



## Mountain Building Part I: the Grenville Mountains

The shape and position of North America has changed dramatically over the last billion years, and geologic processes continue these changes today. The Earth is estimated to be 4.5 billion years old. The *oldest rocks* known are nearly 4 billion years old, and although these ancient rocks are found on almost every continent, they are not found at the Earth's surface anywhere in the Southeast. In North America, these most ancient rocks are found exposed at the surface in parts of Canada, comprising the Precambrian shield, a stable core of the North American continental landmass. The oldest rocks in the Southeast are Precambrian rocks from the Blue Ridge of North Carolina.

The Earth is dynamic, consisting of plates that are made of rigid continental and oceanic lithosphere overlying a churning, plastically flowing asthenosphere (Figure 1.2) and are constantly in motion. Plates are 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 because they are part of the moving plates. This not only shapes the land, but also affects the distribution of rocks and minerals, natural resources, climate and life.

Compression from colliding plates, stretching from plates pulling apart, addition of land to North America, weathering and erosion have combined to slowly sculpt the form of the continent. Scientists can reconstruct what the ancient Earth may have looked like by studying rocks, fossils and other geologic features. More than a billion

The **oldest rocks** found on Earth date back 3.9 billion years. Ancient metamorphic gneiss from this time is found in South Africa, Antarctica, Greenland and Northwest Canada. Sedimentary rocks of the same age have been found in western Australia.

### How do plates move?

Although the rock of the **asthenosphere** would seem very solid if you could observe it in place, under long term stress it does slowly bend and flow. In addition, there are rising plumes of partly melted rock within the Earth's mantle and crust that can be detected with geophysical instruments. The lithosphere is the outermost layer of the Earth, a rigid crust and upper mantle broken up into many **plates**. The crust capping each plate is either thick continental crust (especially thick where there are mountains) or thinner oceanic crust. The plates of the lithosphere pull the surficial portions of the plates towards subduction zones. Some of these plates converge toward the trenches as fast as 10 cm/yr (but often much less.)

<for more on the oceanic vs. continental crust, see p. \_\_>

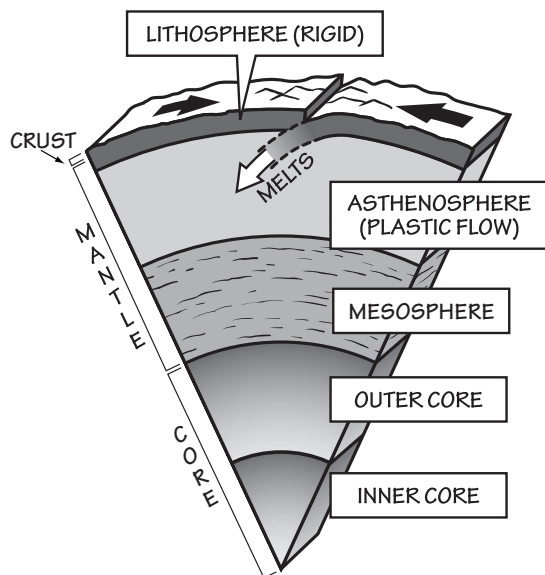


Figure 1.2: Compositionally, the Earth is divided into three basic layers: the very dense core, the mantle, and the crust. The crust is the outermost layer and the least dense. Based on physical properties, the Earth is divided up another way: the lithosphere, asthenosphere, mesosphere, outer core, and inner core. The rigid crust of the lithosphere, is constantly moving over the plastically flowing asthenosphere. Figure by J.

Cenozoic	Quaternary	Present
	Tertiary	
Mesozoic	Cretaceous	65
	Jurassic	
	Triassic	
	Permian	
Paleozoic	Pennsylvanian	255
	Mississippian	
	Devonian	
	Silurian	
	Ordovician	
	Cambrian	
	Precambrian	545
		4600





# Geologic History

The **Precambrian shield** has had very little tectonic activity (faulting, folding) for millions of years. Shields are the stable cores of all continents, often covered by layers of younger sediment.

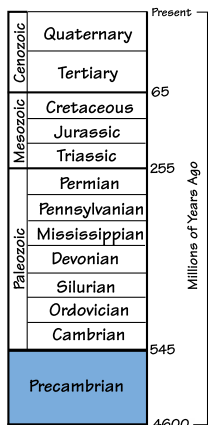
'Proto-' **North America** refers to the ancestral landmass which gradually was shaped into the North American continent that we see today.

