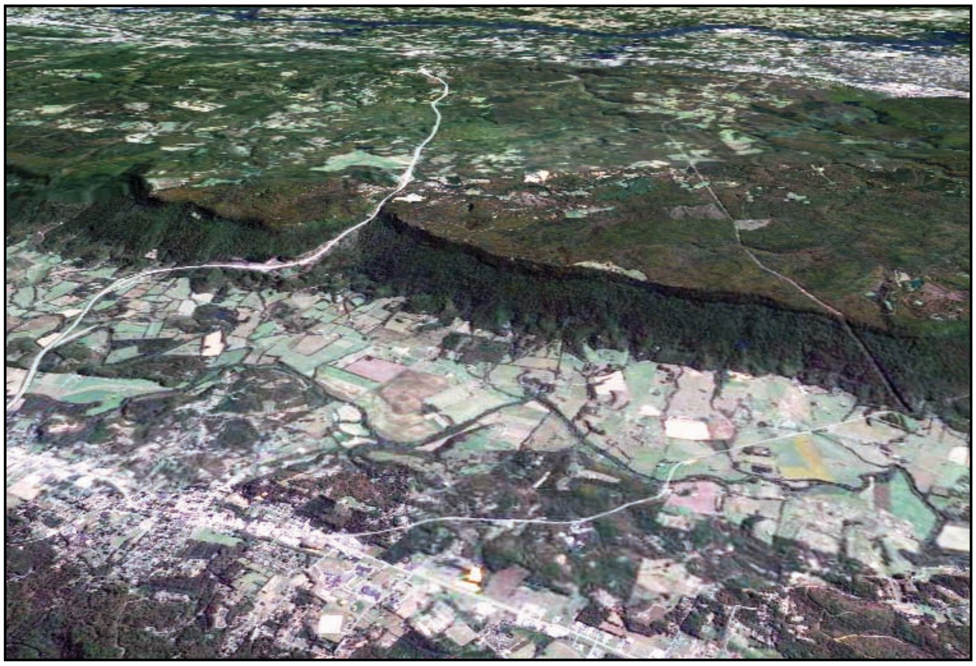
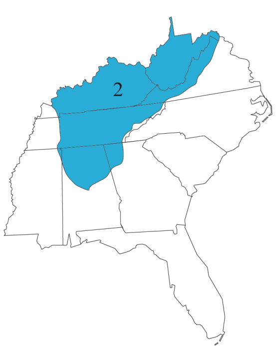


Figure 4.19: A steep escarpment, Walden Ridge, rises from the eastern edge of the Sequatchie Valley near Chattanooga, Tennessee.

The Sequatchie Valley represents the western extent of thrust faulting from the adjacent Valley and Ridge—the last of the tight wrinkles of folded strata from the continental collision that formed the Appalachians. The thrust fault shallows as it nears the surface, and was therefore more easily reached by erosion. The older Paleozoic strata exposed within the Sequatchie Valley show the classic northeast to southwest "grain" typically found in rocks farther east and at lower elevations. Sinkholes and caverns occur in the valley where its protective caprock is breached. Grassy Cove, an enclosed valley at Sequatchie's northern tip, contains notable karst formations. Eventually, once the remaining higher layers of rock separating Grassy Cove from the rest of Sequatchie Valley are removed by erosion, it will become a northeastern extension of the main valley.

The Appalachian Plateau narrows into Alabama to become an area of flat-topped plateaus, including Sand Mountain and Blount Mountain, separated by steep-sided valleys. These plateaus, which slope gently toward the southwest, flank an extensive geologic basin—the Black Warrior Basin—that lies at the southern tip of the Appalachians. The Black Warrior Basin's topography is mostly



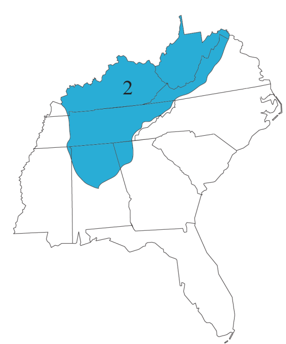
horizontal, with tablelands formed by coal-rich clastic rocks. The eastern edges of this basin were impacted by Appalachian mountain building to become part of the adjacent Valley and Ridge topography.

See Chapter 6: Energy for more about coal resources in the Inland Basin.

dendritic drainage • *a drainage pattern where many smaller streams join and contribute to ever larger streams.*

The western margin of the Appalachian Plateau has an irregular geographic outline, modified by west-flowing creeks and rivers that erode the west edge of the plateau. The drainage pattern here is dominantly **dendritic** (*see Figure 4.16*), flowing northwest into the basins of the Interior Low Plateaus. Differential weathering of slightly tilted sedimentary strata has formed stair-stepped topography in the valleys, and waterfalls are a common occurrence. Fall Creek Falls in Tennessee is considered the highest waterfall east of the Mississippi River, with a plunge of 78 meters (256 feet). Cumberland Falls in Kentucky is another large waterfall, 21 meters (68 feet) high and 38 meters (125 feet) wide, that spans the Cumberland River on the border of McCreary and Whitley counties (*Figure 4.20*).

Figure 4.20: Cumberland Falls, McCreary and Whitley counties, Kentucky.



The Interior Low Plateaus

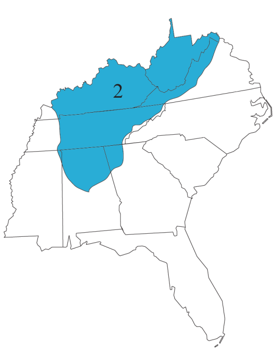
Broad, gently folded basins and domes with surrounding highland rims dominate the basic structure that controls the topography of the Interior Low Plateaus. Here, largely flat-lying sedimentary bedrock is close to the surface, and the area's topography is dependent on its resistance to erosion. Rolling

Region 2

***Cincinnati Arch** • an uplifted region that existed between the Illinois Basin, the Michigan Basin, and the Appalachian Basin during the late Ordovician and Devonian.*

***Cambrian** • a geologic time period lasting from 541 to 485 million years ago.*

***Ordovician** • a geologic time period spanning from 485 to 443 million years ago.*



limestone plains are punctuated with occasional rugged hills, swampy valleys, and expanses of karst. Streams and rivers cut deeply into the softer bedrock.

An extensive dome-like area, the slightly curved **Cincinnati Arch**, dominates the central portion of the Interior Low Plateaus (*Figure 4.21*). This foreland bulge parallels the trend of the Appalachians and stretches through Ohio, Kentucky, and Tennessee much like a slightly wrinkled rug. Erosion has breached the Cincinnati Arch's crest in several areas, forming rounded topographic basins over the otherwise dome-like uplifted strata—examples of inverted topography. The Bluegrass area of Kentucky and the Central Basin of Tennessee are prime examples of this phenomenon. These uplifted structural domes, now eroded into topographic basins, create bowl-shaped depressions that influence surface drainage. Except where large rivers cut the landscape, like the Tennessee and Cumberland rivers in Tennessee and the Kentucky and Licking rivers in Kentucky, drainage occurs toward the centers of the topographic basins. For example, the extensive "1000-year flooding" in Central Tennessee in 2010 occurred as rainwater filled the Central Basin faster than it could find its way out down the nearby rivers.

