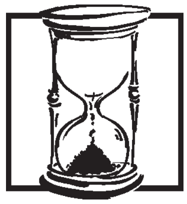

Chapter 1: Geologic History of the Southeastern US: Reconstructing the Geologic Past

Geologic history is the key to this guide and to understanding the story recorded in the rocks of the Southeastern US. By knowing more about the geologic history of your area, you can better understand the types of rocks that are in your backyard and why they are there. In this chapter, we will look at the history of the Southeast as it unfolded: as a series of major events that created and shaped the area over the past one billion years. These events will act as the framework for the topics in the chapters to follow and will shed light on why our region looks the way it does!

The shape and position of North America has changed dramatically over the last billion years, and geologic processes continue these changes today. The Earth's outer layer—the **crust**—is dynamic, consisting of constantly moving **plates** that are made of a rigid continental and oceanic **lithosphere** overlying a churning, plastically flowing **asthenosphere**—part of the Earth's **mantle** (*Figure 1.1*). These plates are slowly pulling apart, colliding, or sliding past one another with great force, creating strings of **volcanic islands**, new ocean floor, **earthquakes**, and mountains. The continents are likewise continuously shifting position relative to each other. This not only shapes the land, but also affects the distribution of rocks and **minerals**, natural resources, **climate**, and life.

How do we know what the past is like?

Reconstructing the geologic past is a lot like solving a mystery. Geologists use scraps of evidence to piece together events they have not personally observed, but to do so they must contend with two major complications. First, the overwhelming majority of geologic history occurred long before there were any human witnesses. Second, much of the evidence for the older events is highly fragmented. By studying rocks, **fossils**, and other geologic features, however, scientists can still reconstruct a great deal of what the ancient Earth might have looked like.

Rocks and sediments are indicators of past geologic processes and the environments in which those processes took place. In general, **igneous rocks**, created through tectonic activity, reflect the history of molten rock, both below the surface (**plutonism**) and at the surface (**volcanism**). Likewise, **metamorphic rocks**, created

See Chapter 2: Rocks to learn more about the different types of rocks found in the Southeast.

crust • *the uppermost, rigid outer layer of the Earth.*

plates • *large, rigid pieces of the Earth's crust and upper mantle, which move and interact with one another at their boundaries.*

lithosphere • *the outermost layer of the Earth, comprising a rigid crust and upper mantle broken up into many plates.*

asthenosphere • *a thin semifluid layer of the Earth, below the outer rigid lithosphere, forming much of the upper mantle.*

mantle • *the layer of the Earth between the crust and core.*

volcanic island • *one of a string of islands created when molten rock rises upward through oceanic crust.*

CHAPTER AUTHORS

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Geologic History

Reconstructing

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

ultramafic rocks • *igneous rocks with very low silica content (< 45%), which are composed of usually greater than 90% mafic minerals.*

metamorphic rocks • *rocks formed by the recrystallization and realignment of minerals in pre-existing sedimentary, igneous, and metamorphic rocks when exposed to high enough temperature and/or pressure.*

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

sedimentary rock • *rock formed through the accumulation and consolidation of grains of broken rock, crystals, skeletal fragments, and organic matter.*

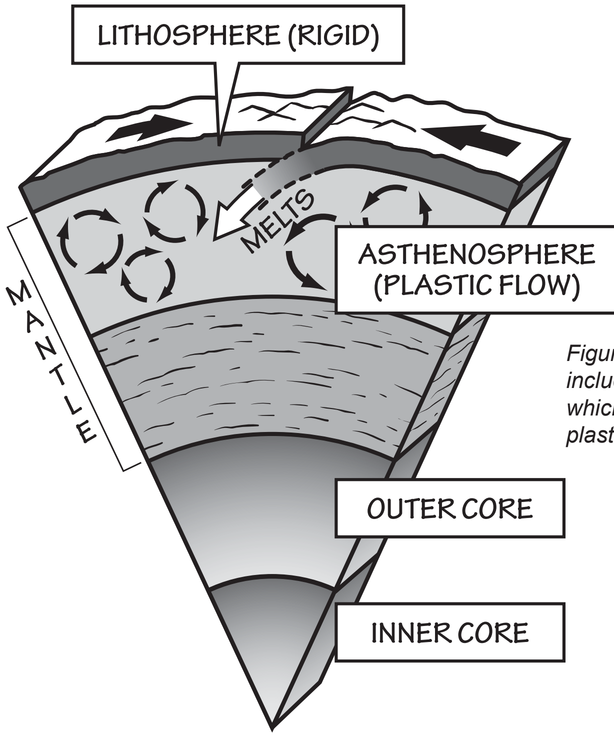


Figure 1.1: The layers of the Earth include the rigid crust of the lithosphere, which is constantly moving over the plastically flowing asthenosphere.

Lithosphere and Asthenosphere: What's the difference?

The lithosphere is the outermost layer of the Earth, a rigid layer of crust and upper mantle broken up into fragments called plates. Although the rock of the asthenosphere would seem very solid if you could observe it in place, under long-term stress it slowly bends and flows, like very thick syrup. The difference between crust and mantle is mainly chemical: the lithosphere's composition typically varies between basalt in oceanic crust and *granite* in continental crust, while the mantle is composed of homogenous *ultramafic* material. The boundary between rigid lithosphere and flowing asthenosphere is usually found within the mantle, and is largely a result of temperature increase with depth beneath the surface. In tectonically active regions of extension such as a mid-ocean ridge, where temperature rises rapidly with depth compared to more tectonically stable regions, the asthenosphere begins nearly at the base of the crust.

when sediment is subjected to intense **heat** and pressure, provide important clues about past mountain-building events, and geologists often use them to map the extent of now-vanished mountain ranges. **Sedimentary rocks** tell perhaps the most comprehensive story of the Earth's history, as they record characteristics of far-away mountain ranges, river **systems** that transported the sediments, and the final environment in which the sediments accumulated and **lithified**. The size and shape of sediments in sedimentary rocks, as well as the presence of fossils and the architecture of sedimentary rock layers (sedimentary structures), can help us infer how the sediments were transported and where they were finally deposited. However, because rocks are often reformed into different rock types, ancient information is lost as the rocks cycle through the igneous, metamorphic, and sedimentary stages.

Fossils indicate both the type of life that once flourished in an area and the kind of climate in which that life existed. Paleontologists use groups of fossils found in the same place to construct pictures of ancient ecosystems. These ecosystems of the past are matched to similar present-day ecosystems, whose climate conditions are then used to infer what sort of climate the fossilized organisms lived in. Unfortunately, few organisms can be easily preserved as fossils, and many environments also do not lend themselves to preserving organisms as fossils. As a result, the clues that fossils give us provide only incomplete glimpses of the ancient world, with many important details missing.

See Chapter 3: Fossils for more information about the Southeast's prehistoric life.

Landscapes and geologic structures are also indicators of past geologic processes and the environments in which they occurred. For instance, the shape of a valley reflects the forces that carved it. Valleys with V-shaped profiles tend to be the products of stream **erosion**, whereas U-shaped valleys are more likely to have been carved by **glaciers**. Layers of intensely folded rock indicate a violent past of tectonic plate collisions and mountain building. Sedimentary structures, such as **ripple marks** or **cross-bedding**, can demonstrate the direction and energy level of the water that transported the sediment. Although landscapes tell us much about the geologic processes that created them, they inevitably change over time, and information from the distant past is overwhelmed by the forces of the more recent past.

See Chapter 4: Topography for more detail about the landscape of the Southeastern states.

Ultimately, geologists rely upon the preserved clues of ancient geologic processes to understand Earth's history. Because younger environments retain more evidence than older environments do, the Earth's recent history is better known than its ancient past. Although preserved geologic clues are indeed fragmentary, geologists have become increasingly skilled at interpreting them and constructing ever more detailed pictures of the Earth's past.

Reconstructing

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

lithification • *the process of creating sedimentary rock through the compaction or sementation of soft sediment.*

erosion • *the transport of weathered materials.*

glacier • *a body of dense ice on land that does not melt away annually and has sufficient mass to move under its own weight.*

ripple marks • *surface features created when sediment deposits are agitated, typically by water currents or wind.*

cross-bedding • *layering within a bed in a series of rock strata that does not run parallel to the plane of stratification.*

1 Geologic History

Reconstructing

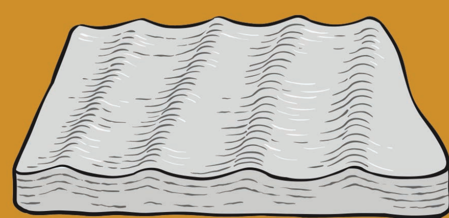
geologic time scale • *a standard timeline used to describe the age of rocks and fossils, and the events that formed them.*

Archean • *a geologic time interval that extends from 4 billion to 2.5 billion years ago.*

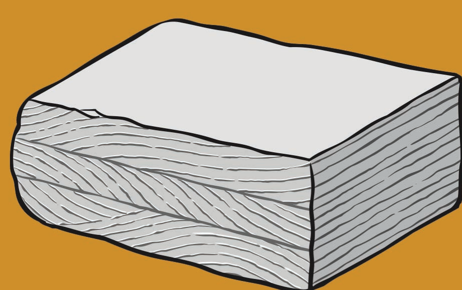
Proterozoic • *a geologic time interval that extends from 2.5 billion to 541 million years ago.*

Sedimentary Structures

Sedimentary rocks often reveal the type of environment in which they formed by the presence of structures within the rock. Sedimentary structures include ripple marks, cross-beds, mud cracks, and even raindrop impressions. Consider the type of environments in which you see these sedimentary structures today in the world around you.



Ripple marks suggest the presence of moving water (though wind can also create ripples and even dunes). Mud cracks indicate that the sediment was wet but exposed to the air so that it dried and cracked.



Cross-beds form as flowing water or wind pushes sediment downcurrent, creating thin beds that slope gently in the direction of the flow as migrating ripples. The downstream slope of the ripple may be preserved as a thin layer dipping in the direction of the current, across the natural flat-lying repose of the beds. Another migrating ripple will form an additional layer on top of the previous one.

Earth's Timeline

The **geologic time scale** (*Figure 1.2*) is an important tool used to portray the history of the Earth—a standard timeline used to describe the age of rocks and fossils, and the events that formed them. It spans Earth's entire history and is divided into four principal sections.

The first of these four divisions, the **Precambrian**, extends from the beginning of the Earth, around 4.6 billion years ago, to the beginning of the **Cambrian** period, around 541 million years ago. The Precambrian is subdivided into two sections: the **Archean** (before 2.5 billion years ago) and the **Proterozoic** (2.5

Geologic History

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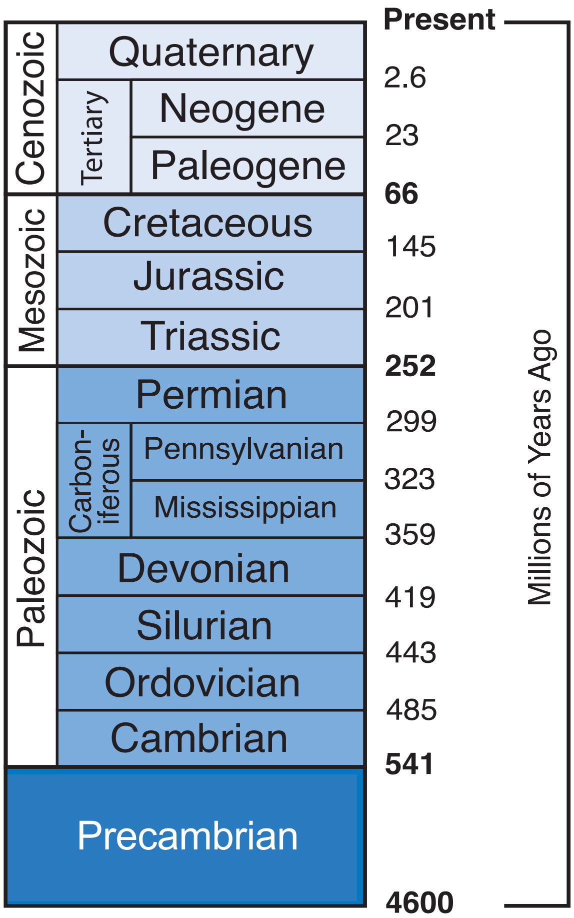
Reconstructing



About the Time Scale:
The time scale in The Teacher-Friendly Guides™ *follows that of the International Commission on Stratigraphy (ICS). The Tertiary period, though it was officially phased out in 2008 by the ICS, remains on the scale in the Guides, since "Tertiary" is found extensively in past literature. In contrast, the Carboniferous and Pennsylvanian & Mississippian periods all enjoy official status, with the latter pair being more commonly used in the US.*

Figure 1.2: The Geologic Time Scale (spacing of units not to scale).

