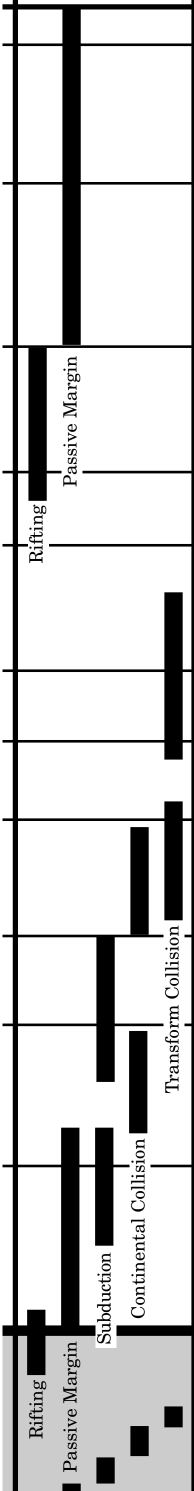
Tectonic Events Affecting Northeast North America	Important Geologic Events in New York	Inferred Position of Earth's Landmasses



Important Geologic Events in New York

Advance and retreat of last continental ice

Uplift of Adirondack region

Sands and shales underlying Long Island and Staten Island deposited on margin of Atlantic Ocean

Development of passive continental margin

Initial opening of Atlantic Ocean
North America and Africa separate

Intrusion of Palisades sill
Pangea begins to break up

Extensive erosion

Appalachian (Alleghanian) Orogeny caused by collision of North America and Africa along transform margin, forming Pangea

Catskill Delta forms
Erosion of Acadian Mountains

Acadian Orogeny caused by collision of North America and Avalon and closing of remaining part of Iapetus Ocean

Salt and gypsum deposited in evaporite basins

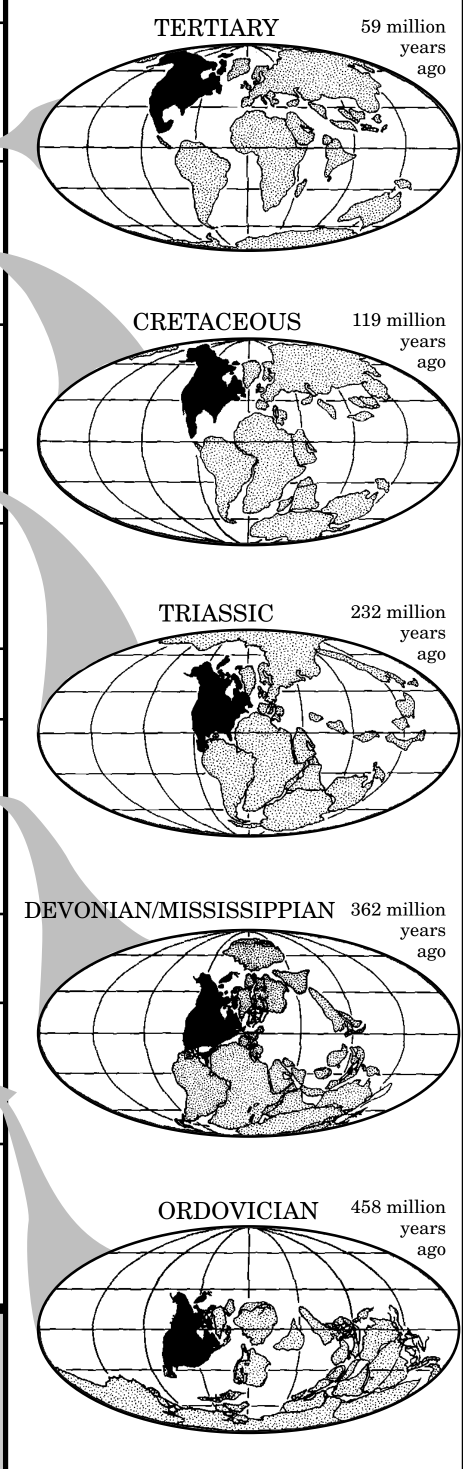
Erosion of Taconic Mountains; Queenston Delta forms

Taconian Orogeny caused by closing of western part of Iapetus Ocean and collision between North America and volcanic island arc