See Chapter 9: Earth Hazards to learn more about major floods in the Southeastern states.

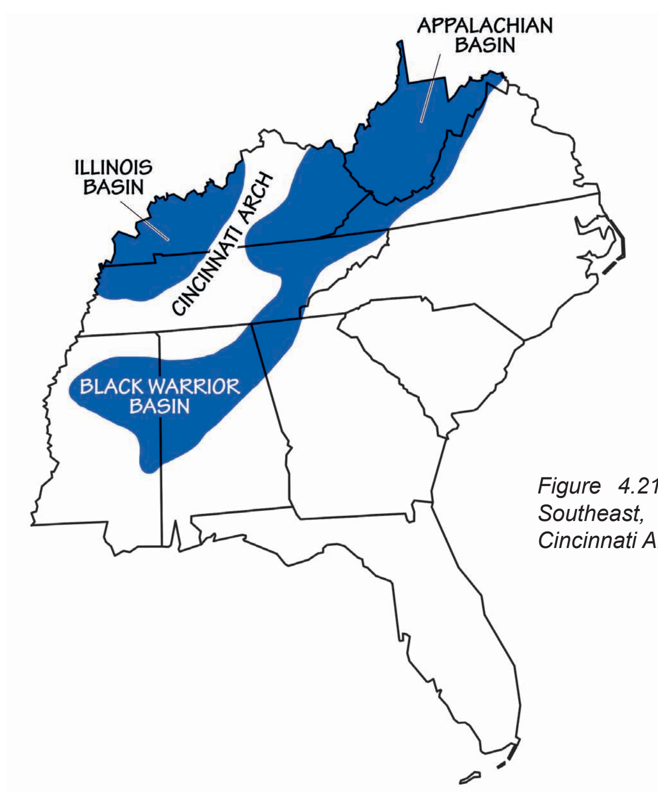


Figure 4.21: Sedimentary basins of the Southeast, separated by the uplifted Cincinnati Arch.

The rims of these basins are generally steep drainage divides that expose cuts of younger to older Paleozoic strata. The bottoms of the basins expose rocks of **Cambrian** to **Ordovician** age, surrounded by the middle and late

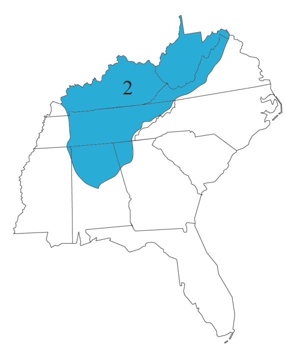
Carboniferous • a geologic time period that extends from 359 to 299 million years ago.

Illinois Basin • an inland basin centered in the state of Illinois, which formed when Baltica approached North America in the Ordovician.

Paleozoic rocks of the rims. For example, the Central Basin is surrounded by a ridge called the Highland Rim, a hilly area that extends south into Alabama, north to the border of Kentucky, east to the Cumberland Plateau, and west to the Tennessee River (*Figure 4.22*). The rocks of the Highland Rim are largely **Carboniferous** in age, while those exposed at the bottom of the Central Basin are Ordovician. Differences in the rock layers' durability have resulted in slight differences in the basins' internal topography, such that that they can be divided into "inner basins" of nearly horizontal strata with low rolling landscapes surrounded by "outer basins" of slightly more dissected rolling hill terrain. The Kentucky Bluegrass is an excellent example—the Inner Bluegrass is an area of gently rolling hills and rich soils of weathered limestone (*Figure 4.23*), while the Outer Bluegrass is characterized by deep erosional valleys. Exposed rocks in the basins are predominantly carbonates that have undergone chemical dissolution to form extensive karst topography (*Figure 4.24*). Sinkholes and cavern systems are common features, as are streams that disappear into the ground.

Figure 4.22: The Buffalo River Valley in central Tennessee marks a major tributary of the Duke River, which cuts through the Western Highland Rim and enters the Tennessee River.

Flanking the Cincinnati Arch and its inverted erosional basins are true down-warped geologic basins that have been centers of deposition for most of their existence. These basins, which escaped the deformational mountain building processes that formed the Appalachians, accumulated and were eventually filled with thick layers of sediment. Today, the topographic expression of these horizontal layers of deposited sediment masks the basins' true structural down-warped shape. The Western Kentucky Coal Field is one such basin and is an extension of the much larger **Illinois Basin** that stretches into the midcontinent.



4 Topography

Region 2

Figure 4.23: The rolling hills of the Inner Bluegrass in Scott County, Kentucky are underlain by shales and limestones.

Figure 4.24: Delicate formations called speleothems grace the walls and ceiling of Mammoth Cave in Kentucky, the longest known cave system in the world. These formations, deposits of dissolved calcium carbonate, grow extremely slowly—about one cubic inch every 100 years! The cave developed in dissolved limestone underlying a layer of resistant sandstone, so its passages are remarkably stable.

Impact Craters

Most Southeastern topography is directly attributable to tectonic forces, deposition, and erosion acting over millions of years. There are a few topographic features that are "extraterrestrial" in origin. Impact craters of varying sizes occur in many areas of the Southeast. The Wells Creek Crater in northwestern Tennessee is an ancient scar produced by an impact that probably occurred during the Paleozoic. The fault-bounded circular pattern, easily visible as a basin surrounded by ridges, is over 12 kilometers (7 miles) in diameter. The Middlesboro Crater on the Cumberland Plateau at the border of Kentucky, Virginia, and Tennessee is also visible at the surface and contains the entire town of Middlesboro, Kentucky. Fracturing of the rocks on the edge of the Middlesboro Crater helped to form the Cumberland Gap, through which Dr. Thomas Walker and Daniel Boone opened up westward expansion beyond the Cumberland Mountains. Other craters in the Southeast include the Wetumpka impact structure in Alabama and the Flynn Creek Crater in Tennessee. See Chapter 2: Rocks for a map of major impact craters in the Southeast.

***gravel** • unconsolidated, semi-rounded rock fragments larger than 2 millimeters (0.08 inches) and smaller than 75 millimeters (3 inches).*

***sand** • rock material in the form of loose, rounded, or angular grains, and formed as a result of the weathering and decomposition of rocks.*

***Cenozoic** • the geologic time period spanning from 66 million years ago to the present.*

Topography of the Coastal Plain
Region 3

The entire eastern and southern margin of the Southeast consists of relatively flat to gently-sloped loose **gravel**, **sand**, and clay sediments of Mesozoic and **Cenozoic** age. The Coastal Plain begins at the Fall Line, where slow erosion of the Piedmont's crystalline rocks forms numerous waterfalls and rapids, and extends east to the Atlantic Ocean and south to the Gulf of Mexico. Rivers flowing east out of the Piedmont over the Fall Line quickly deepen and widen as they erode the Coastal Plain's looser materials. The region's sediments form a thickening "clastic wedge" nearly 15,000 meters (49,000 feet) thick, which extends below sea level to become the continental shelf-slope-rise system. Most of the Atlantic states subdivide the Coastal Plain into an upper hilly and dissected plain and a flatter, sloping lower plain (*Figure 4.25*). From the Atlantic Seaboard, the Coastal Plain wraps around into the Gulf of Mexico, the Gulf Coastal Plain, and up into the Mississippi Embayment at the region's western margin. To the south, the Florida peninsula represents the carbonate Florida Platform.