Geologic Time

How did geologists come up with the timeline for the history of the Earth? The geologic time scale was developed over the course of many years—beginning in the early 19th century—and through the combined work of many geologists around the world. No single location on Earth contains the complete sequence of rocks from Precambrian to present. Geology as a science grew as geologists studied individual stacks or sections of rock and connected them to each other. Gradually, successions of fossils were discovered that helped geologists determine the relative ages of groups of rocks. These layers could then be correlated with similarly aged rock units from around the world. The names you see for the different periods on the geologic time scale have diverse origins; most are based on geographic areas where rocks of that age were first well studied. Time periods were named after dominant rock types, geography, mountain ranges, and even ancient tribes like the Silures of England and Wales, from which the "Silurian" period was derived.

Geologic History

Big Picture

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

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

dinosaur • *a member of a group of terrestrial reptiles with a common ancestor and thus certain anatomical similarities, including long ankle bones and erect limbs.*

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

extinction • *the end of species or other taxonomic groups, marked by death of the last living individual.*

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

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

billion to 541 million years ago). Less is known about the Earth during the Precambrian than during later parts of its history, since relatively few fossils or unaltered rocks have survived. Nevertheless, the evidence that has been preserved and discovered reveals much about the planet's first several billion years, including clear evidence that life first appeared on the planet some 3.9 billion years ago in the form of single-celled organisms.

The second division, the **Paleozoic**, extends from 541 to 252 million years ago. Geological evidence shows that during this time period, continents moved, mountains formed, and life evolved in the oceans and gradually colonized the land.

The third division, the **Mesozoic** (from 252 to 66 million years ago), is also called the "Age of Reptiles" since **dinosaurs** and other reptiles dominated both marine and terrestrial ecosystems. It is also noteworthy that during this time the last of the Earth's major supercontinents, **Pangaea**, formed and later broke up, producing the Earth's current geography.

Pangaea, meaning "all Earth," began to assemble over 300 million years ago and lasted for almost 150 million years. All of the Earth's continents were joined as one to form a giant supercontinent.

The last and current division, the **Cenozoic**, extends from the **extinction** of the dinosaurs, nearly 66 million years ago, to the present. With the demise of the dinosaurs, mammals became much more diverse and abundant. We humans didn't come into the picture until the last two million years. To get some perspective on this, if the entire geologic time scale were reduced to 24 hours, we wouldn't come onto the stage until two seconds before midnight!

The Southeastern States
The Big Picture

The geologic history of the Southeastern United States is a story of active mountain building and the quieter processes of **weathering**, erosion, and deposition of sediments. The Southeast is at the edge of a continent (North America), but in the middle of a plate (the North American plate), which extends from the mid-Atlantic ridge to the West Coast. Today this part of North America is tectonically inactive, but this was not always the case. Millions of years ago, the Southeast was the site of multiple continent-continent collisions and the **rifting** of supercontinents. Repeated episodes of mountain building, sea level changes, and the erosion and deposition of sediment shaped the Southeast as we know it today.

In this volume, the Southeastern states are divided up into three different geologic provinces or regions (*Figure 1.3*): the Blue Ridge and Piedmont (1), the Inland Basin (2), and the Coastal Plain (3). Each of these regions

Geologic History

1

Mtn Building 1

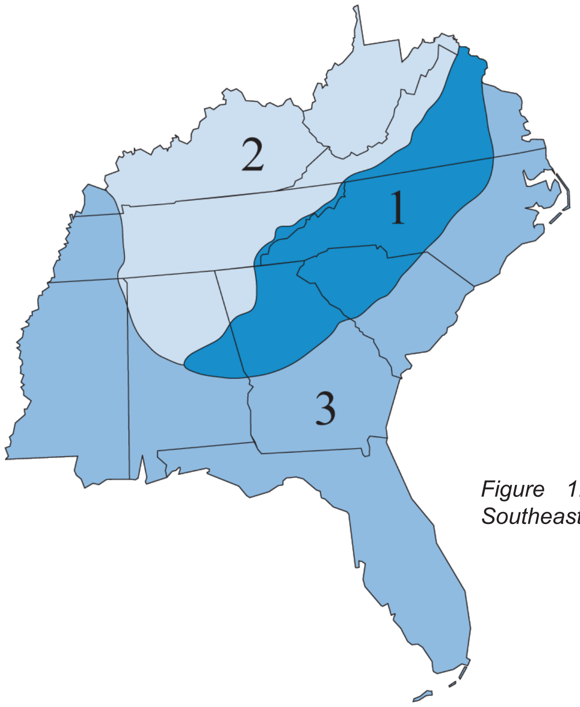


Figure 1.3: Geologic regions of the Southeast.

has a different geological history, and thus varies in terms of rocks, fossils, **topography**, mineral resources, **soils**, and other geological features. The Blue Ridge and Piedmont is composed of the peaks and foothills found at the southern end of the chain of mountains known as the Appalachians. This is the core or "backbone" of Southeastern geology. The Inland Basin, to the west of the Appalachians, includes a number of structural depressions that have filled with sediment, mostly eroded from the mountains. To the east and south is the Coastal Plain, a gently sloping area between the mountains and the ocean.

Southeast Mountain Building, Part 1

The Grenville Mountains

The Earth is estimated to be approximately 4.6 billion years old—an age obtained by dating **meteorites**. Rocks dating to around four billion years old are found on almost every continent, but they are not found at the Earth's surface anywhere in the Southeast. The oldest rocks known on Earth are 4.3-billion-year-old rocks found along the eastern shore of Hudson Bay in northern Quebec. These are part of the **Canadian Shield**, the ancient core of the North American continental landmass, which has experienced very little tectonic activity (**faulting** and folding) for millions of years. Shields, or **cratons**, are the stable cores of all continents and are often covered by layers of younger sediments. They formed and grew during pulses of **magmatic** activity, as bodies of molten rock deep in the Earth's crust contributed to form new crust. The oldest rocks exposed in the Southeast are Precambrian **gneisses** from Roan Mountain, on the border between North Carolina and Tennessee. These rocks, dated at more

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

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

meteorite • *a stony or metallic mass of matter that has fallen to the Earth's surface from outer space.*

Canadian Shield • *the stable core of the North American continental landmass, containing some of the oldest rocks on Earth.*

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.*

craton • *the old, underlying portion of a continent that is geologically stable relative to surrounding areas.*

magma • *molten rock located below the surface of the Earth.*

than 1.8 billion years old, were later metamorphosed during a major episode of mountain building called the **Grenville Orogeny**.

The shape and position of North America has changed dramatically over the last billion years, and geologic processes continue these changes today. **Compression** from colliding plates, tension from plates pulling apart, the addition of land to North America, weathering, and erosion have all combined to slowly sculpt the form of the continent. The Grenville Orogeny was one of several Precambrian continental collisions that led to the assembly of the supercontinent **Rodinia** between about 1.4 billion and 900 million years ago (Figure 1.4). During the **orogeny**, a number of smaller continental blocks and offshore islands were added to the much older core of the proto-North American continent, called Laurentia. Sediment eroded from the mountains that formed during this stage was transported by rivers and streams across the ancient continental margins and into the adjacent oceans. The sediment deposited in the ocean waters on the eastern margin of Laurentia composes a series of rocks that geologists call the Grenville Series (or the "Grenville Belt" in older literature).

The name Grenville comes from a unit of metamorphosed sedimentary rocks located in Quebec, Canada. It is used to refer both to an event (the Grenville Orogeny), and to rocks that formed as a result of that event (Grenville rocks).

The ancient Grenville rocks tell a story of repeated collision-related mountain building on North America's east coast. Intense heat and pressure associated with these continent-continent collisions produced molten rock that was injected into the crust, metamorphosing sediments that had eroded from the craton. The

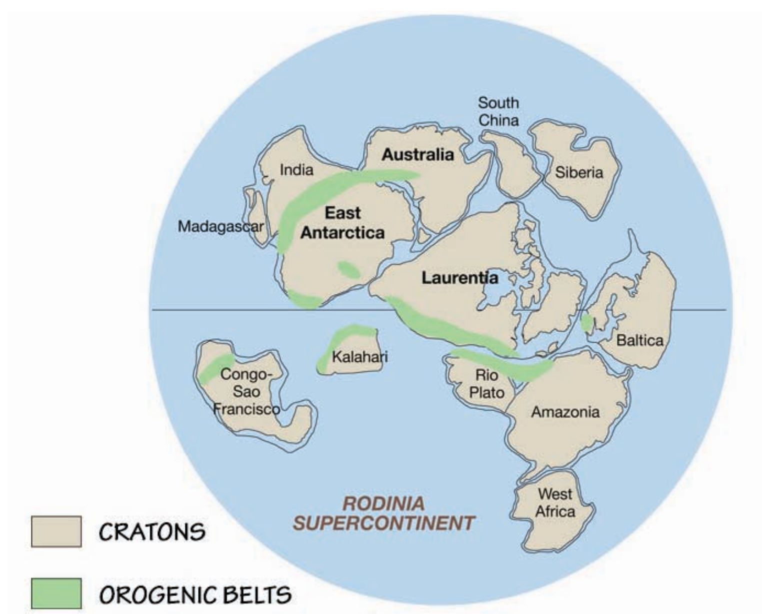


Figure 1.4: The supercontinent Rodinia, around 1.1 billion years ago. Laurentia represents proto-North America. (See TFG website for full-color version.)

Grenville Orogeny • *a mountain-building event, about 1.3 to 1 billion years ago, that played a role in the formation of the supercontinent Rodinia.*

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

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

orogeny • *a mountain-building event generally caused by colliding plates and compression of the edge of the continents.*

Ancient Continents and Their Names

It has taken hundreds of millions of years for the continents to take on the shapes we see today. Ancient continents looked very different. To simplify descriptions of ancient geography, geologists have given names to earlier "proto-continents" to distinguish them from their modern counterparts. Proto-Europe (northwestern Europe without Ireland and Scotland) in the early Paleozoic is known as Baltica; proto-North America is known as Laurentia; and proto-Africa was part of a larger continent known as Gondwana, which included what are now Africa, Australia, Antarctica, India, and South America. To simplify descriptions of geological events on these ancient continents, compass directions generally refer to modern, rather than ancient orientations. Thus, "eastern Laurentia" means the margin of proto-North America that today faces east, but which faced south during the Paleozoic.

collisions created a tall (perhaps Himalaya-scale) mountain range, the Grenville Mountains, which stretched from Canada to Mexico. Orogenic compression folded (and even completely overturned) the metamorphosed sedimentary rocks and igneous **intrusions** of these mountains, forming the **basement rock** of today's Appalachians. At this point in geologic time, very little existed of the Southeast as we now know it. The rocks of the Piedmont and the basement rocks of Florida would not be attached to Laurentia until hundreds of millions of years later. The sediments that eventually solidified into the rocks of most of the present Gulf and Atlantic coastal states had not yet been deposited.