Iapetus passive margin forms

Rifting and initial opening of Iapetus Ocean
Erosion of Grenville Mountains

Grenville Orogeny: Ancestral Adirondack Mtns. and Hudson Highlands formed



Ancient continents

It has taken millions of years for the continents to take on the shapes we see today. To simplify ancient geography, geologists have given names to the proto-continents to distinguish them from their modern counterparts: **proto-Europe** *(Northern Europe without Ireland and Scotland) is known as* **Baltica***; proto-North America is known as Laurentia; and Proto-Africa was part of a group of continents known as Gondwana.*

'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.*

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

An **orogeny** *is a mountain-building event (like the formation of the Taconic or Grenville Mountains) caused by colliding plates and compression of the edge of the continents. Orogeny is derived from the Greek word, 'oro,' meaning mountain.*

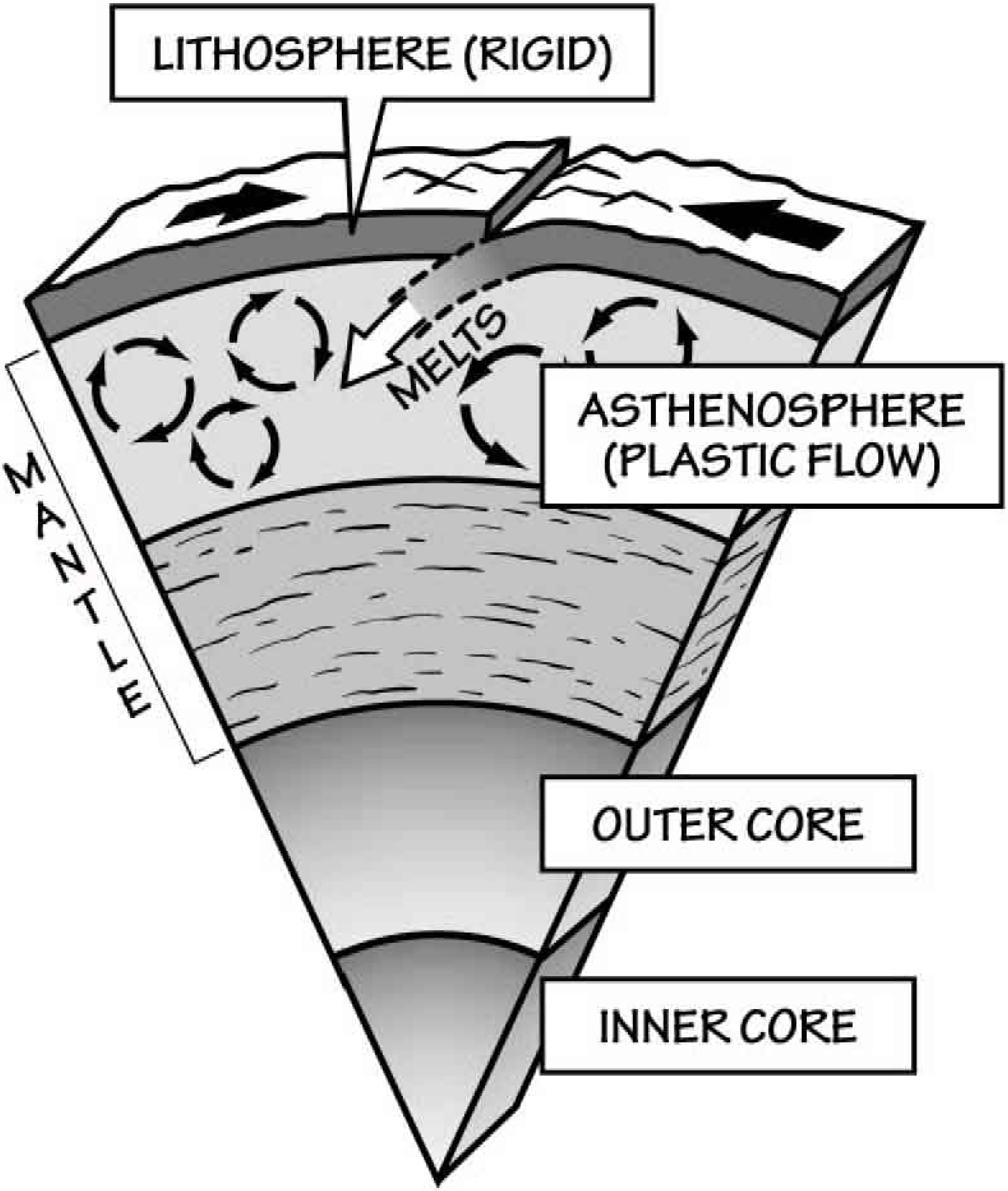
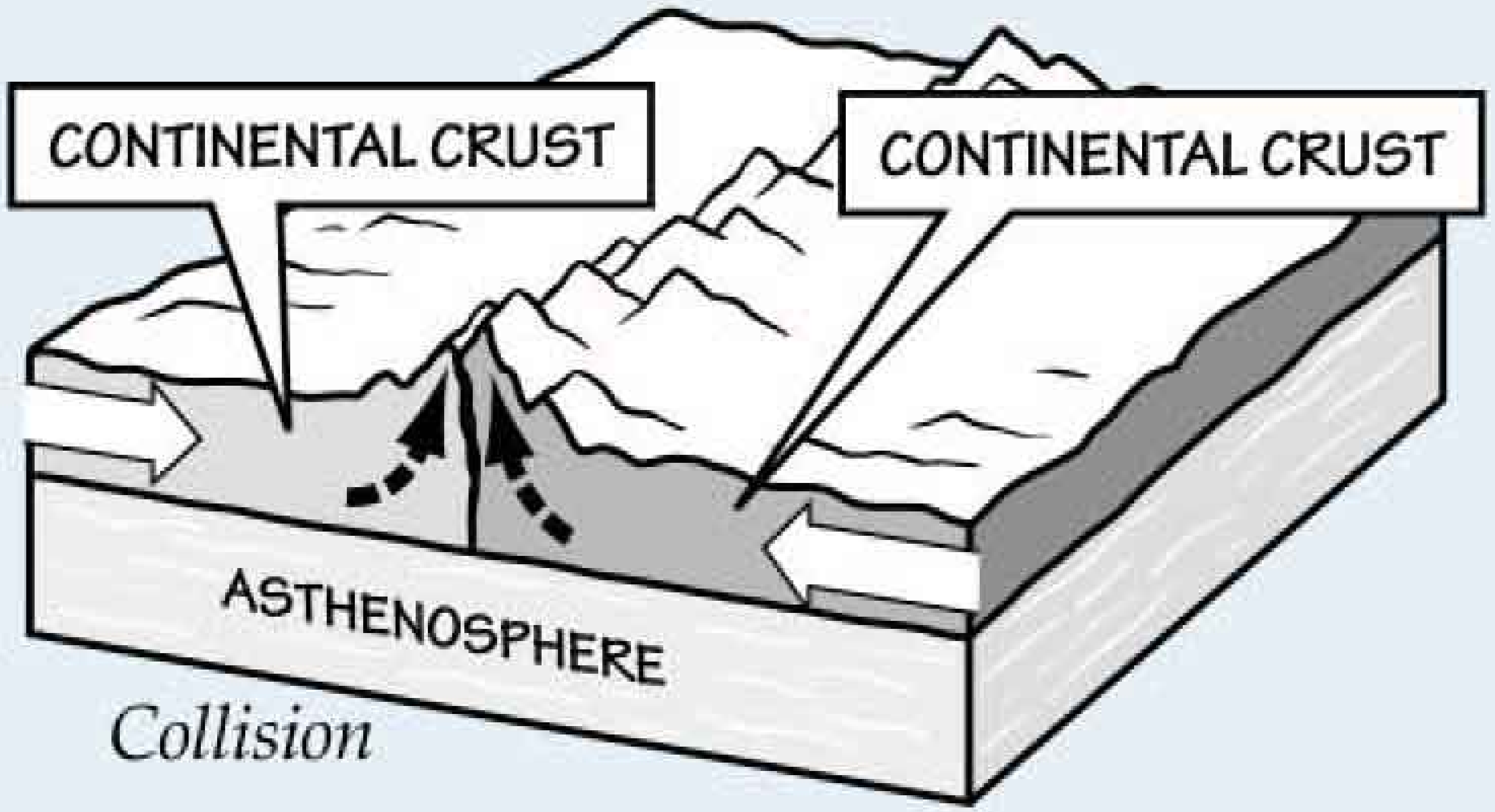


Figure 1.2: The layers of the Earth include the rigid crust of the lithosphere, which is constantly moving over the plastically flowing asthenosphere. Figure by J. Houghton.