Region 3

last glacial maximum *• the most recent time the ice sheets reached their largest size and extended farthest toward the equator, about 26,000 to 19,000 years ago.*

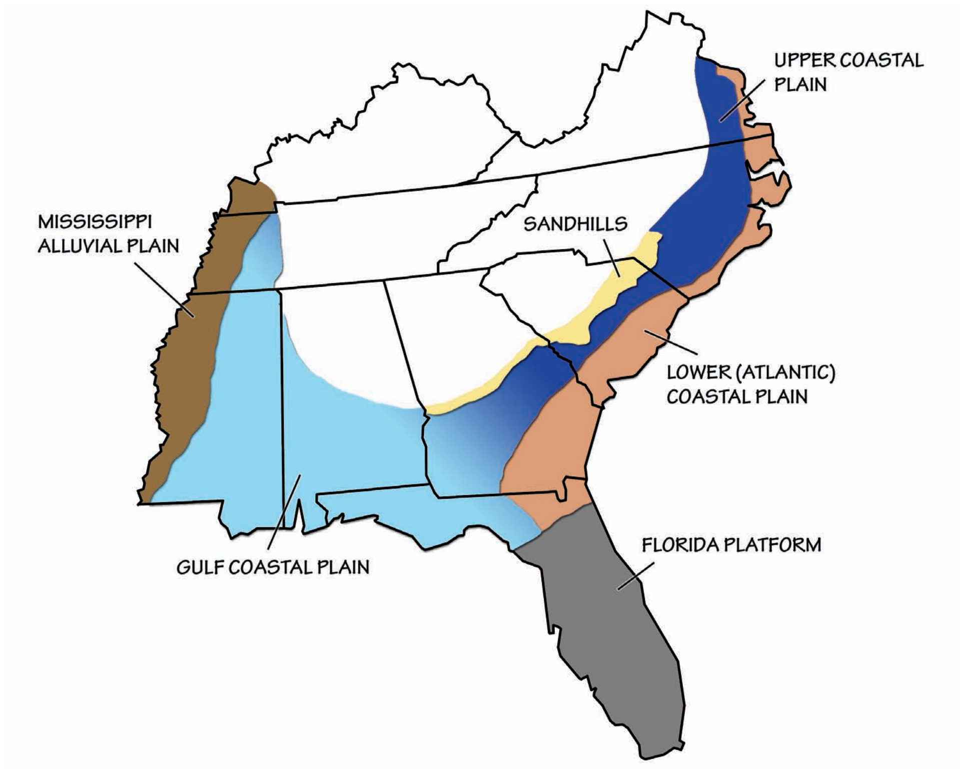


Figure 4.25: Physiographic subdivisions of the Coastal Plain. (See TFG website for full-color version.)

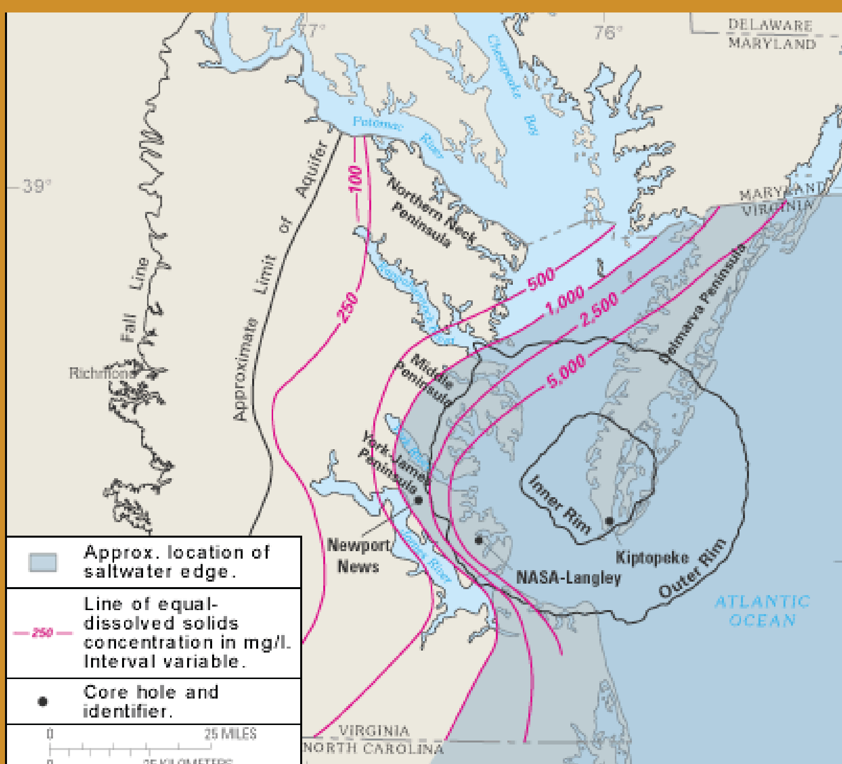
The Gulf and Atlantic Coastal Plain

The interior portions of the Coastal Plain are topographically broad uplands displaying low slopes toward the sea and gentle drainage divides with mostly dendritic drainage structures (*see Figure 4.16*). These rivers, such as the Chattahoochee in Georgia, have their headwaters in the Blue Ridge and Piedmont region (*Figure 4.26*). Where stream erosion has incised more deeply—drainage slopes may show elevations of 20 to 75 meters (60 to 250 feet). Closer to the coast, relief is much more subdued, with elevations ranging from 0 to 20 meters (0 to 60 feet). Coastal boundaries become very irregular with multiple drowned river valleys—broad, deeply indented coastal inlets that represent the original course of a river. In Virginia, the eastward-flowing rivers crossing the Piedmont (e.g., Potomac, Rappahannock, York, and James rivers) become tidal estuaries that empty into the Chesapeake Bay, itself a uniquely large drowned river, which then empties into the Atlantic Ocean (*Figure 4.27*). For example, the Susquehanna River flows through the Chesapeake lowland region for more than 90 kilometers (56 miles) before emptying into the modern Chesapeake Bay, which was submerged about 5000 to 6000 years ago with the drowning of the Susquehanna's lower reaches.

Several drops in sea level since the **last glacial maximum** have resulted in topography that preserves relict shorelines traceable into the Gulf and Atlantic coasts. In fact, much of the currently drowned continental shelf was emergent

Chesapeake Bay

The Chesapeake Bay owes its original existence to an impact event that occurred 35 million years ago. The circular Chesapeake Bay Crater (over 85 kilometers [53 miles] in diameter and 1.3 kilometers [0.8 miles] deep) is not currently visible at the surface because it was modified by later processes of erosion and deposition; however, the deep depression of the impact topographically influenced the drainages that produced the present-day Chesapeake Bay—explaining why it is the only drowned river of its size on the East Coast.