Weathering and erosion are constants throughout the history of time. Rocks are constantly worn down and broken apart into finer and finer grains by **wind**, rivers, wave action, freezing and thawing, and chemical breakdown. Over millions of years, weathering and erosion can reduce a mighty mountain range to low rolling hills. Just as mountains continually erode today, the Grenville Mountains eroded for the next few hundred million years after their formation. In most areas, ancient Grenville rocks are now covered by thousands of meters of younger rocks. However, in the Southeast, weathering left the ancient mountain cores exposed in such places as Blowing Rock in North Carolina, Red Top Mountain in Georgia, and Old Rag Mountain in Virginia (Figure 1.5).

See Chapter 2: Rocks for more information about geologic windows.

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

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

wind • *the movement of air from areas of high pressure to areas of low pressure.*

1st Breakup

ice sheet • *a mass of glacial ice that covers part of a continent and has an area greater than 50,000 square kilometers (19,000 square miles).*

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

Iapetus Ocean • *the proto-Atlantic Ocean, located against the eastern coast of North America's ancestral landmass before Pangaea formed.*

rift basin • *a topographic depression caused by subsidence within a rift.*

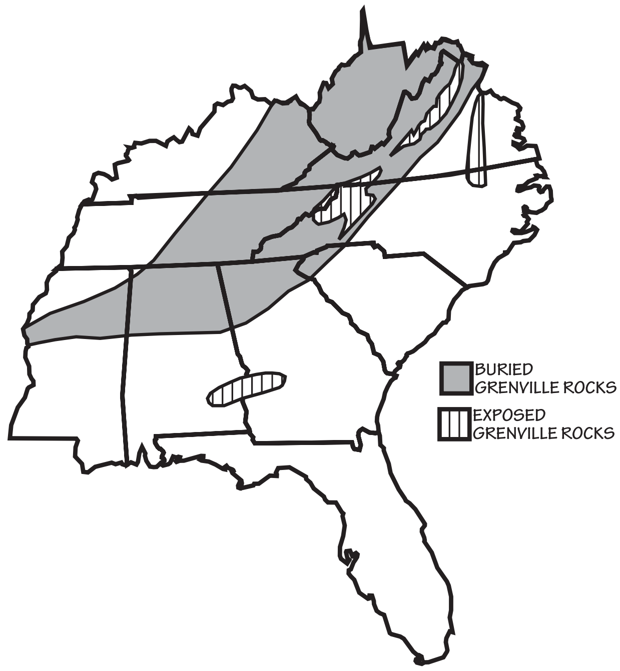


Figure 1.5: Extent of buried and exposed Grenville-aged rocks in the Southeast.

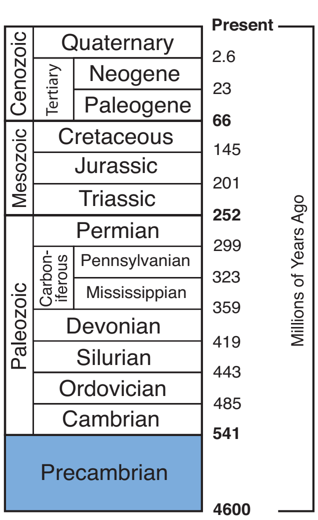
Ancient Rifting

The First Breakup

Following Rodinia's assembly around 700 million years ago, Laurentia began to break away from the rest of the supercontinent as a result of tensional forces beneath the continental crust. A series of cracks known as rifts formed throughout the landmass. During this time, the Earth experienced the most extreme episodes of glaciation in its history, with **ice sheets** spreading all the way into tropical latitudes. One place in which glacial sediment from this interval can be seen is near Valle Crucis in Watauga County, northwestern North Carolina. Around 565 million years ago, the continents split apart completely at a major rift that was floored by oceanic (**basaltic**) crust and flooded by ocean water. Geologists call this ocean the **Iapetus Ocean** (or proto-Atlantic), because the modern Atlantic Ocean opened up in a similar way and position relative to modern-day North America and Europe.

Not all of Rodinia's rifts broke completely across the continent. Instead, some of them remained as **rift basins** within the continental crust, formed when crustal blocks slid downward along faults (*Figure 1.6*). These basins filled with sediment, some of which is preserved in the rocks of Grandfather Mountain, North Carolina. The basaltic **lava** that welled up through cracks in the basin can also be seen in western North Carolina, near Bakersville in Mitchell County.

The rift that became the Iapetus Ocean is marked by ancient **sandstone**, which is visible at the top of Pilot Mountain in Surry County, North Carolina. This rifting

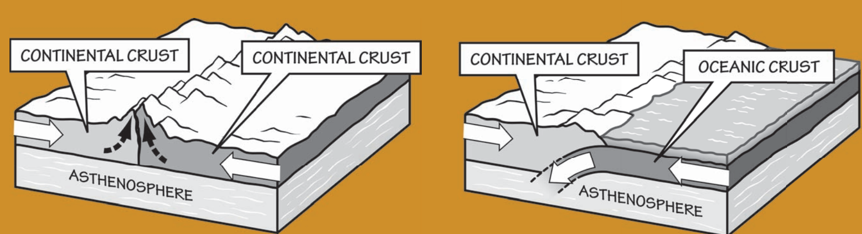


Geologic History 1

1st Breakup

Continental and Oceanic Crust

The lithosphere includes two types of crust: continental and oceanic. Continental crust is less *dense* but significantly thicker than oceanic crust. The higher density of the oceanic crust means that when continental crust collides with oceanic crust, the denser oceanic crust (made mostly of dense rocks such as basalt) will be dragged (or subducted) under the buoyant continental crust (made mostly of less dense rocks such as granite). Although mountains are created at these oceanic/continental crust collisions due to the compression of the two plates, much taller ranges are produced by continental/continental collisions. When two buoyant continental crusts collide, there is nowhere for the crust to go but up! The modern Himalayas, at the collision site of the Asian and Indian plates, are a good example of very tall mountains formed by a collision between two continental crusts.



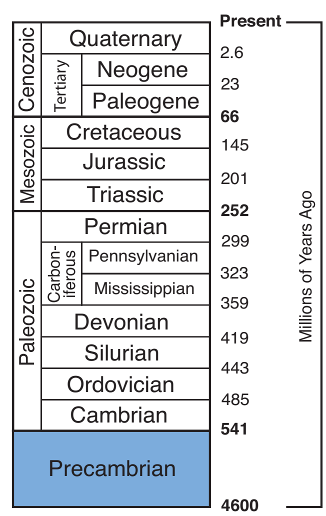
The Iapetus Ocean

In Greek mythology, Iapetus was the son of Uranus, the sky god, and Gaia, the mother of Earth and all the other gods. Geologists use the name Iapetus for the ocean that formed to the south of the ancient continent Laurentia during the Paleozoic. In many textbooks, Iapetus refers to the entire ocean between Laurentia and Gondwana. Some geologists use it in a narrower sense, referring only to the stretch of ocean between Laurentia and the Taconic island arcs prior to the Taconic Orogeny.

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

sandstone • *sedimentary rock formed by cementing together grains of sand.*

density • *a physical property of minerals, describing the mineral's mass per volume.*



1st Breakup

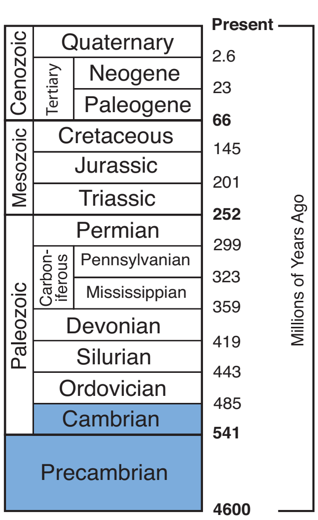
embayment • *a bay or recess in a coastline.*

passive margin • *a tectonically quiet continental edge where crustal collision or rifting is not occurring.*

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

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

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



formed an irregular margin along the edge of Laurentia, consisting of a series of projections or promontories (that are found in what is now Alabama, New York, and the St. Lawrence region of Quebec), and **embayments** (Tennessee, Pennsylvania, Newfoundland). The promontories received little or no sediment during the Precambrian, but the embayments accumulated thick piles of sediment from the eroding continent.

A rift occurs when tectonic plates move away from each other. Magma rises up into the margin, cooling to produce new oceanic crust. The resulting action is similar to two conveyor belts moving away from each other. A failed rift occurs when the existing crust is stretched thin and magma begins to well up, but the plate is never completely broken.

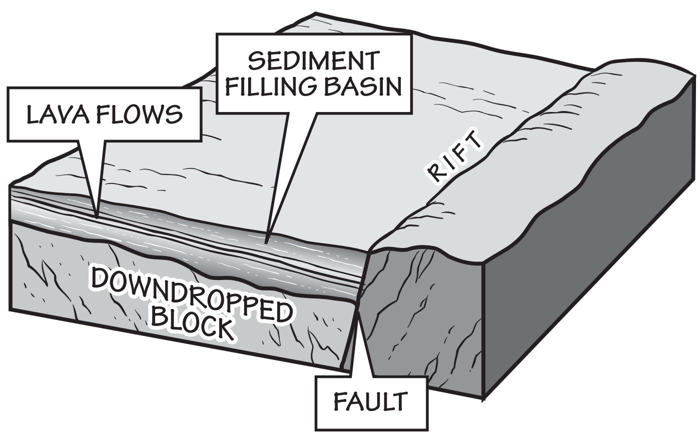


Figure 1.6: A typical rift basin, filled with sediment and lava flows.

During the late Precambrian and early Cambrian, Laurentia was positioned near the equator, and the Southeast was rotated roughly 90° clockwise relative to its current position—today's east coast faced south (*Figure 1.7*). The lack of tectonic activity along the continent's coastline made it a **passive margin**, similar to the Atlantic and Gulf coasts of the US today. As the young Iapetus Ocean widened, global sea levels also rose, flooding much of Laurentia's interior (and that of other continents) with seawater. These relatively shallow epicontinental seas were sites of widespread deposition of **carbonate** sediment derived from the abundant organisms living there (*Figure 1.8*); these sediments formed **limestones,** including those seen today in Kentucky and Tennessee. Sediments continued to erode from either side of the Grenville Mountains into the deeper Iapetus Ocean to the south (presently east) and the shallow **inland sea** to the north (presently west).

See Chapter 2: Rocks to learn more about the environments in which carbonate rocks are found and the organisms that form them.

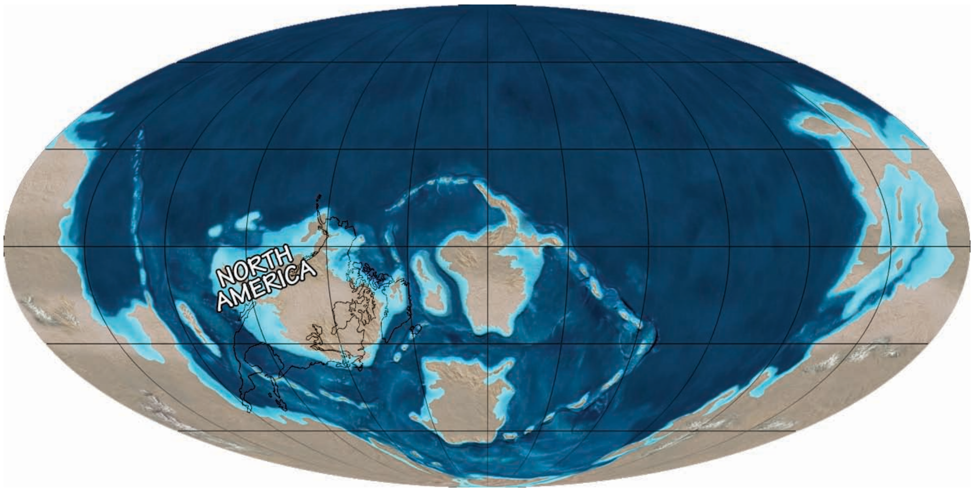


Figure 1.7: Earth during the early Cambrian, around 545 million years ago.

