Mountain Building Part I: *the Grenville Mountains*

North America was not always the shape we see today. The continent was formed over billions of years, and geologic processes continue to shape it today. The Earth is estimated to be 4.5 billion years old. The ***oldest rocks*** that we know of are nearly 4 billion years old. Although these ancient rocks are found on almost every continent, none are found at the Earth's surface in the Northeast. In North America, these most ancient rocks are found exposed at the surface in many parts of Canada. These rocks make up the Precambrian shield, a stable continental landmass that is the core of North America. The dynamic plates of the Earth are constantly in motion, made of rigid continental and oceanic crust overlying the churning, plastically flowing ***asthenosphere*** *(Figure 1.2)*. Plates are pulling apart, colliding into one another, or sliding past each other with great force, creating strings of volcanic islands, new ocean floor, earthquakes, and mountains, melting rock and injecting magma into the overlying crust. As these plates move, the continents resting atop them are continuously shifting position. This not only shapes the land, but also affects the type of rocks and minerals, natural resources, climate and life present.

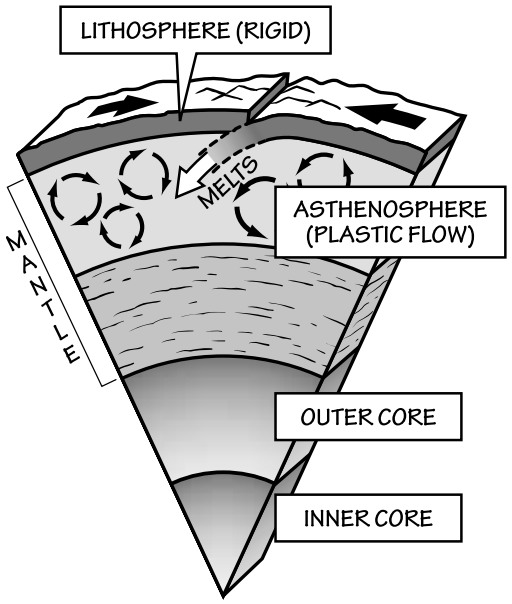


Figure 1.2: The layers of the Earth include the rigid crust of the lithosphere, which is constantly moving over the plastically flowing asthenosphere. Figure by J. Houghton.

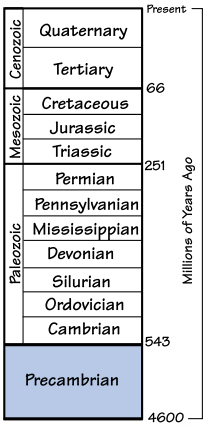
A series of additions of land to North America, compressions from colliding plates, stretching from the pulling apart of plates, and erosion have combined to slowly sculpt the form of the continent. The earliest positioning and shape we can reconstruct of North America dates back billions of years to the formation of continents. Narrow strips of land were smashed together to form the beginnings of North America and what is now the ***Precambrian shield.***

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?

The **lithosphere** *is the outermost layer of the Earth, a rigid crust and upper mantle broken up into many plates. The heat and pressure created by the overlying lithosphere, make the solid rock of the* **asthenosphere** *bend and move like metal when heated. The flowing rock in the asthenosphere moves with circular convection currents, rising when hot and falling when cool. The plates of the lithosphere move with the underlying asthenosphere, as much as 18 cm/yr (but normally much less.)*

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 sediments.*



Geologic History

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

Many geologists believe that North America collided with **ancient Europe**, *also called Baltica in the Precambrian.*

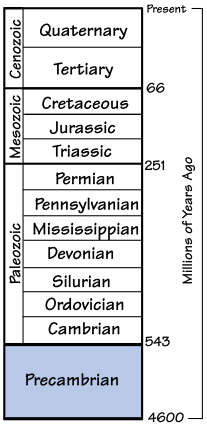
This ***proto-North America*** had sediment eroding off of its continental margins, into the adjacent oceans. The sediments deposited on the eastern margin of proto-North America are called the Grenville belt.

Over 1 billion years ago, proto-North America collided with ***another continent***. The Grenville belt of margin sediments was caught in between the colliding continents and was thrust up onto the side of proto-North America. The collision crumpled the crust, creating a tall mountain range that stretched from Canada to Mexico: the Grenville Mountains. These mountains are the earliest evidence of mountain building in our region, and the rocks remaining from that ancient mountain chain are the oldest rocks that we see exposed at the surface in the Northeast today.