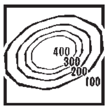
Boundaries of the Chesapeake Bay Impact Crater

low coastal plain during the last **ice age**. Relatively low, wide, and flat **terraces** stairstep downward in elevation toward the coast (*Figure 4.28*). Narrow steps that mark former shorelines, known as scarps, are recognized by narrow contour lines traceable at the same elevation throughout the Southeast. Higher terraces to the west represent older and higher shorelines formed when sea level was higher, during **interglacial** periods; lower terraces formed when sea

__ice age__ • a period of global cooling of the Earth's surface and atmosphere, resulting in the presence or expansion of ice sheets and alpine glaciers.

__terrace__ • a flat or gently sloped embankment or ridge occurring on a hillside, and often along the margin of (or slightly above) a body of water, representing a previous water level.

__interglacial__ • a period of geologic time between two successive glacial stages.

4 

Topography

Region 3

Figure 4.26: From its source in Georgia's Blue Ridge Mountains, the Chattahoochee River flows southwest to form the southern half of the Alabama/Georgia state line before entering the Florida Panhandle.

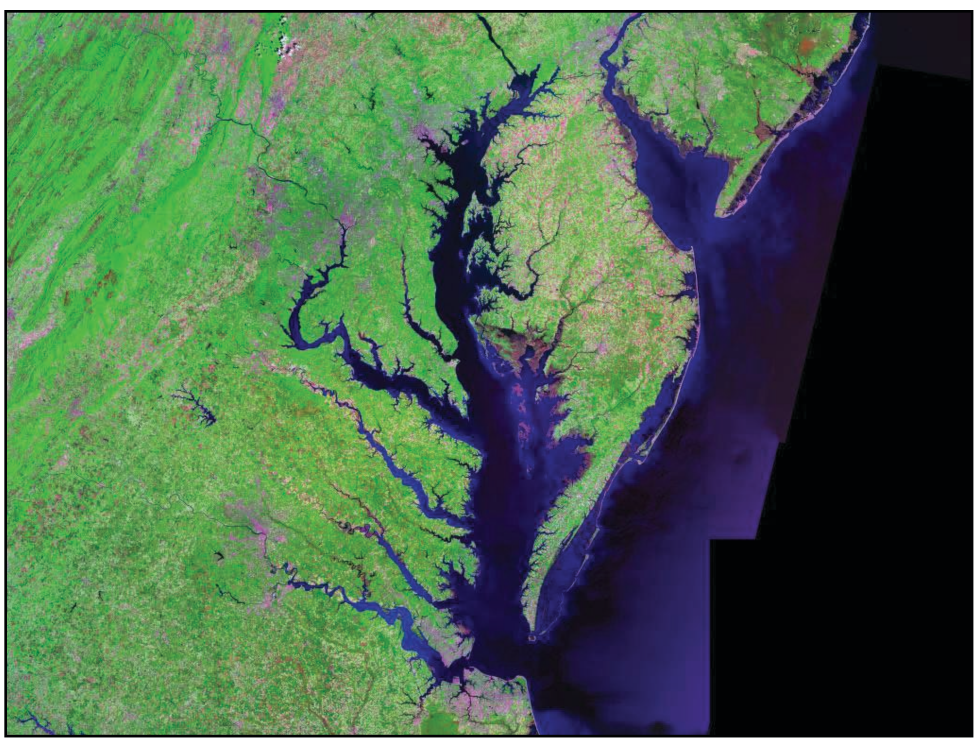


Figure 4.27: A satellite image of Chesapeake Bay on Virginia's Atlantic coast.

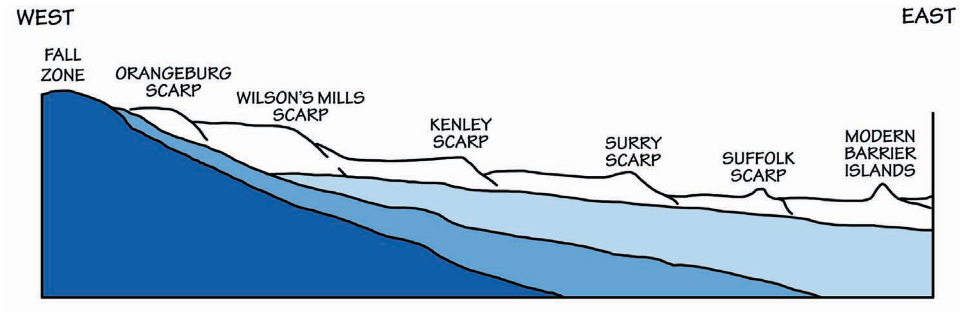


Figure 4.28: The scarps and intervening terraces of North Carolina's Coastal Plain.

level dropped during glaciations. In South Carolina, seven terrace-scarp pairs stairstep the topography of the lower Coastal Plain, representing seven cycles of the receding ocean levels. These seven sea level shifts are traceable along the Atlantic seaboard and include two that occurred during the **Pliocene** epoch, followed by four during the Pleistocene epoch and the current Holocene shift. For example, the Orangeburg Scarp, extending from central North Carolina to northeast Florida, formed from wave erosion during an interval of high sea level during the mid- to late Pliocene (3.5–2.5 million years ago).

See Chapter 8: Climate to learn about sea-level change throughout Earth history and its implications for the future.

The Sandhills, a strip of ancient beach dunes, are a distinctive feature of the Upper Coastal Plain and stretch from North Carolina into Georgia along the Fall Line. This formation of broad flat ridges and rolling hills formed from a combination of fluvial **Cretaceous** sediments deposited around 90 million years ago by meandering streams, and marine sediments deposited about 45 million years ago during a sea level highstand (*Figure 4.29*). These sandy sediments are highly **permeable**, easily absorbing precipitation; as a result, the Sandhills are not highly eroded. A portion of South Carolina's peach industry thrives in the area's sandy soils.

An unusual topographic feature of the Lower Coastal Plain, best seen in North and South Carolina, are the Carolina Bays. These are not actually marine coastal bays, but large, elliptical inland depressions whose long axes are aligned in the same general northwest to southeast direction (*Figure 4.30*). The bays are often difficult to visualize from land, as their rims can be only a few centimeters in height. They can be as large as thousands of acres, and nearly 500,000 of them occupy the Atlantic Coastal Plain. They are visible on maps and photographs from space, especially where lakes, boggy swamps, or savannahs occupy the bays. Several theories have been proposed for the Bays' formation, including sea currents, groundwater seepage, **aeolian** processes, and even extraterrestrial impact.

Pliocene *• a geologic time interval extending from roughly 5 to 2.5 million years ago.*

Cretaceous *• a geologic time period spanning from 144 to 66 million years ago.*

permeability *• a capacity for fluids and gas to move through fractures within a rock, or the spaces between its grains.*

aeolian *• pertaining to, caused by, or carried by the wind.*

4 Topography

Region 3

Figure 4.29: The Sandhills of Peachtree Rock Preserve in South Carolina support a scrubby forest of longleaf pine and oak.