> ***subduction*** *• the process by which one plate moves under another, sinking into the mantle.*

> ***accretion*** *• the process by which a body of rock increases in size due to the addition of further sedimentary particles or of large chunks of land.*

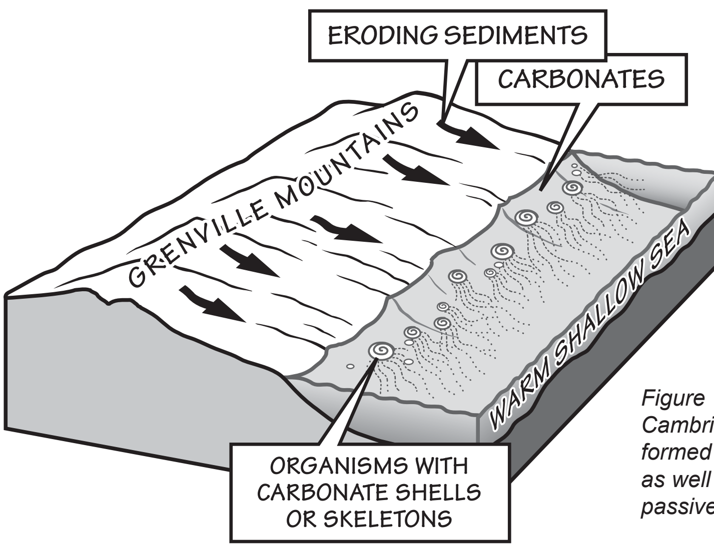


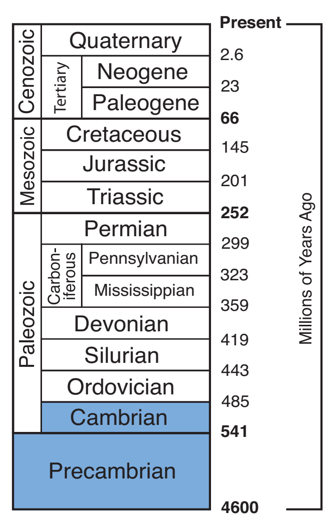
Figure 1.8: During the early Cambrian, carbonate rocks formed in shallow inland seas as well as along North America's passive continental margin.

Around 500 million years ago, the Iapetus Ocean stopped widening and the continents began to move back toward each other. The ocean floor split open to form a **subduction** zone, and the Taconic volcanic island arc was formed as melting and volcanism occurred. These volcanoes apparently occurred on or very close to one or more small pieces of continental crust, perhaps similar to what has taken place on the modern island of Madagascar.

Southeast Mountain Building, Part 2

The Taconic Mountains

As the Iapetus Ocean continued to narrow, the Taconic islands and their associated volcanoes eventually collided with the margin of North America, **accreting** to the continent. The subduction of the oceanic plate beneath the Taconic islands as they collided with North America is recorded by a series



*of rocks called **ophiolites**. These rocks, which include deep-sea sediments overlying the crust, the oceanic crust itself, and rock from the upper mantle, were scraped off the descending plate and attached to the continental crust (*Figure 1.9*). This set of collisions caused a new episode of mountain building between around 490 and 460 million years ago, known as the **Taconic Orogeny** (*Figure 1.10*). The pressure of these collisions was so great that large slabs of crust broke free and were pushed up and over the edge of the continent in a process called thrust faulting. This combination of folding, thrusting, **uplift**, and intrusion occurred along the entire margin of North America.

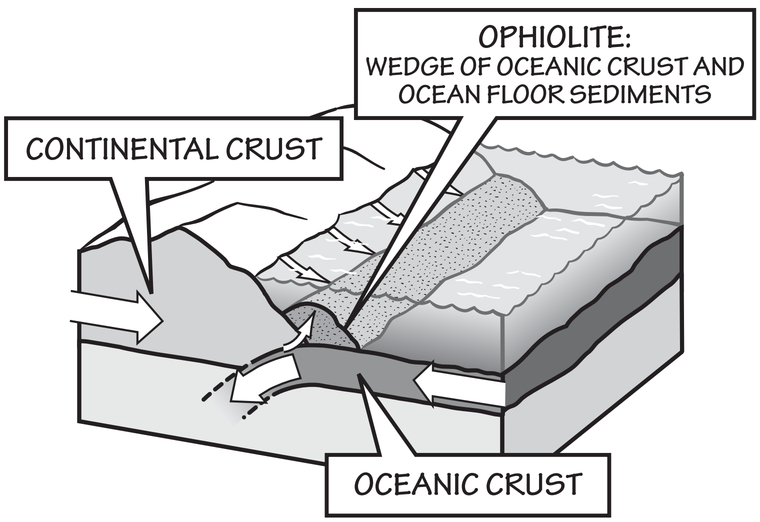


Figure 1.9: The formation of an ophiolite.

Volcanic Island Arcs

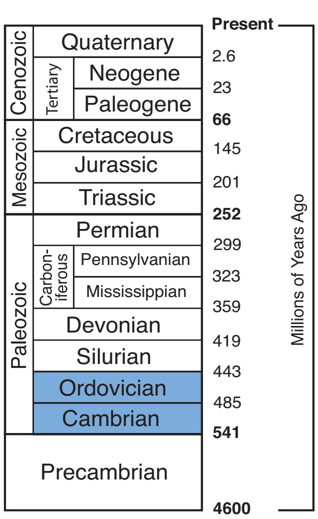
Volcanic islands are common at subduction zones between colliding oceanic plates, where one plate moves (is subducted) beneath the other. They frequently form in curved lines, and are therefore called island arcs. As the plates press together, friction between them generates enough heat and pressure to melt some of the crust. The molten rock rises through the crust and creates volcanoes along the edge of the overlying plate. The Aleutian Islands, Philippine Islands, and Lesser Antilles are all modern examples of volcanic island arcs associated with subduction. Because island arc volcanoes mix the more *mafic* composition of the ocean floor with the more *felsic* composition of overlying sediment derived from continents, they are usually of "intermediate" composition along this spectrum.

ophiolite • *a section of the Earth's oceanic crust and the underlying upper mantle that has been uplifted and exposed above sea level and often thrust onto continental crustal rocks.*

Taconic Orogeny • *a late Ordovician mountain-building event involving the collision and accretion of a volcanic island arc along the eastern coast of North America.*

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

mafic • *igneous rocks that contain a group of dark-colored minerals, with relatively high concentrations of magnesium and iron.*

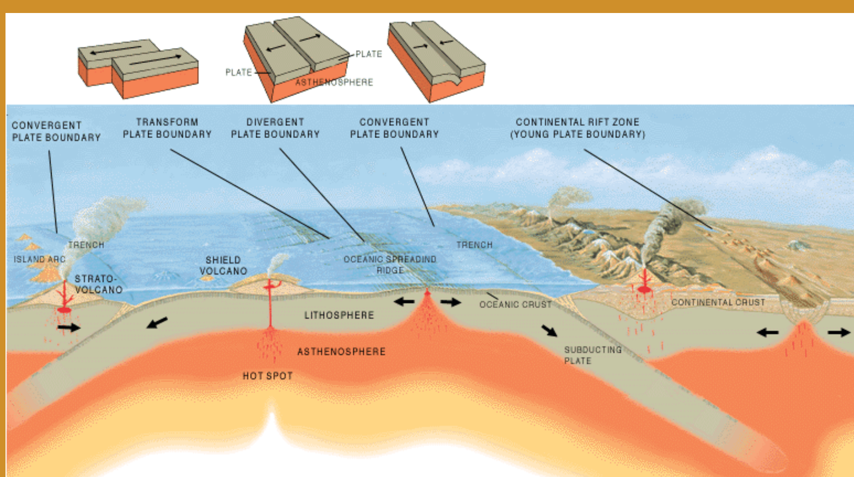


Mtn Building 2

Understanding Plate Boundaries

Active plate margins **are the boundaries between two plates of the Earth's crust that are colliding, pulling apart, or moving past each other as they move over the mantle. Some of these plates move as fast as 10 centimeters/ year (4 inches/year). The processes of plate movement, spreading, subduction, and mountain building are collectively called plate tectonics.**

When one plate slides beneath another, it is called a *convergent boundary* or subduction zone. When two plates pull apart from each other, it is called a *divergent boundary* or rift margin. When the plates slip past each other in opposite directions, it is a *transform boundary*.



Large chunks of rock like the Taconic islands, which originate in one place and are eventually added to a continent, are called **terranes** (or sometimes "exotic" terranes to emphasize their distant origin). Some terranes are little more than chains of volcanoes; others are small blocks of continental crust that are sometimes called **microcontinents**. Addition (or accretion) of terranes is one of the major ways in which continents grow in size, as they are pressed against the edge of the continent in a process sometimes known as "docking." After accretion, the boundaries between adjacent terranes are marked by major faults or fault zones. In the Southeast, the islands that collided with North America during the Taconic Orogeny are today known as the Piedmont Terrane (*see Figure 1.12*); farther north, in New England, they are called the Taconic Mountains.

felsic • *igneous rocks with high silica content and low iron and magnesium content.*

active plate margin • *the boundary between two plates of the Earth's crust that are colliding, pulling apart, or moving past each other.*

terrane • *a piece of crustal material that has broken off from its parent continent and become attached to another plate.*

microcontinent • *a piece of continental crust, usually rifted away from a larger continent.*

Era		Period	Millions of Years Ago
			Present
Cenozoic		Quaternary	2.6
Cenozoic	Tertiary	Neogene	23
Cenozoic	Tertiary	Paleogene	**66**
Mesozoic		Cretaceous	145
Mesozoic		Jurassic	201
Mesozoic		Triassic	**252**
Paleozoic		Permian	299
Paleozoic	Carbon-iferous	Pennsylvanian	323
Paleozoic	Carbon-iferous	Mississippian	359
Paleozoic		Devonian	419
Paleozoic		Silurian	443
Paleozoic		Ordovician	485
Paleozoic		Cambrian	**541**
		Precambrian	**4600**

Mtn Building 3

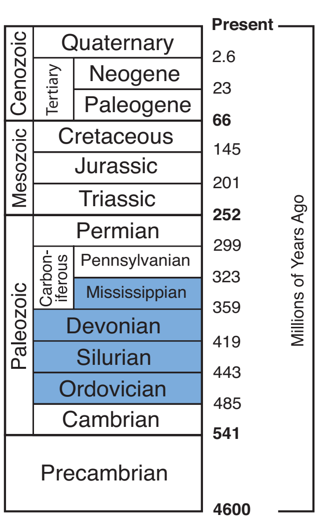
downwarp *• a segment of the Earth's crust that is broadly bent downward.*

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

inland basin *• a depression located inland from the mountains, and formed by the buckling (downwarping) of the Earth's crust.*

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

Silurian *• a geologic time period spanning from 443 to 419 million years ago.*



The compression induced by the collision of the Iapetus and Taconic rocks with North America also depressed (**downwarped**) the crust to the west of the Taconic Mountains, creating the **Appalachian Basin.** This basin, actually a connected set of basins that stretched from New York to Tennessee and formed in stages between the Ordovician and **Carboniferous**, was flooded by a broad, shallow inland sea and filled with sediment eroded from the Taconic Mountains. Other **inland basins** also formed from the compressional forces of Taconic mountain building, including the Black Warrior Basin of northwest Alabama and northeast Mississippi.

Geologically "quiet" times in the Southeast, between the rise of great mountains and crushing crusts of colliding plates, were marked by erosion of the highlands and very little plate movement and compression. The Taconic Orogeny ended by the late **Ordovician**, and for many millions of years afterward, the Southeast experienced a time during which erosion from the Taconic highlands and deposition in the inland sea were the main geological events. Huge thicknesses of sedimentary rocks accumulated in and on the margins of the inland sea during the **Silurian**. As sediment weathered from the western side of the Taconic Mountains, **deltas**—wedge-shaped deposits formed when eroded sediment is transported from the mountains and fans out across lower elevations—spread along the shoreline (Figure 1.11). Most of this sediment was concentrated to the north, extending southward only as far as West Virginia and Virginia.

The Mississippi Delta is a modern delta that dumps sediment from the Mississippi River into the Gulf of Mexico.