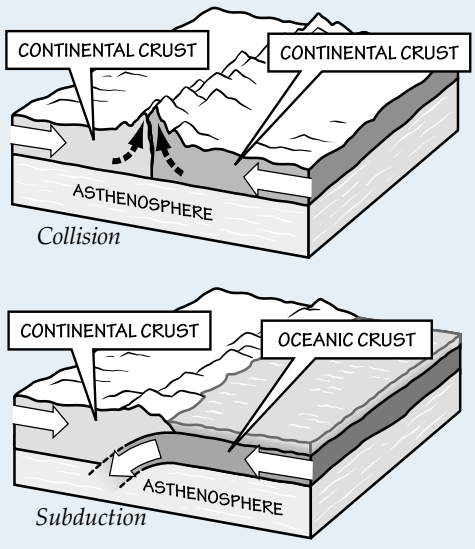
The Grenville rocks themselves have quite a story. The intense heat and pressure generated from the collision produced volcanic material, injected hot molten rock into the crust, and metamorphosed the sediments that had eroded from the margin of the Precambrian shield before the collision occurred. Evidence of this violent past is clear in the Grenville rocks, which are usually metamorphosed sedimentary rocks with igneous intrusions (from the hot molten injections) that have been folded and overturned by the collision-induced compression.

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.



Continental and oceanic crust:



The lithosphere has 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 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. Figures by J. Houghton.

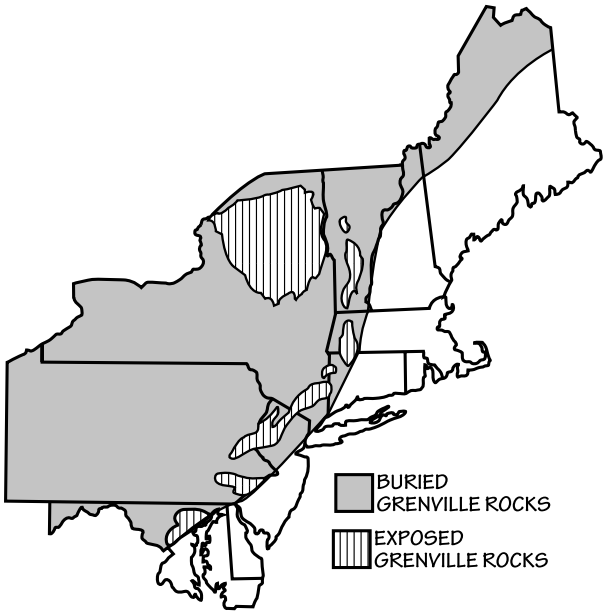


Figure 1.3: Exposures of Grenville-age rocks are found up and down the East Coast and Canada. Figure by J. Houghton.

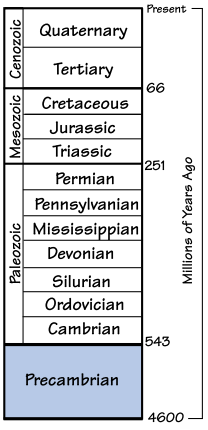
Over time, the Grenville Mountains ***eroded***, just as the Appalachians, Rockies and Himalayan Mountains are constantly being eroded today. By 600 million years ago, weathering and erosion had worn away the mountains, leaving exposed only their innermost cores. These ancient cores are the Grenville rocks that we see exposed today in the Northeast and eastern Canada *(Figure 1.3)*. The Grenville rocks are covered in many areas by younger rocks; however, exposures are found where overlying rocks have been worn away by erosion and the scraping action of glaciers. In the Northeast, the Grenville rocks are exposed in the Adirondacks, the Hudson and Jersey Highlands, Manhattan and Westchester in New York, the Green Mountains of Vermont, the Reading Prong of Pennsylvania, and the Berkshire Hills of Massachusetts.

During the erosion of the Grenville Mountains in the late Precambrian, the geography of the world looked nothing like today. North America was positioned on its side across the Equator, with today's east coast facing south. Sediments were eroding from the Grenville Mountains on either side. The ocean breaking on the shores of the east coast was known as the ***Iapetus*** or ***Proto-Atlantic Ocean***. Given the equatorial position of the continent, the

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.*

If you could travel back in time to the Precambrian, you would not recognize the Northeast region. Parts of the Northeast were not added on until later and North America was not even in the same spot on the Earth! The Northeast region was just south of the Equator, making for much warmer weather.

The **Proto-Atlantic** *is also known as the* **Iapetus Ocean**. *In Greek Mythology, Iapetus was the father of Atlantis.*



Northeast was experiencing a warm climate. This is the earliest geography of the Northeast region that can be reconstructed. At this point in geologic time, all of New England east of the Berkshires and Green Mountains was not yet part of North America. New England was not assembled for several million more years.

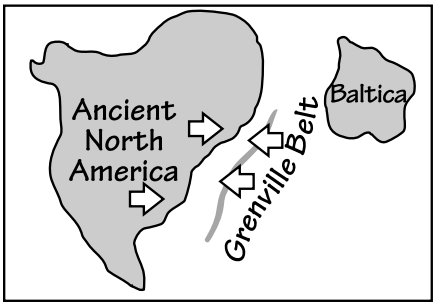


Figure 1.4: Grenville Mountain Building
-Baltica approaches and collides with North America
-Grenville belt pushed onto side of ancient North America
-Grenville Mountains erode away, only roots remain
-North America straddles the equator