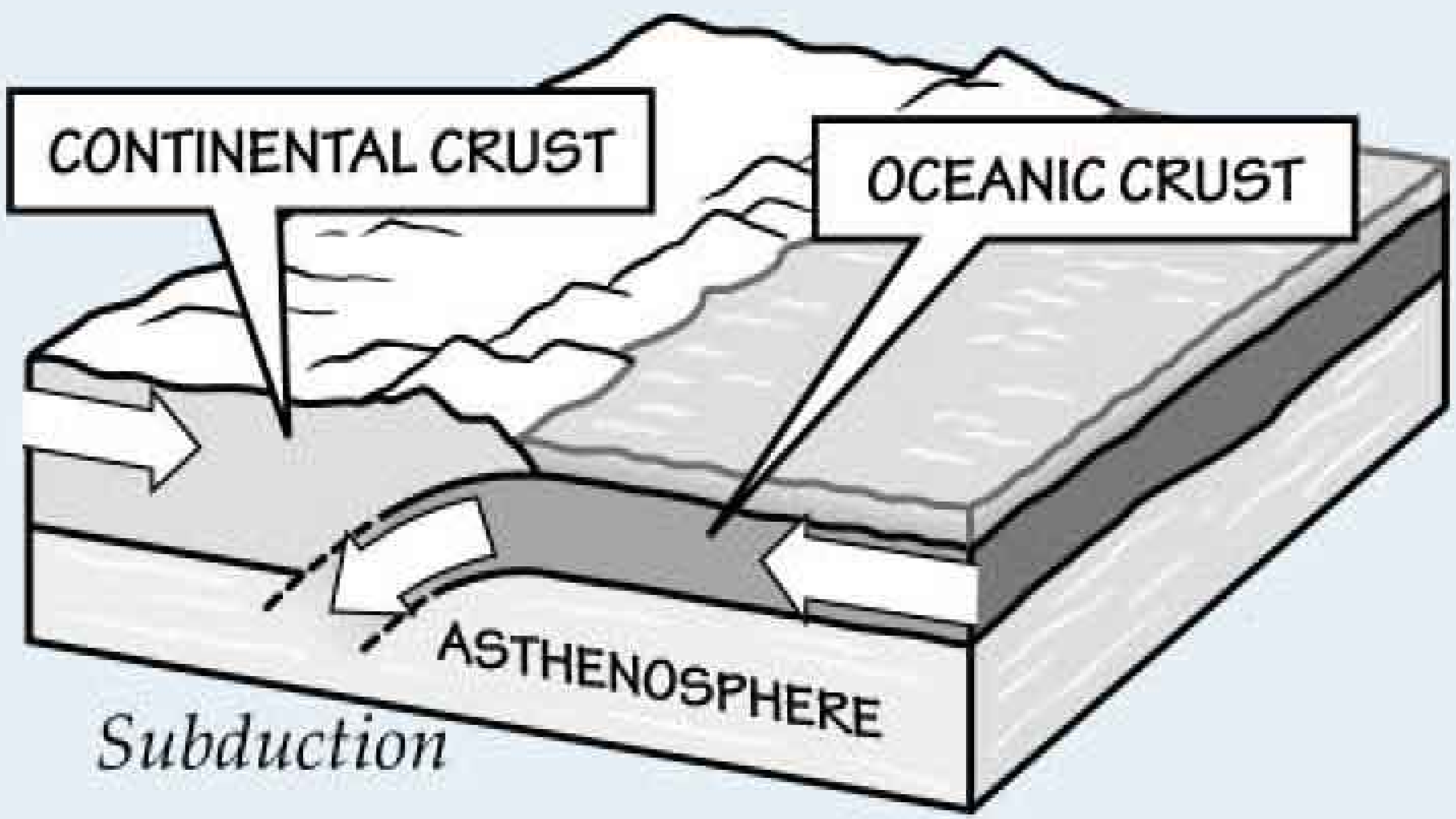
How do plates move?