Southeast Mountain Building, Part 3

The Acadian Mountains

Beginning around 430 million years ago in the mid-Silurian, and ending around 345 million years ago in the early **Mississippian**, another series of continent-continent collisions took place along North America's margin, resulting in the **Acadian Orogeny** (Figure 1.12). It began in the north as **Baltica** (proto-Europe) collided with the northeastern part of North America and proceeded to the south like a closing zipper. More southern collisions involved at least three other terranes that broke off from **Gondwana** when the supercontinent Rodinia broke apart. Rocks from the Carolina Terrane became the southern and central Appalachians, while the **Avalon** and Gander terranes include much of the northern Appalachians (Figure 1.13). To make the story even more complicated, these terranes are themselves the result of the collision of multiple smaller terranes (and are for this reason sometimes called "superterranes"). Two smaller pieces of the Carolina Terrane—the Talladega Slate Belt and the Carolina Slate Belt—are noteworthy for containing fossils that indicate their origin far from North America.

See Chapter 3: Fossils to learn about trilobites found in the Carolina State Belt.

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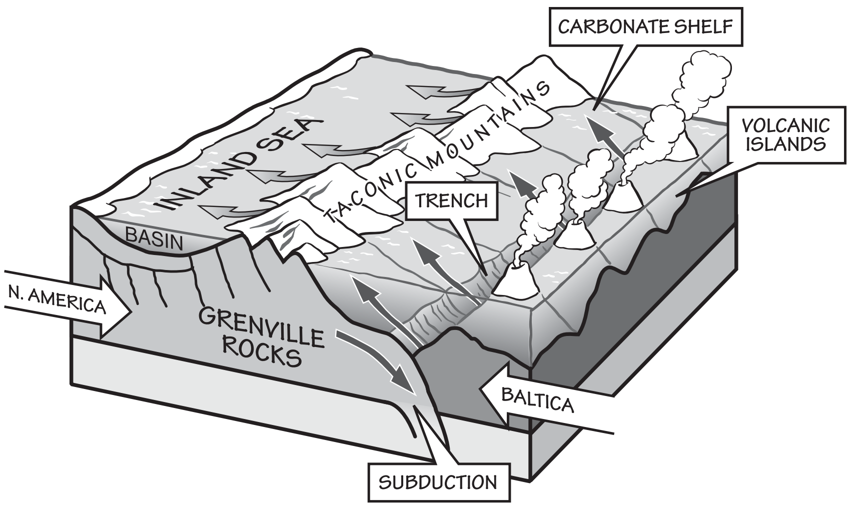


Figure 1.10: Volcanic islands formed where the plates were forced together as the Iapetus Ocean closed. The compression crumpled the crust to form the Taconic Mountains and a shallow inland sea farther to the west.

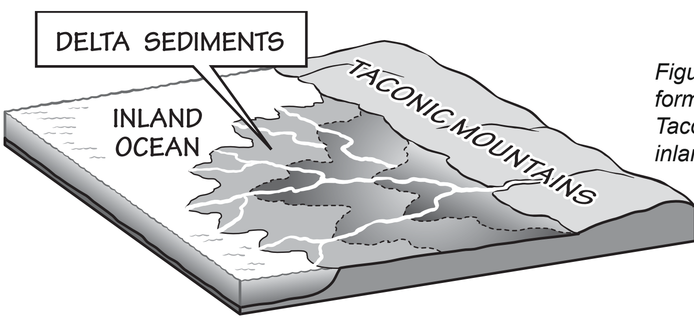


Figure 1.11: Delta deposits formed along the eroding Taconic Mountains into the inland sea.

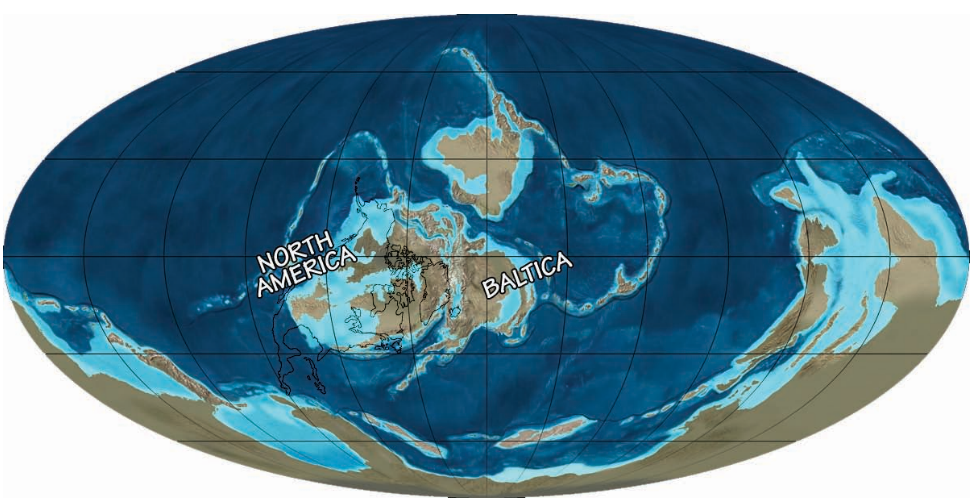


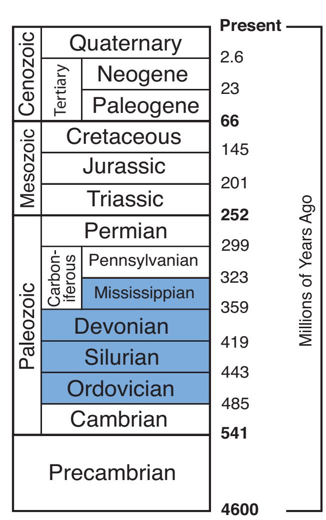
Figure 1.12: Earth during the Silurian, about 430 million years ago.

Mississippian • *a subperiod of the Carboniferous, spanning from 359 to 323 million years ago.*

Acadian Orogeny • *a Devonian mountain-building event involving the collision of the eastern coast of North America and the accreted terrane of Avalon.*

Baltica • *a late-Proterozoic, early-Paleozoic continent that included ancient Europe.*

Gondwana • *the super-continent of the Southern Hemisphere, composed of Africa, Australia, India, and South America.*



Mtn Building 4

Devonian • *a geologic time period spanning from 419 to 359 million years ago.*

Pennsylvanian • *a subperiod of the Carboniferous, spanning from 323 to 299 million years ago.*

Permian • *the geologic time period lasting from 299 to 252 million years ago.*

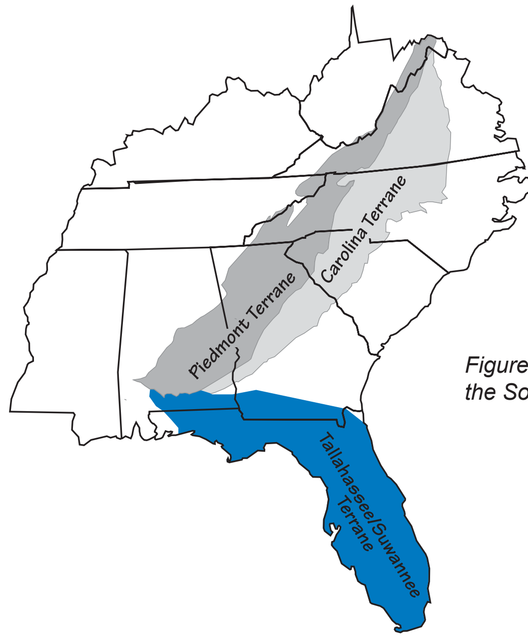


Figure 1.13: Modern locations of exotic terranes in the Southeastern states.

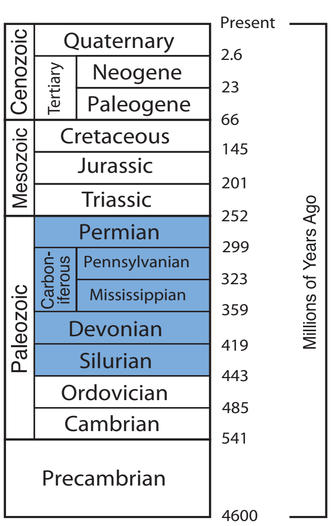
Southeast Mountain Building, Part 4

Pangaea and the Appalachians

The Avalon and Gander terranes collided with what is now New England around 410 million years ago, and the Carolina Terrane was accreted farther south, perhaps 360 million years ago. As with the Taconic Orogeny, these Acadian collisions caused the rocks of North America's eastern margin to be squeezed, folded, metamorphosed, and intruded by magma. During this time, North America gradually moved closer to its present geographic position and rotated toward the north-south alignment we are familiar with today (*Figure 1.14*). At the time of the Acadian mountain building and subsequent erosion during the **Devonian**, the Southeast was located south of the equator, and experienced a tropical climate. Africa, South America, India, Australia, Antarctica, and what is now Florida were combined into the southern supercontinent Gondwana. Most or all of the continental landmasses were gradually moving closer together.

See Chapter 8: Climate to learn how Earth's climate changed when the supercontinents re-arranged.

During the Mississippian period, the Inland Basin region was still flooded with a warm inland sea, in which abundant limestone was deposited. Approximately 300–250 million years ago, through the **Pennsylvanian** and **Permian** periods, a final mountain-building event occurred as Gondwana collided with North America to form the supercontinent Pangaea, creating the central and southern Appalachians (*Figures 1.15 and 1.16*). This mountain-building event is known



as the **Alleghanian Orogeny**, and it is responsible for the Appalachians' basic structure. Sea levels began to fluctuate and ultimately fall, due to a combination of glaciation at the South Pole and the renewed forces of mountain building. Along the margins of this retreating sea, enormous coastal swamps formed from modern Pennsylvania to Alabama. When the vegetation in these swamps died, it fell into stagnant oxygen-poor water. This slowed decomposition, forming huge deposits of **peat**. Sediment covered these deposits, compressing and ultimately metamorphosing them into some of the largest **coal** beds in the world. Together with similar deposits in Western Europe, they give the Carboniferous period its name.

See Chapter 6: Energy for more on the formation of coal in the Southeast.

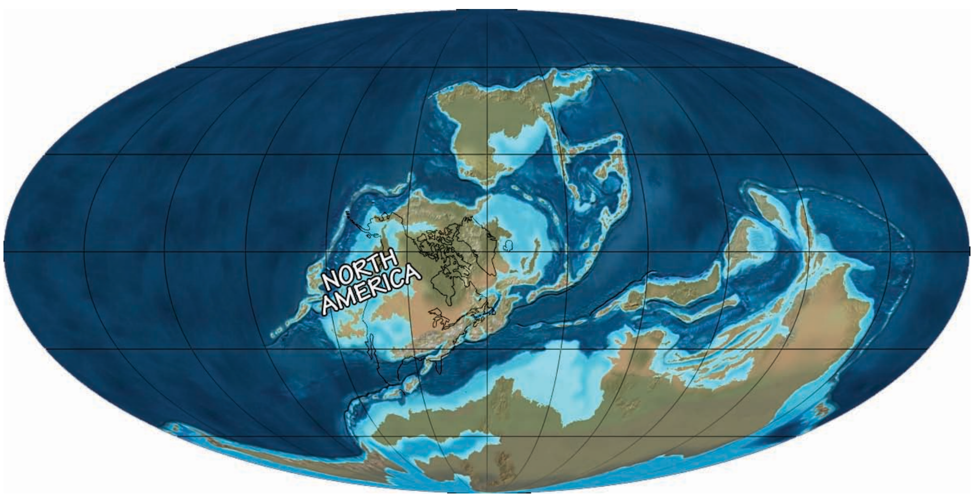


Figure 1.14: Earth during the late Devonian, about 370 million years ago.