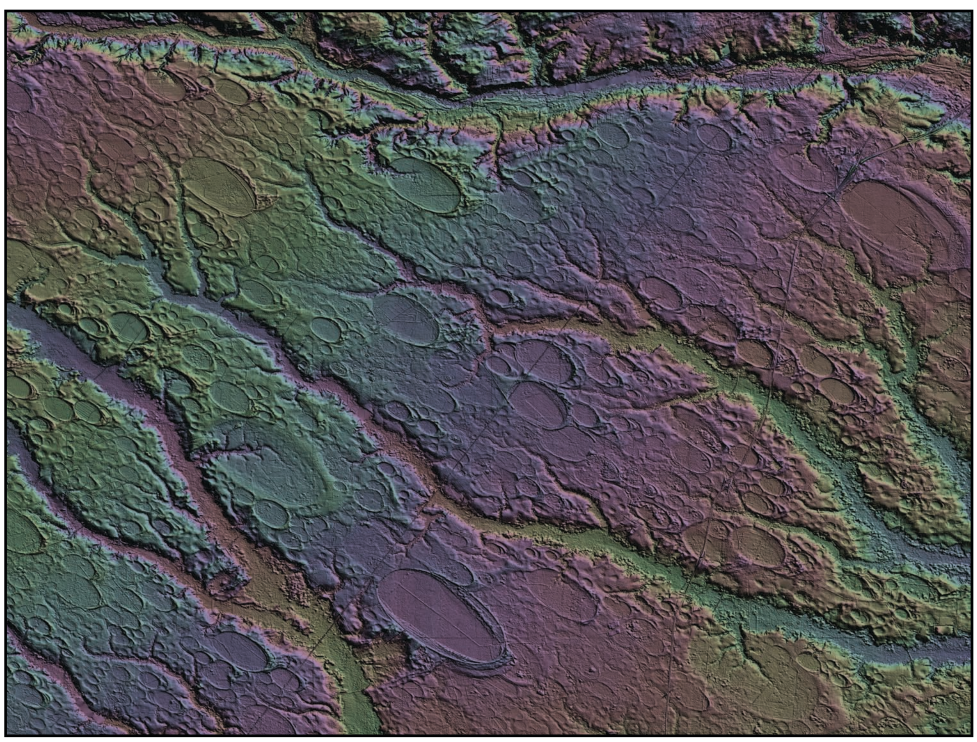


Figure 4.30: Digital elevation map data collected by remote sensing LIDAR technology reveals the presence of hundreds of Carolina Bays in a 600-square-kilometer (230-square-mile) segment centered on Robeson County, North Carolina.

Extending from the eastern Shore of Virginia along the coasts of North and South Carolina, Georgia, and portions of Florida is an extensive **barrier island** complex. Locally, the shapes of barrier islands can change from submergent coastlines protected by relatively linear, thin ribbons of island (Outer Banks, North Carolina) to beach-fronted mainlands with smaller barriers (South Carolina, Georgia, and south into Florida). Along the Gulf Coast, barrier islands also extend to the Mississippi River Delta. Barrier islands of the Atlantic region are zoned ribbons of mostly **quartz** sand, dynamically sculpted into beaches, dune fields (e.g., Kitty Hawk, North Carolina), marshes, and protected sounds. In North Carolina, the linear stretches of the Outer Banks separate the Atlantic Ocean from the much more irregularly shaped marshes and protected bays of Pamlico and Albemarle sounds. Thanks to the protection of the Outer Banks, Pamlico and Albemarle sounds have the distinction of being the two largest "landlocked" bays on the East Coast. At Capes Hatteras, Lookout, and Fear, the direction of the Outer Banks shift, making sharp, prominent turns. Storm systems and shifting sand bars have caused hundreds of shipwrecks, and North Carolina's barrier islands are sometimes called "The Graveyard of the Atlantic."

Most topography in the eastern Gulf Coast mimics that of the Atlantic Coast; however, beginning at Mobile Bay in Alabama, some notable coastal changes occur. Mobile Bay is a submerged, drowned river valley. East of the bay, barrier islands form close to the mainland or occur as long spits attached to the mainland (e.g., Fort Morgan Peninsula, Alabama) with only small estuarine bays behind them. West of Mobile Bay, a long line of thin, offshore barrier islands (e.g., Dauphin, Petit Bois, Ship, and Horn islands) stretches latitudinally to the Mississippi River Delta, protecting an extensive waterway called the Mississippi Sound (*Figure 4.31*). Gulf barrier islands are similar in topography and zonation to the Outer Banks, but tend to be shorter and narrower. They constantly change shape due to storms entering the Gulf.

The Florida Platform

The majority of Florida is situated much farther south than the rest of the Coastal Plain, stretching toward the subtropics. While most topography in northern Florida and the Florida Panhandle resembles that of the Atlantic and Gulf coasts (especially in terms of terracing), middle peninsular and southern Florida is a relatively flat carbonate platform, originally formed underwater and now exposed barely above sea level (*Figure 4.32*). The Florida Platform divides the Gulf of Mexico from the Atlantic Ocean, and on its western margin (the Florida Escarpment) steep undersea cliffs drop off sharply to over 3000 meters (10,000 feet) in depth. The terrestrial Florida peninsula is located toward the eastern side of the platform, which terminates as few as 5 to 6.5 kilometers (3 to 4 miles) from the land's edge. The Florida Platform's carbonate rocks have easily eroded to produce a flat, subdued topography throughout central and southern Florida. The platform's bedrock is overlain by a layer of **porous** karst limestone, which has eroded to produce extensive systems of caves, sinkholes, and springs.

Florida's karst contains the most productive **aquifer** in the US, called the Floridian Aquifer. It is composed largely of Paleocene and Miocene limestone.

barrier island *• a long, thin island next to and parallel to a coastline.*

quartz *• the second most abundant mineral in the Earth's continental crust (after the feldspars), made up of silicon and oxygen (SiO_2).*

porosity *• the percentage of openings in a body of rock such as pores, joints, channels, and other cavities, in which gases or liquids may be trapped or migrate through.*

aquifer *• a water-bearing formation of gravel, permeable rock, or sand that is capable of providing water, in usable quantities, to springs or wells.*

4 Topography

Region 3

Figure 4.31: Mobile Bay, Alabama, with associated barrier islands.