Geologists are not sure of the exact size and shape of **Rodinia**. It was not the same supercontinent as Pangea, which formed (or was assembled) several hundred million years later during the Permian.

A **mountain building** event is also called an **orogeny**.

## Three types of rock

Minerals are the building blocks of the three basic rock types: igneous, metamorphic and sedimentary. Igneous rocks form from cooling molten rock. Metamorphic rocks form by increasing the temperature and pressures on a pre-existing rock. Sedimentary rocks form by the compaction and cementation of sediment particles resulting from the breakup of pre-existing igneous, metamorphic and sedimentary rocks.



years ago narrow strips of land collided and compressed to form the beginnings of the North American continent and what is now the **Precambrian shield**. From this **proto-North America**, sediment was eroded and transported by rivers and streams across the ancient continental margins and then into the adjacent oceans. The sediment deposited in the ocean waters on the eastern margin of proto-North America comprise what is presently called the Grenville belt.

Over 1 billion years ago, proto-North America collided with other conti-

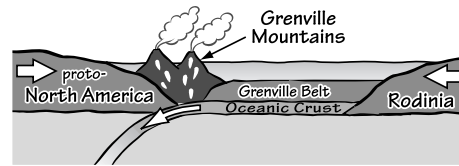
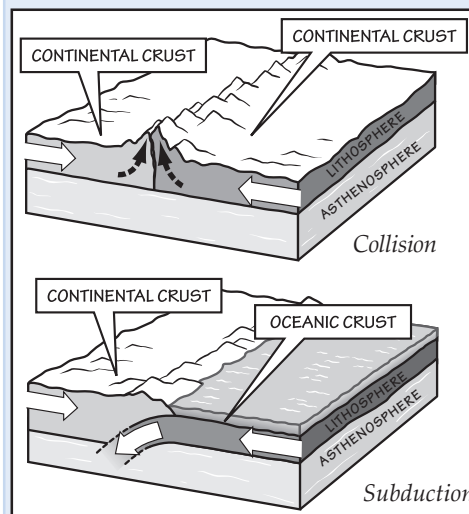


Figure 1.3: A Precambrian cross-section showing the Grenville belt of ocean floor sediment being squeezed between proto-North America and Rodinia.

nents to form a large supercontinent that we now call **Rodinia**. Such collisions of continental crust result in mountains. The Grenville sediment that had been deposited in the ocean was caught in the collision and thrust up onto the side of proto-North America (Figure 1.3). The collision crumpled the crust, creating a tall

(Himalaya-size) mountain range that stretched from Canada to Mexico: the Grenville Mountains. These mountains are the earliest evidence of **mountain building** in the Southeast, and the rocks remaining from that ancient mountain chain are the oldest rocks exposed at the surface in the Southeast today. At this point in geologic time, very little existed of the Southeast as we now know it. The rocks of the Piedmont region and the foundation rocks of Florida would not be attached to North America for a few hundred million years more. Also, the Coastal Plain

## Continental and oceanic crust:



The outermost layer of the lithosphere is either continental or oceanic crust. Continental crust is less dense but significantly thicker than oceanic crust. When continental crust collides with oceanic crust, the more dense oceanic crust will be dragged (or subducted) under the buoyant continental crust. 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.

Figure 1.4 and 1.5 by J. Houghton.





sediment and the sediment that eventually became the rocks of the Inland Basins region and Blue Ridge were not yet deposited (most of the present Gulf and Atlantic coastal states).

The ancient Grenville rocks tell a story of collision-related mountain building, a process which has been repeated three more times on the east coast of North America so far. The intense heat and pressure associated with the collision produced molten rock that was injected into the crust, and metamorphosed the sediment that had eroded from the margin of the Precambrian shield before the collision occurred. Evidence of this violent past is clear in the Grenville rocks, which are typically metamorphosed sedimentary rocks with igneous intrusions (from the now-cooled molten injections) that have been folded and overturned by later **compressional** forces during mountain building.