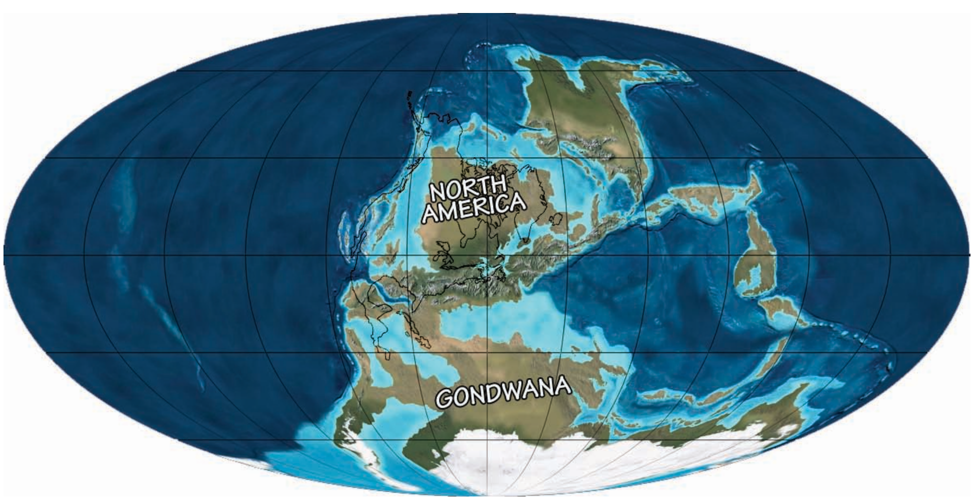


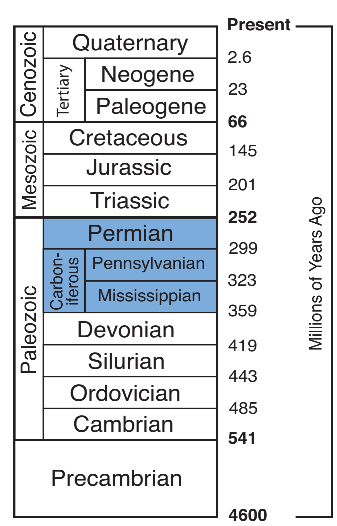
Figure 1.15: Initial formation of Pangaea during the late Carboniferous, around 300 million years ago.

Mtn Building 4

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.*

peat • *an accumulation of partially decayed plant matter.*

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



Mtn Building 4

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

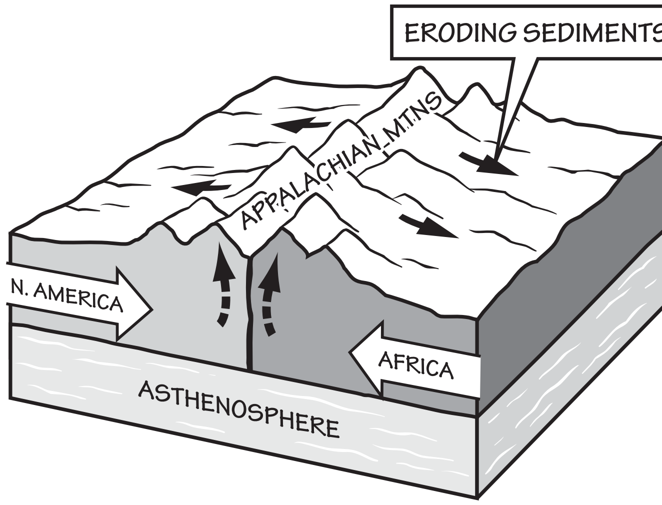


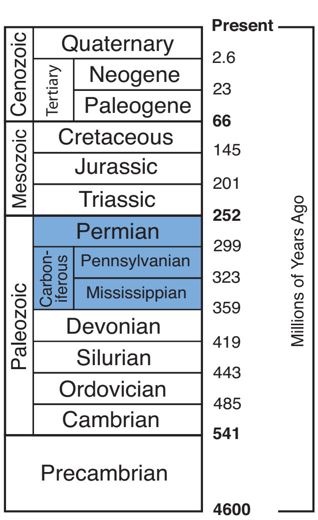
Figure 1.16: North America and Africa (part of Gondwana) collided to form the Appalachian Mountains.

The burial of so much carbon lowered the amount of carbon dioxide (CO_2) in the Earth's **atmosphere**, and abundant plant life raised global oxygen levels. Global temperatures continued to fall, accelerating glaciation in the southern hemisphere and lowering sea level worldwide. Ultimately, the sea retreated completely from the Interior Basin, which is why there is no marine sediment younger than Pennsylvanian in age across this area of the continent.

Like the Acadian Orogeny before it, the Alleghanian began in the north and moved south, closing what remained of the Iapetus Ocean like a zipper. The Alleghanian Orogeny caused the rocks along the eastern margin of North America to compress westward like a collapsing telescope. Slices of crust were thrust westward along enormous faults such as the Brevard Fault Zone, running along the eastern edge of the Blue Ridge from Alabama to the North Carolina-Virginia border (*Figure 1.17*). This event caused the crust to shorten by almost 200 kilometers (120 miles). The resulting Appalachian Mountain chain extends from Alabama to Canada. The South American portion of Gondwana also collided with North America during the early Pennsylvanian, forming the Ouachita Mountains of Arkansas and Texas. These mountains originally extended into Mississippi, but are now buried beneath younger sediments.

The orogeny affected sediment deposited in the inland ocean throughout the Paleozoic era as well as the Iapetus and Avalon rocks that had been added to North America from the Ordovician through the Devonian. Although the Appalachian Mountains were formed over 250 million years ago, they are still around today. Once perhaps as tall and rugged as the Himalayas of India, these mountains have been worn down by the same forces of erosion and weathering that also filled the Appalachian Basin with their sediment.

The geological basement of the modern Florida peninsula was the last major piece of present-day North America to be attached. This basement is composed



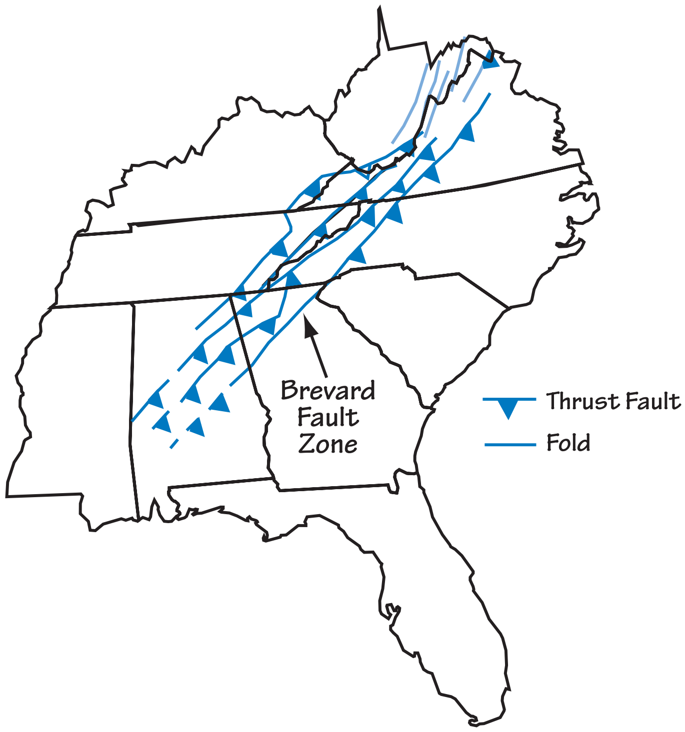


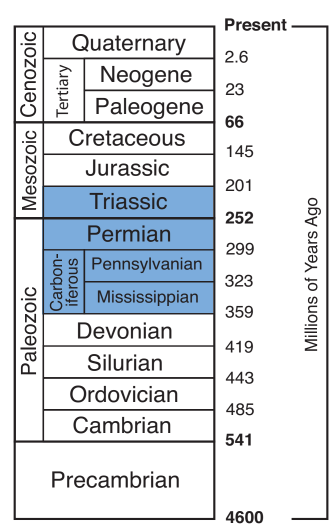
Figure 1.17: Major thrust faults of the Southeast. The Brevard Fault Zone divides the Blue Ridge from the Piedmont. Folds (rather than thrusts) are common in West Virginia, northern Virginia, and farther north.

of two major pieces: the Florida-Bahama Block and the Suwannee Basin Block (also known as the Tallahassee-Suwanee Terrane). Both of these pieces were part of Gondwana when it collided with southeastern North America in the late Paleozoic. They are recognizable today as different from the rest of the continent due to the distinctive rocks and fossils they contain. We know about Florida's ancient basement only from drill cores and other remote geophysical methods, as no surface rock in Florida is older than the Cenozoic.

The Second Breakup

Pangaea Comes Apart

Pangaea lasted less than 100 million years, before Earth's dynamic crust began to break it apart. Tension slowly began to pull North America away from the other merged continents. Rifts once again developed in the middle of the supercontinent, eventually leading to its breakup. These rifts occurred along a series of cracks in the Earth's crust roughly parallel to the present eastern coastline of North America. Blocks of crust slid down the faults on the rift margins to form rift basins bounded by tall cliffs. Some rift basins are exposed at the surface in Virginia and North Carolina; younger sediment buried others throughout the Southeastern states (*Figure 1.18*). Deposits of ash and lava flows originating from volcanoes in the rift area alternate with sandstone



Geologic History

Mtn Building 4

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

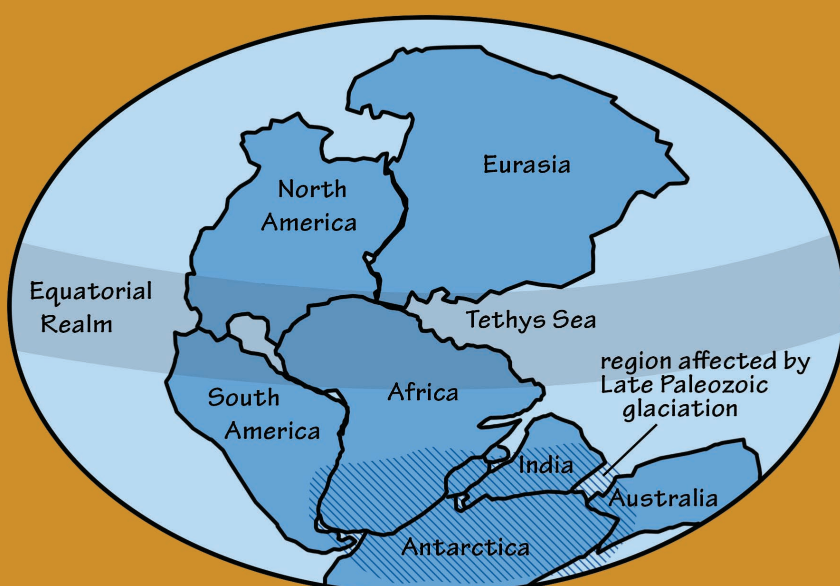
Newark Supergroup • *a sequence of nonmarine sedimentary rocks that accumulated along what is now eastern North America in the late Triassic to early Jurassic.*

salt • *a mineral composed primarily of sodium chloride (NaCl).*

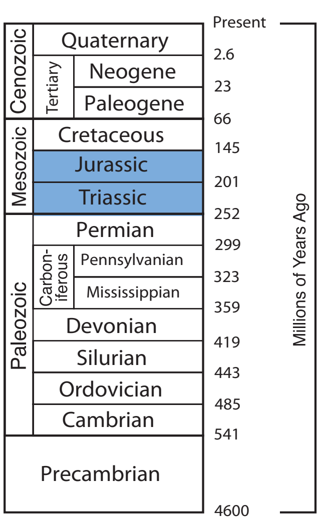
petroleum • *a naturally occurring, flammable liquid found in geologic formations beneath the Earth's surface.*

Evidence for Pangaea

How do we know that Pangaea existed 250 million years ago? Long before the discovery of plate tectonics in the 1960s and early 1970s, fossils and mountain belts provided evidence that the continents had not always been in their current positions. For example, the Permian-aged fossil plant *Glossopteris* had seeds too heavy to be blown across an ocean. Yet *Glossopteris* fossils are found in South America, Africa, Australia, India, and Antarctica! The mountain belts along the margins of North America, Africa, and Europe line up as well and have similar rock types, an indication that the continents at one time were joined as Pangaea. Despite the discovery of *Glossopteris* and other geologic evidence, the theory of continental drift was not accepted for decades, until the mechanisms of continental movement were discovered and reformulated under the modern theory of plate tectonics. The super-continent Pangaea existed for approximately 100 million years, reaching its largest size during the Triassic period. During the Jurassic, the landmass began to fragment into the modern continents, which slowly moved toward their present-day positions over the following 150 million years.