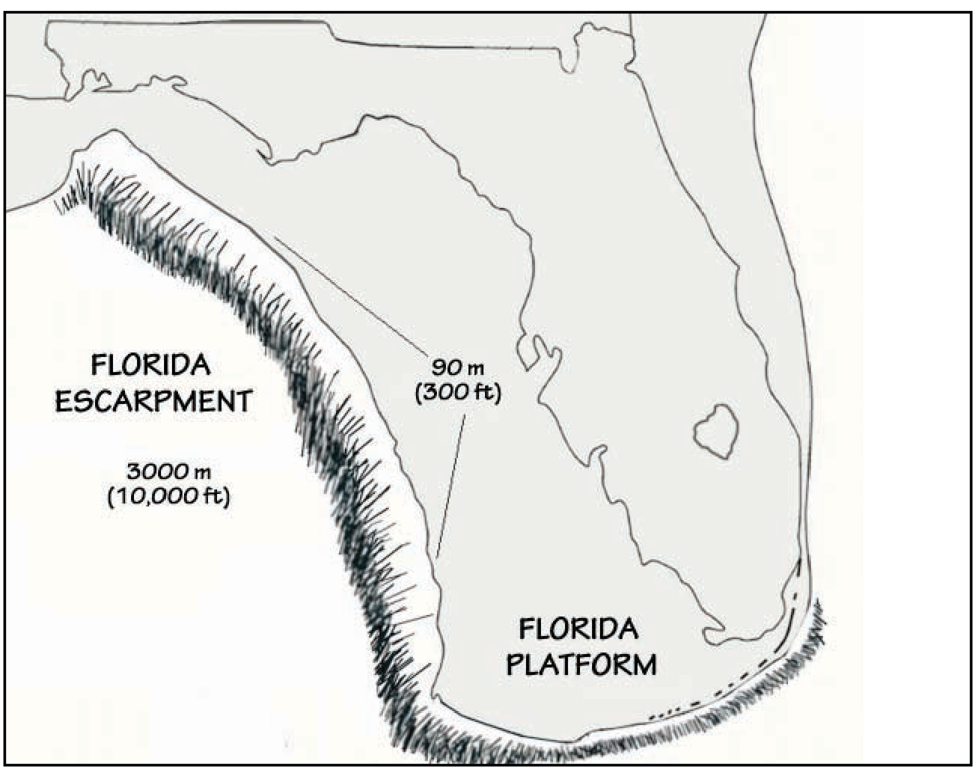


Figure 4.32: The extent of the Florida Platform and surrounding water depths.

This aquifer underlies all of Florida, as well as parts of South Carolina, Georgia, and Alabama. In the northwest part of peninsular Florida, between Tampa Bay and Tallahassee, the aquifer is *unconfined*, meaning water can flow directly between it and the surface. Elsewhere, it is *confined* beneath a less permeable layer, and thus under pressure. One result of this is that Florida has numerous springs (more than 700, including large ones, such as Wakulla Springs in Wakulla County, and Weeki Wachee Springs in Hernando County), which are natural **artesian** outflows from the Floridian Aquifer (*Figure 4.33*). Water temperatures in these springs are usually relatively constant (generally around 24°C [75°F]), and as a result some of them provide unique habitat for several species of plants and animals, including manatees.

artesian *• a channel that releases pressure from an aquifer, allowing the aquifer's internal pressure to push the water up to the surface without the aid of a pump.*

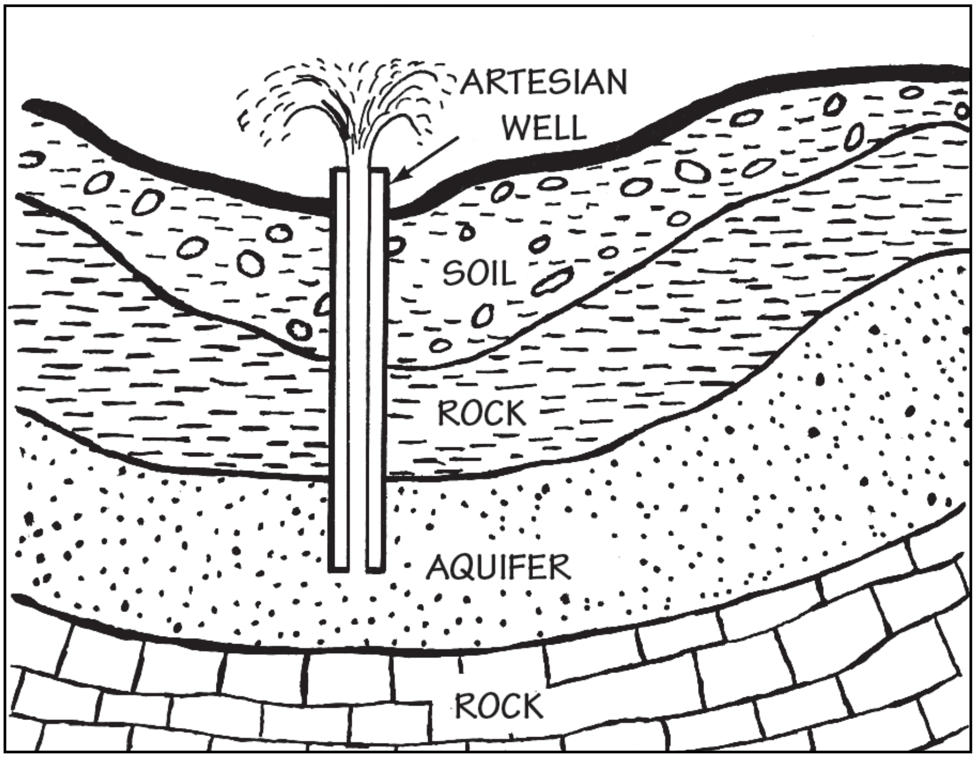


Figure 4.33: Diagram of an artesian well, following the same principle as a natural artesian spring. Water beneath an impermeable layer of rock is frequently under pressure. When a well or natural channel opens into the aquifer, the internal pressure pushes the water up to the surface without the aid of a pump.

Lake Okeechobee (in the lower half of peninsular Florida; *see Figure 4.32*) is the largest freshwater lake in Florida and the seventh largest in the US, covering 1900 square kilometers (730 square miles). The lake sits in a shallow trough underlain by compacted clay deposits; water flowing into the topographical low originally built up wetlands that were later drowned as water level increased. Lake Okeechobee is extremely shallow, with an average depth of only 3 meters (9 feet), but it can hold 3.8 trillion liters (1 trillion gallons) of water at its fullest capacity, and it is the headwaters of the Everglades. The Everglades are the "World's Largest Sawgrass Swamp"—rarely more than 2 meters (6.5 feet)

Groundwater

Groundwater is the water present beneath Earth's surface in pore spaces in the soil and in fractures in subsurface rock. A unit of rock or an unconsolidated deposit is called an aquifer if it can yield a usable quantity of water. The level below which groundwater saturates the aquifer is called the water table. All groundwater ultimately comes from precipitation, which percolates into the aquifer from the surface in a process called recharge. Groundwater naturally comes to the surface in springs, seeps, and wetlands. It is also withdrawn through wells for agricultural, industrial, or municipal use.

Groundwater supplies approximately 25% of the fresh-water used by humans each year in the US. (the rest comes from surface water, such as rivers and lakes). This varies geographically; in Florida and Mississippi, more than 60% of all freshwater used comes from groundwater, whereas in most of the other Southeastern states it is less than 10%.