Over a few hundred million years, the Grenville Mountains **eroded**, just as the mountains today are constantly being eroded. Weathering and erosion wore away the Grenville Mountains, leaving exposed only the ancient mountain cores---the only the Grenville rocks in the Southeast. The Grenville rocks are now covered by thousands of meters of younger rocks in most areas; however, exposures are found where overlying rocks have been worn away by erosion (*Figure 1.6*). In the

**Compressional** forces occur by pushing objects (such as plates) together.

**Weathering and erosion** are constants throughout the history of time. Rocks are constantly being 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.

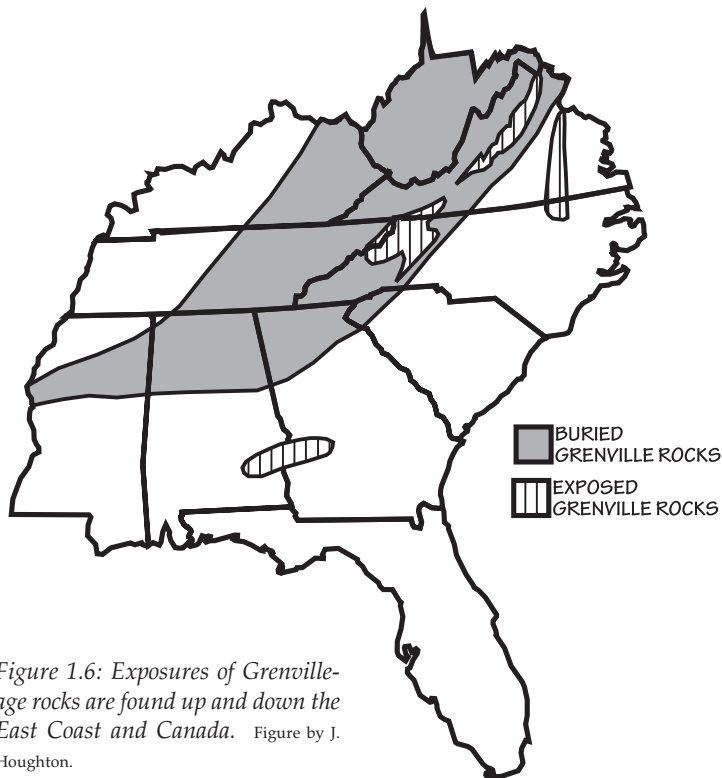
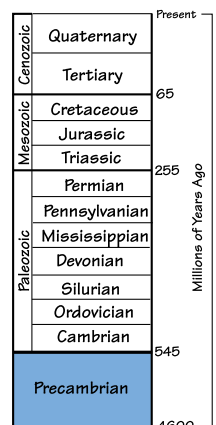


Figure 1.6: Exposures of Grenville-age rocks are found up and down the East Coast and Canada. Figure by J. Houghton.

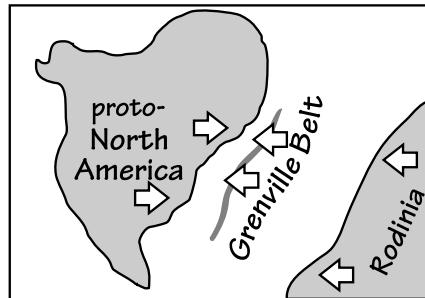




# Geologic History

**Basement rocks** are the foundation that underlies the surface geology of an area. These rocks are generally igneous or metamorphic crystalline rock. In certain areas of the Piedmont and Blue Ridge regions, the basement rock is exposed at the surface either because it has been thrust upward during mountain building events, or erosion of overlying units has exposed the basement rocks. Often a combination of both of these factors exposes basement rock at the surface.

Southeast, the Grenville rocks are exposed in such places as Blowing Rock, North Carolina, Red Top Mountain, Georgia, and Old Rag Mountain, Virginia. Though the exposures of Grenville-age rocks in the Southeast are relatively sparse, they are important because of the geologic story they tell about the region. Grenville-age rocks are literally the foundation of the inner continent and because in many areas they are mostly overlain by sedimentary rocks, they are called *basement rocks*.



**Figure 1.7: Grenville Mountain Building**

- North America collides with other continents, forming a supercontinent (Rodinia)
- Grenville belt of ocean sediment pushed onto the side of ancient North America
- Grenville Mountains form from the collision