Pangaea during the late Paleozoic era



and **shale** to fill the basins. These flat-lying rock layers were eventually faulted again and tilted, exposing the edges of sedimentary rock and cooled lava. In many instances, the hardened lava was more resistant to erosion than the sedimentary rock was, so ridges of cooled lava have been worn into topographic highs. These late **Triassic** and early **Jurassic** rocks are collectively called the **Newark Supergroup**.

During the Jurassic, the final break between North America, Gondwana, and Baltica occurred along what is now the Mid-Atlantic Ridge. Pangaea gradually fragmented into the modern continents, each slowly moving into their present positions (*Figure 1.19*). The Atlantic Ocean began to widen as Africa separated from North America, and the Gulf of Mexico opened up as South America pulled away. The east coast of North America no longer experienced the strong tectonic activity associated with the compression and rifting of a plate margin; it once again became a passive margin.

In the early stages of its formation, the Gulf of Mexico was the site of abundant **salt** formation, as seawater from the first tentative arms of the ocean evaporated. Eventually, this Jurassic salt was deeply buried beneath sediments carried into the Gulf by rivers, and would later become important in the trapping of **petroleum** and **natural gas** beneath the modern Gulf.

Beginning 95 million years ago, North America passed over a **hot spot** in the mantle. The rising magma uplifted a portion of the Ouachita-Appalachian Mountains, creating an arch and causing the range to be preferentially weathered. After the continent passed over the hot spot, the crust there had thinned significantly, and it began to cool and **subside**, eventually forming a basin. As the ocean flooded the area between the Interior Highlands and the Appalachians, what is now the **Mississippi Embayment** was created. The Embayment area today extends from the confluence of the Ohio and Mississippi Rivers in the north, to the Gulf of Mexico in the south. This is the origin of the relatively low, flat area that now separates the Appalachian and Ouachita mountain ranges.

Building the Coastal Plain

The late **Cretaceous** period was marked by very high sea levels worldwide, in part due to the significant increase in **plate tectonic** activity that accompanied the breakup of Pangaea. When the continents began to move apart, they were separated by oceanic crust that formed at deep-sea ridges like the Mid-Atlantic Ridge, where new oceanic crust continues to form today. The subsequent displacement of ocean water contributed to a higher global sea level. Spreading eventually slowed and the ridges subsided, allowing sea level to fall. Despite minimal tectonic activity throughout the last 140 million years, the face of the Southeast has changed significantly due to erosion, deposition, sea level fluctuations, and the **ice age**.

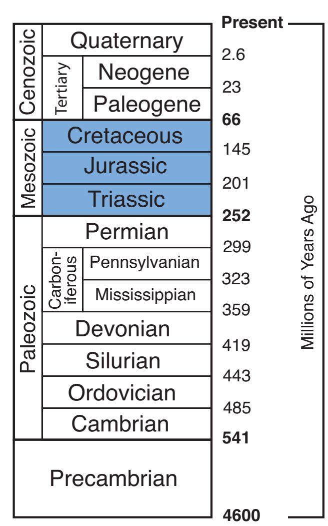
Because the North American continent is still drifting away from the Mid-Atlantic Ridge, the eastern margin of North America transitioned to a passive

natural gas • *a hydrocarbon gas mixture composed primarily of methane (CH_4), but also small quantites of hydrocarbons such as ethane and propane.*

subsidence • *the sinking of an area of the land surface.*

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

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



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

Paleogene • *the geologic time period extending from 66 to 23 million years ago.*

Tertiary • *an unoffical but still commonly used term for the time period spanning from 66 million to 2.5 million years ago, including the Paleogene, Neogene, and part of the Pleistocene.*

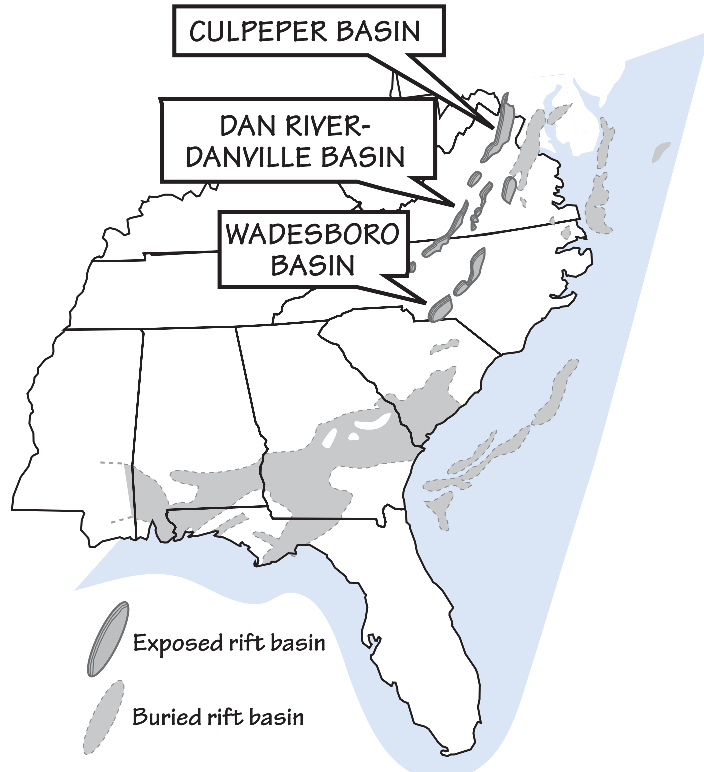


Figure 1.18: The Triassic-Jurassic Rift Basins of the Southeast formed as North America broke away from Pangaea. Many basins are buried by younger sediment and are located on the continental shelf as well as on land.

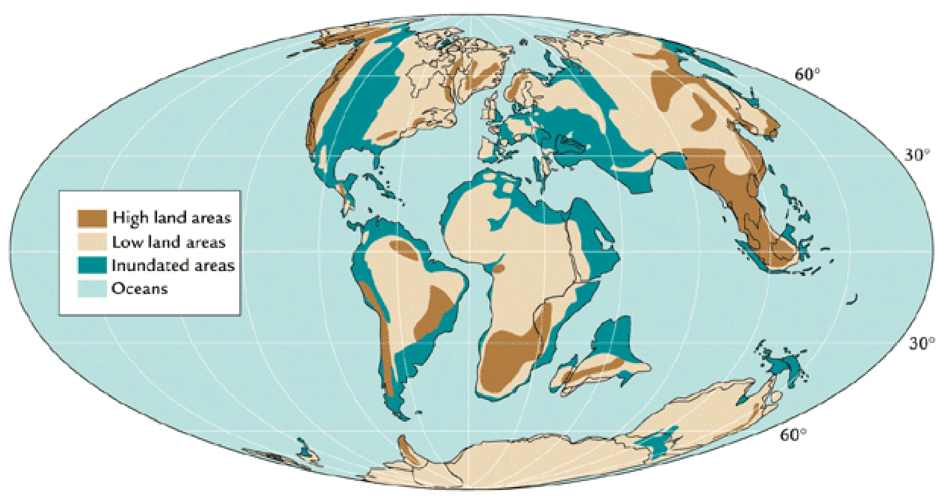


Figure 1.19: Landmasses following the breakup of Pangaea. (See TFG website for full-color version.)

Era		Period	Millions of Years Ago
			Present
Cenozoic		Quaternary	2.6
Cenozoic	Tertiary	Neogene	23
Cenozoic	Tertiary	Paleogene	**66**
Mesozoic		Cretaceous	145
Mesozoic		Jurassic	201
Mesozoic		Triassic	**252**
Paleozoic		Permian	299
Paleozoic	Carbon-iferous	Pennsylvanian	323
Paleozoic	Carbon-iferous	Mississippian	359
Paleozoic		Devonian	419
Paleozoic		Silurian	443
Paleozoic		Ordovician	485
Paleozoic		Cambrian	**541**
		Precambrian	**4600**

continental margin. Rivers and streams transported sediment from the mountains to the coast, forming successive layers that fanned out across the gently sloping continental shelf and built up the Atlantic and Gulf Coastal plains. The Fall Line, a break between the harder inland rock and the softer sediments of the coast, marks the boundary between the Coastal Plain and the Blue Ridge and Piedmont region.

See Chapter 4: Topography to learn more about the Fall Line.

Just like the breakup of Rodinia, the rifting and breakup of Pangaea left an irregular continental margin on eastern North America, marked by higher promontories jutting eastward into the Atlantic, and lower embayments that the ocean filled to the west. The embayments became sites of deposition for thick piles of eroded sediments, and each embayment has a separate **stratigraphic** sequence. Geologists build a larger knowledge of geologic history in the Coastal Plain by connecting these sequences with each other, correlating the different sedimentary layers through the characteristics of the fossils in each one.

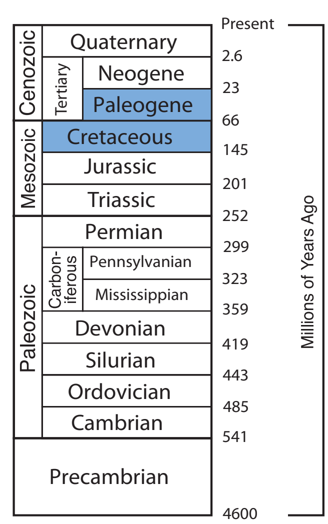
The Cretaceous-**Paleogene** (K-Pg) boundary (previously known as the Cretaceous-**Tertiary** [K-T] boundary) marks one of the most significant physical and biological events in Earth history. The boundary marks the contact between the Mesozoic and Cenozoic eras at around 65 million years ago, representing a time during which a large proportion (perhaps 50–70%) of all species of animals and plants (both marine and terrestrial, from microscopic one-celled organisms to massive dinosaurs) abruptly became extinct. Most geologists and paleontologists think these extinctions resulted from the impact of a large comet or asteroid, perhaps associated with an impact crater in the subsurface of Mexico's Yucatan Peninsula. There is also evidence for the occurrence of extensive volcanism at the K-Pg boundary, indicated by large basaltic lava flows in India called the Deccan Traps. The end-Cretaceous event greatly altered the history of life, and these changes are clearly visible in the Southeast's fossil record. The boundary itself is rarely preserved in the geologic record, due to an incomplete sedimentary record and widespread erosion.

One of the rift basins that developed as Pangaea broke up in the early Mesozoic extended from what is now the northeastern corner of the Gulf of Mexico to the Atlantic coast of Georgia. This basin, which geologists call the Gulf Trough (or the Suwanee Straits), had a major impact on Florida's Cenozoic history. During the Paleogene, it separated the eroding Appalachians from the growing carbonate bank to the south. The Trough diverted sediment from the Appalachians, which would otherwise have covered the Florida carbonate bank. As the Trough eventually filled with sediment, the Florida Platform was inundated with material from the mainland, but not before a huge amount of limestone had already formed there. Florida's modern peninsula is the above-water section of the much larger Florida Platform, made mostly of limestone and coated with a relatively thin layer of **sand** (*Figure 1.20*). Today, the main sites of carbonate deposition in the Southeast are the southern tip of Florida and the Florida Keys, where **reefs** still grow thanks to warm temperatures and a low influx of **siliciclastic** sediment.