The amount of water that can be removed from an aquifer depends on its recharge rate and permeability. Recharge depends on precipitation and human use, both of which are affected by climate. Permeability refers to the ease with which water can move through the aquifer. This property varies widely, depending on the type of materials that constitute the aquifer. Fine-grained material such as clay or silt is less permeable than sand and gravel. Crystalline rocks such as granite have a very low permeability unless they have been fractured, creating openings through which groundwater can move.

in relief, but covering 13,000 square kilometers (5000 square miles) of land. The Everglades swamp is really a river flowing south from Lake Okeechobee to Florida Bay. Slight topographic highs, called "hammocks," punctuate the swamp (*Figure 4.34*).

Region 3

__reef__ • a feature lying beneath the surface of the water, which is a buildup of sediment or other material built by organisms, and which has positive relief from the sea floor.

__Rodinia__ • a supercontinent that contained most or all of Earth's landmass, between 1.1 billion and 750 million years ago, during the Precambrian.

__embayment__ • a bay or recess in a coastline.

Figure 4.34: Mangroves and hardwood hammocks punctuate the Florida Everglades' vast tall-grass swamp.

At the southern tip of Florida lies a curved island archipelago, the Florida Keys, extending out toward the southwest. The Keys are the exposed remnants of an ancient coral **reef** chain, and reefs continue to grow in the warm, tropical waters to the south. At the western tip of the Keys are the Dry Tortugas islands, a cluster of smaller islets. The majority of the Florida Keys occur in the Florida Straits, which separate the Gulf of Mexico and the Atlantic Ocean.

Florida has the longest coastline in the contiguous United States, at a length of about 2170 kilometers (1350 miles).

The Mississippi Embayment

The Mississippi Embayment, stretching from Illinois to Louisiana, actually originated in the Precambrian during the breakup of **Rodinia**. Many smaller rifts in the crust formed adjacent to the major rift that split North America away from the supercontinent. One of these smaller rifts is located beneath the modern day Mississippi Embayment. During parts of the Paleozoic era, a proto-Mississippi Embayment existed above the rift. During the Cretaceous, the ocean flooded the **embayment**, and when sea level fell, the Mississippi River was born. Thousands of meters of sediment were deposited in the river valley. Mississippi's major aquifers are found within and beneath these thick beds of sediment. Recurrent activity along faults associated with the deeply buried ancient rifts beneath the embayment caused the 1811–1812 New Madrid Earthquake, one of the largest **earthquakes** ever recorded in North America.

See Chapter 1: Geologic History for more information about the rifting of early supercontinents.

See Chapter 9: Earth Hazards to learn more about the New Madrid Seismic Zone.

4 Topography

Region 3

earthquake • *a sudden release of energy in the Earth's crust that creates seismic waves.*

oxbow • *a stream meander in the shape of a "U," named after the U-shaped collar of an ox yoke.*

levee • *a deposit of sediment built up along the sides of a river's floodplain, or an artificial embankment along a waterway to prevent flooding.*

progradation • *outward building of strata toward the sea in the form of a beach, fan, or delta.*

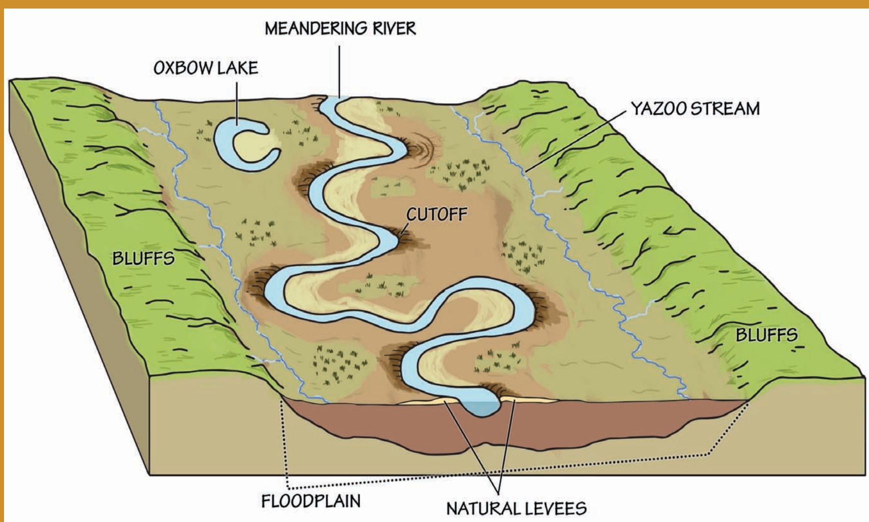
The Mississippi River Valley is bounded by a bluff line paralleling the river course, marking the extent of its meandering river path. The Mississippi is an archetypical meandering river system, and has a very low topographic profile within the valley. Maps show that the river's meandering, snake-like path that has shifted periodically, cutting off some of its loops to produce **oxbows**. Flanking the river itself is a pair of high, linear ridges called **levees**, naturally deposited during flood events, which confine the river course. These are usually the highest elevations of the otherwise wide extensive floodplain. Occasionally, "yazoo tributaries"—small tributary streams running parallel to the larger river—develop on the floodplains.

The extensive Mississippi River Delta, an extremely important coastal area in North America, marks the Southeast's western coastal margin. It is the United States' largest drainage basin, creating a very active depositional environment. The deposits become increasingly younger toward the gulf, due to a depositional process called **progradation**. During this process, the river forms a deposit at its margin, and then overflows it and deposits material on the far side in a continual outward movement. Typical of deltas, the topography here consists of low swampland and lakes. The delta's overall shape is a series of rounded lobes extending out in a "birdfoot" form as they are built up through deposition (*Figure 4.35*). In front of the delta, barrier islands are found in a more north-south orientation (e.g., Cat Island and Chandeleur Islands). The Mississippi River Delta is the terminus for the Mississippi River floodplain system that extends north to Cairo, Illinois.

Figure 4.35: The Mississippi River Delta and sediment plumes from the Mississippi and Atchafalaya rivers.

Meandering Rivers and Streams

A meandering river forms when moving water erodes its banks, widening the river valley and taking on a sinuous shape. Sediments are swept up from the outside edge of river bends, where water flows more swiftly, and deposited back on the bank's inside. Over time, the river or stream forms a snaking pattern across its valley, resulting in a wide, flat floodplain and other representative features such as oxbow lakes. An oxbow lake forms when erosion cuts a meander off from the main stream, creating a U-shaped, freestanding body of water.



Highest and Lowest Elevations by State

Alabama
Alabama's highest point is Cheaha Mountain, a 735-meter-high (2413-foot-high) mountain in the Talladega Mountains, the southernmost segment of the Blue Ridge. Thanks to its tall relief, today the mountain is host to a variety of radio antennas and TV transmitters. The state's lowest point is the shore of the Gulf of Mexico, which lies at sea level.

Florida
Britton Hill, rising 105 meters (345 feet) above sea level, is Florida's highest natural point. The hill, located in Walton County about a half mile south of the Alabama border, is the lowest state high point in the US. The lowest points in Florida are found at sea level along the state's Atlantic and Gulf coastlines.

4 Topography

Elevations

Georgia
The Chattahoochee-Oconee National Forest is home to Brasstown Bald, Georgia's highest mountain. At 1458 meters (4784 feet) in elevation, the peak offers 360 degree views of four states—Georgia, North Carolina, Tennessee, and South Carolina—and on clear days, even the skyline of Atlanta is visible. Georgia's lowest points are found at sea level along the coast, where the shoreline meets the Atlantic Ocean.

Kentucky
At 1263 meters (4139 feet) above sea level, Black Mountain is Kentucky's highest point, located in the Appalachians near the Virginia border in Harlan County. The mountain is located near rich coal veins and was threatened by mountaintop removal mining until the state purchased rights to the summit in 1999. The Mississippi River at Kentucky Bend in southwestern Kentucky is the lowest point in the state, with an elevation of 78 meters (257 feet).

Mississippi
Mississippi's highest point is Woodall Mountain, with an elevation of 246 meters (807 feet). The mountain was originally called Yow Hill, and it was the scene of the 1862 Battle of Iuka during the American Civil War. It is located near Mississippi Highway 25 in the state's northeastern corner. The lowest points in Mississippi are found along the coast, where the shoreline meets the Gulf of Mexico.

North Carolina
At 2037 meters (6684 feet) in elevation, Mt. Mitchell is the highest peak in North Carolina as well the tallest mountain in mainland eastern North America. Mt. Mitchell is part of the Black Mountain subrange of the Appalachians, and is located about 31 kilometers (19 miles) northeast of Asheville. The mountain is named for professor Elisha Mitchell, who first explored the Black Mountains in 1835, and fell to his death at nearby Mitchell Falls when he returned in 1857 to verify his measurements. North Carolina's lowest points are along its coastline, where the shore is at sea level.

South Carolina
Sassafras Mountain, in the Blue Ridge Mountains of northern Pickens County, is South Carolina's highest point. Although the mountain stands 1083 meters (3554 feet) above sea level, it is accessible from a parking lot at the summit. South Carolina's coast, where the shoreline meets the Atlantic Ocean, is the state's lowest point.

Tennessee
Tennessee's highest point is Clingmans Dome, the highest mountain in the Great Smoky Mountains as well as the highest point along the 3499-kilometer (2174-mile) Appalachian Trail. At 2025 meters (6643 feet), it is the third highest mountain east of the Mississippi River, and on clear days offers a panoramic view of seven states: Tennessee, North Carolina, South Carolina, Kentucky, Virginia, Alabama, and Georgia. The Mississippi River at Tennessee's western border is the state's lowest point at 54 meters (178 feet) above sea level.

Virginia

Mt. Rogers, located in Jefferson National Forest on Virginia's border with North Carolina, is the state's highest point, with an elevation of 1746 meters (5729 feet). The mountain is named for William Barton Rogers, Virginia's first State Geologist who also went on to found the Massachusetts Institute of Technology. Virginia's lowest points are along the coast where the Atlantic Ocean touches the shore.

West Virginia

In the Appalachians, the highest point on a ridge is often called a "knob" or "dome." Spruce Knob—the summit of Spruce Mountain, the highest peak in the Allegheny Mountains—is West Virginia's highest point at 1482 meters (4863 feet) above sea level. The lowest point in West Virginia is the Potomac River at Harpers Ferry in Jefferson County, with an elevation of 73 meters (240 feet).

Resources

Books

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Topoquest, https://www.topoquest.com/.

Websites

OpenLandform Catalog, Education Resources, OpenTopography, http://www.opentopography.org/index.php/resources/lidarlandforms. (High resolution topographic images that may be useful in teaching.)

Teaching Geomorphology in the 21st Century, On the Cutting Edge' Strong Undergraduate Geoscience Teaching, SERC, http://serc.carleton.edu/NAGTWorkshops/geomorph/index.html. (A set of resources for college level, some of which may be adaptable to secondary education.)

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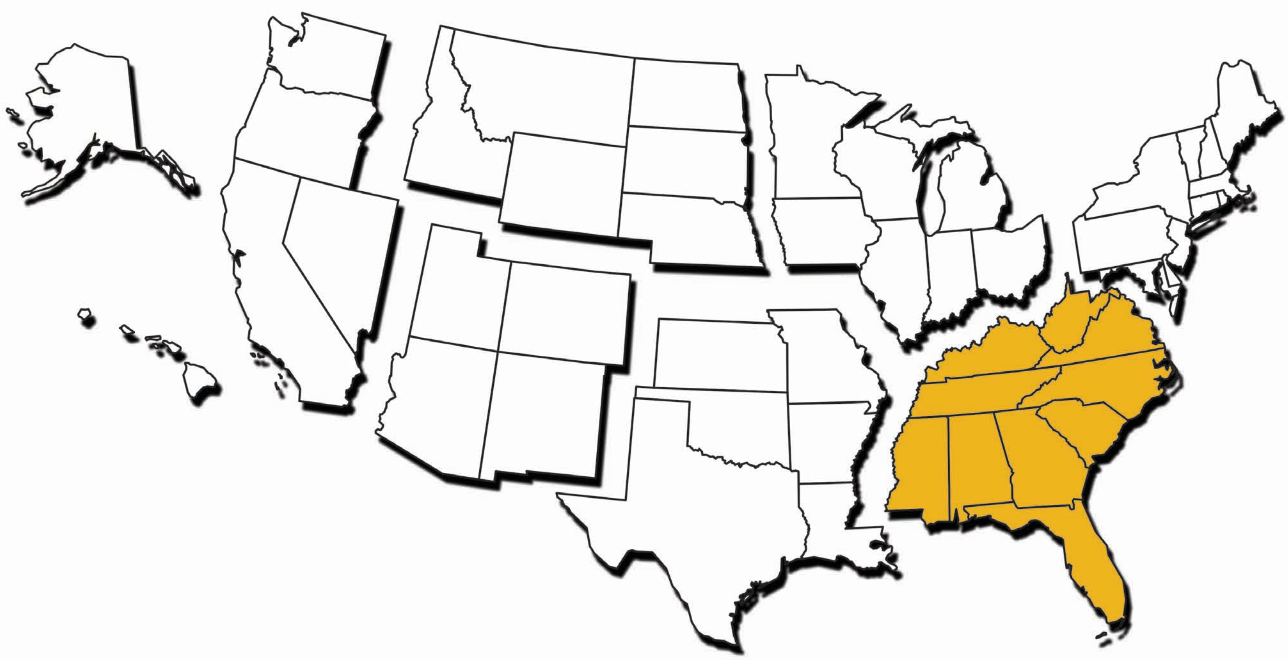

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On the back cover: Blended geologic and digital elevation map of the Southeastern US. Each color represents the age of the bedrock at the surface. Adapted from Barton, K. E., Howell, D. G., Vigil, J. F., *The North America Tapestry of Time and Terrain*, US Geological Survey Geologic Investigations Series I-2781, http://pubs.usgs.gov/imap/i2781.