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

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.*

siliciclastic • *pertaining to rocks that are mostly or entirely made of silicon-bearing clastic grains weathered from silicate rocks.*



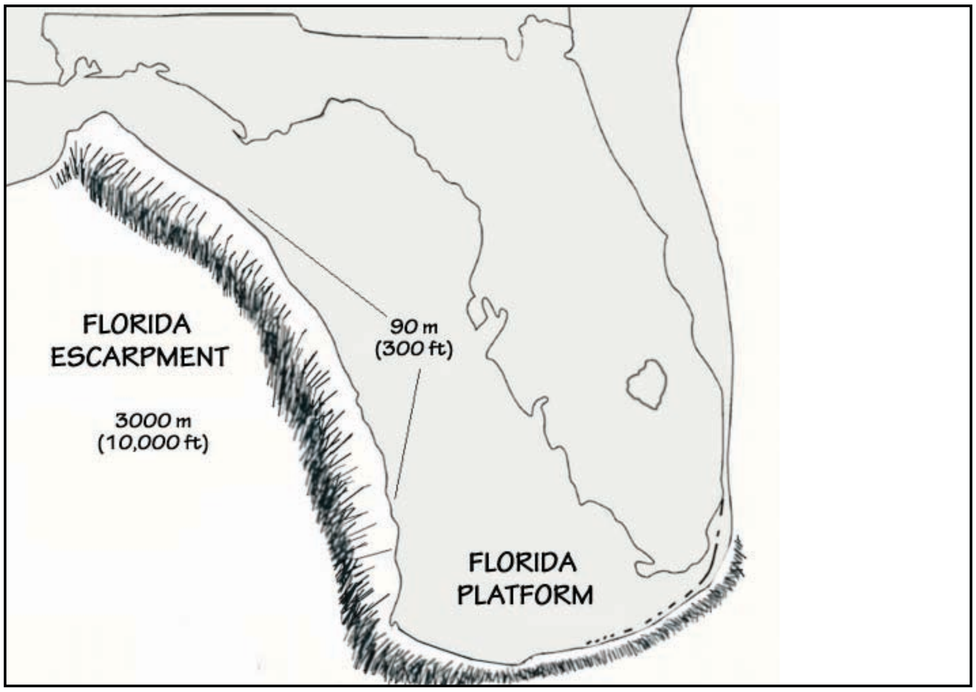


Figure 1.20: The extent of the Florida Platform and surrounding water depths.

The Quaternary
Mountains of Ice

At the start of the **Quaternary** period, about 2.5 million years ago, continental ice sheets began to form in northernmost Canada. Throughout this period, the northern half of North America has been periodically covered by continental glaciers that originated in northern Canada (*Figure 1.21*). The Quaternary period is divided into two epochs: the **Pleistocene** and **Holocene**. During the Pleistocene, ice sheets advanced south and retreated north several dozen times, reaching their last maximum extent 25,000–18,000 years ago. The Holocene epoch is the most recent (and current) period of retreat, and is referred to as an **interglacial** interval. The beginning of the Holocene is considered to be 11,700 years ago, or about 9700 BCE.

The Pleistocene ice sheets did not extend into the Southeast. Here, the predominant effects of the ice age were the rise and fall of sea level, subsequent erosion and deposition, changes in weather and the distribution of plant and animal species, and changes in drainage patterns. At the peak of the last glacial advance (around 22,000 years ago) sea level was over 100 meters (330 feet) below its current level (*Figure 1.22*). Widely fluctuating sea levels drastically affected the erosion and deposition of sediment on the Coastal Plain, creating scarps (such as the Orangeburg Scarp in South Carolina) and river **terraces** as well as steepening stream gradients, which resulted in more rapid erosion of the streambeds. Of all the states in the Southeast, sea level changes have most

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

Holocene • *the most recent portion of the Quaternary, beginning about 11,700 years ago and continuing to the present.*

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

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.*

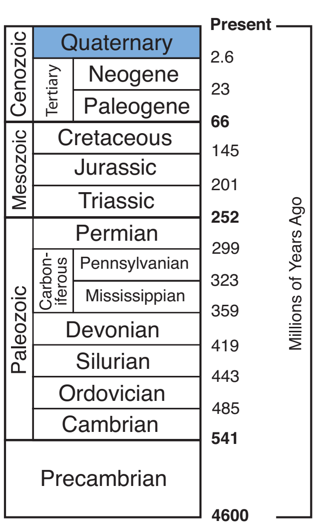


Figure 1.21: Extent of glaciation over North America during the last glacial maximum.

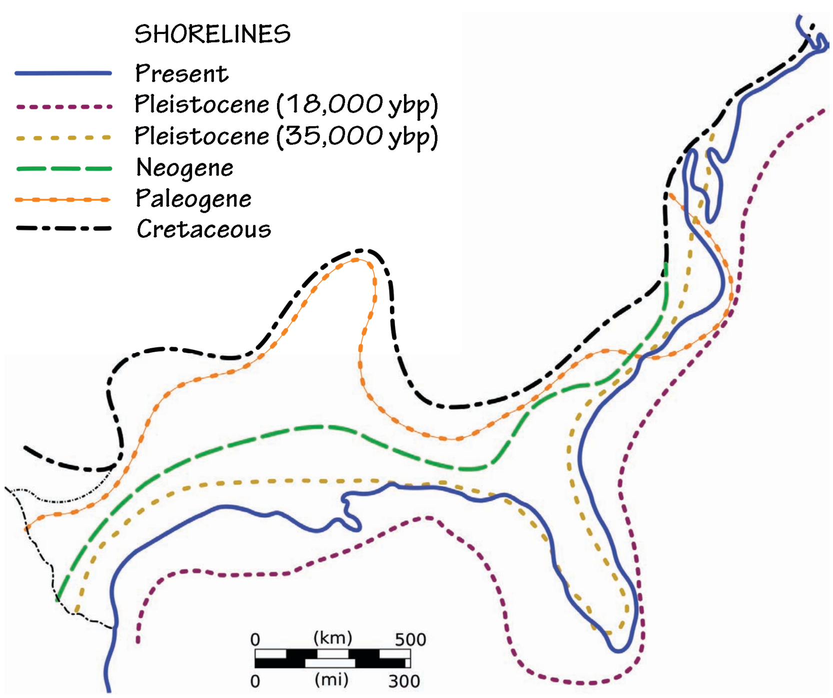
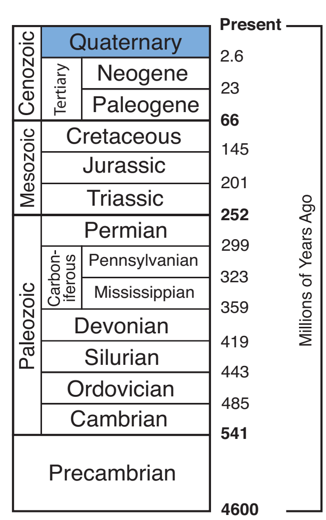


Figure 1.22: Shoreline positions along the Coastal Plain during the past 70 million years. The shoreline reflects the regression that resulted from the last significant glacial advance of the modern ice age.



Quaternary

climate change • *See global warming: the current increase in the average temperature worldwide, caused by the buildup of greenhouse gases in the atmosphere.*

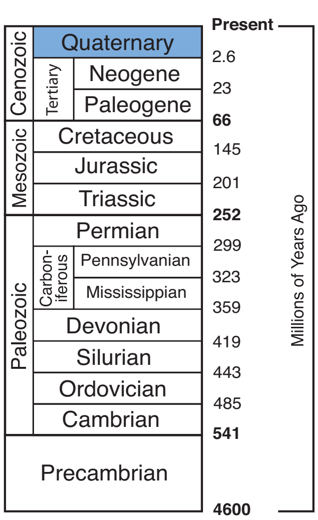
dramatically affected the shape and sedimentary deposits of Florida. When glaciation was at its maximum during the Pleistocene, and sea levels were at their lowest, the peninsula was almost 480 kilometers (300 miles) across at its widest.

The ice age continues today, but the Earth is in an interglacial stage, since the ice sheets have retreated for now. The current interglacial period has slowed both erosional and depositional processes in the Southeast—this, and a higher, more stable sea level, allowed coastal features such as barrier islands and lagoons to form, resulting in the landscape we know today. The glacial-interglacial cycling of ice ages indicates that the world will return to a glacial stage in the future, unless the impacts of human-induced **climate change** radically shift these natural cycles.

See Chapter 9: Climate to learn more about how climate change affects the environment.

Why was there an ice age?

What led to the formation of large continental glaciers in the Northern Hemisphere between 3.5 and 2.5 million years ago? Movement of the Earth's tectonic plates may have been a direct or indirect cause of the glaciation. As plates shifted, continents moved together and apart, changing the size and shape of the ocean basins, and altering ocean currents that transported heat from the equator to the poles. Sufficient precipitation in northern Asia and North America also enabled continental glaciers to grow and flow outward. The rise of the Himalayas exposed new rock that trapped carbon dioxide through chemical weathering; in turn, the decreased levels of carbon dioxide led to a global cooling. Finally, and surprisingly, the formation of the Central American Isthmus, which connects North and South America in what is now Panama, likely had a major effect on climate. Ocean currents that had once flowed east to west through the Central American Seaway were now diverted northward into the Gulf of Mexico and ultimately into the Gulf Stream in the western Atlantic. This strengthened Gulf Stream transported more moisture to high northern latitudes, causing more snow, which eventually formed glaciers.



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to the Earth Science of the Southeastern US

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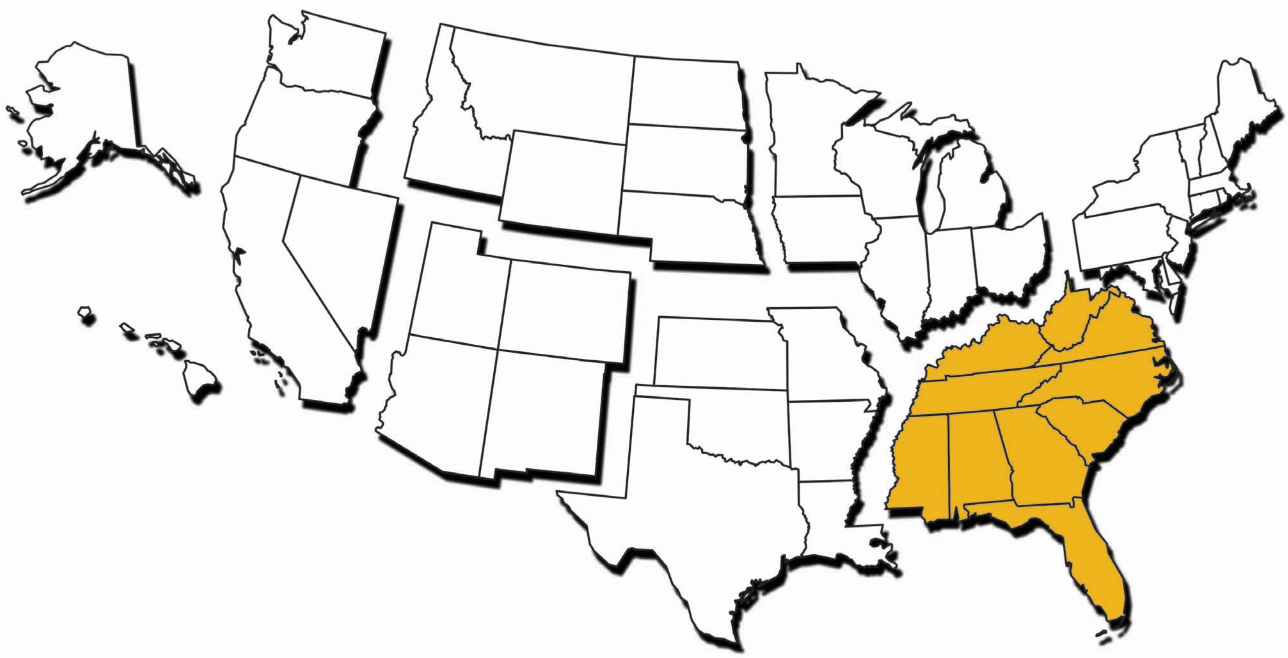

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