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.)*

Continental and oceanic crust:



Collision

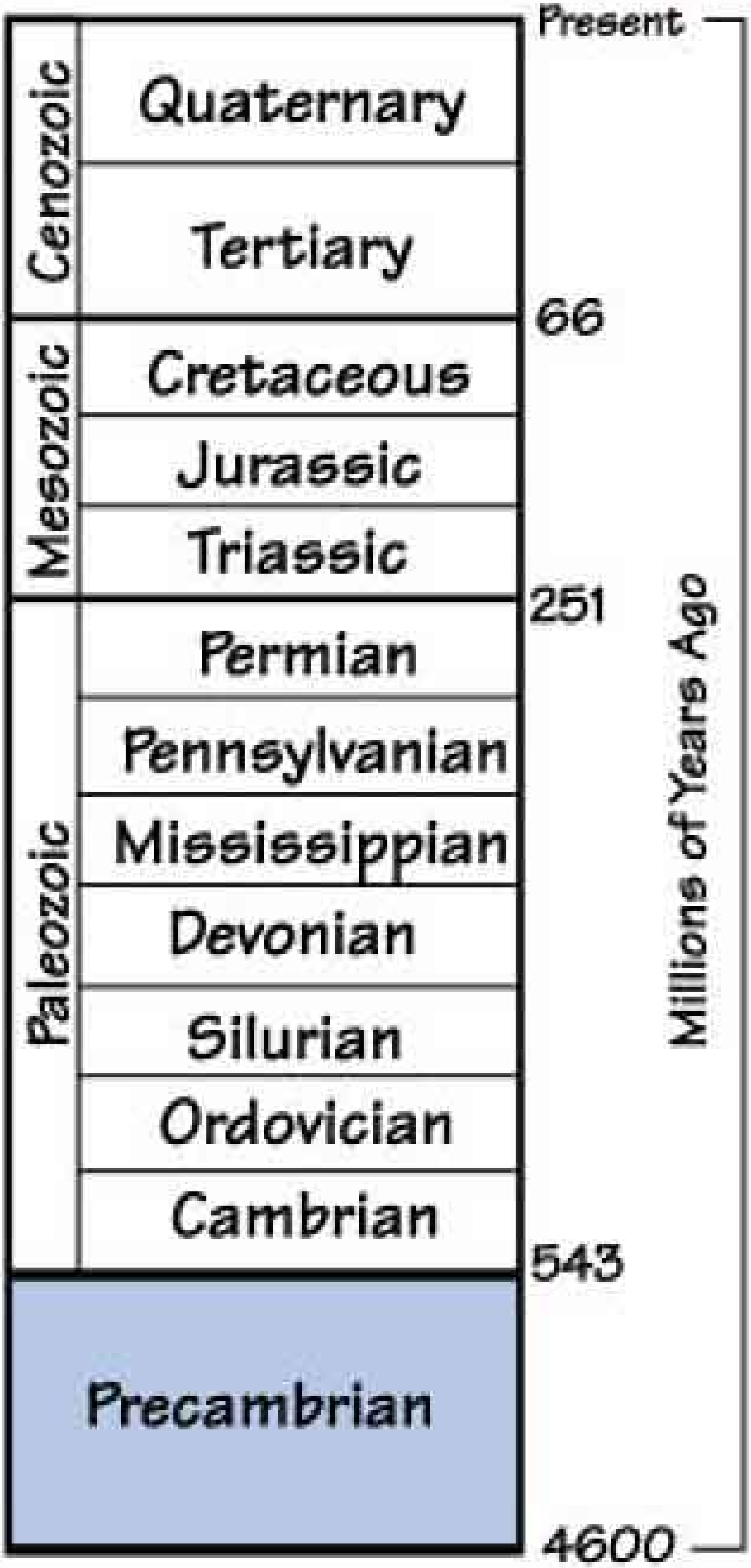


Subduction

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.

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.*

Mountain Building Part I: *the Grenville Mountains*



Present
Cenozoic
Quaternary
Tertiary
66
Mesozoic
Cretaceous
Jurassic
Triassic
251
Paleozoic
Permian
Pennsylvanian
Mississippian
Devonian
Silurian
Ordovician
Cambrian
543
Precambrian
4600
Millions of Years Ago

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.

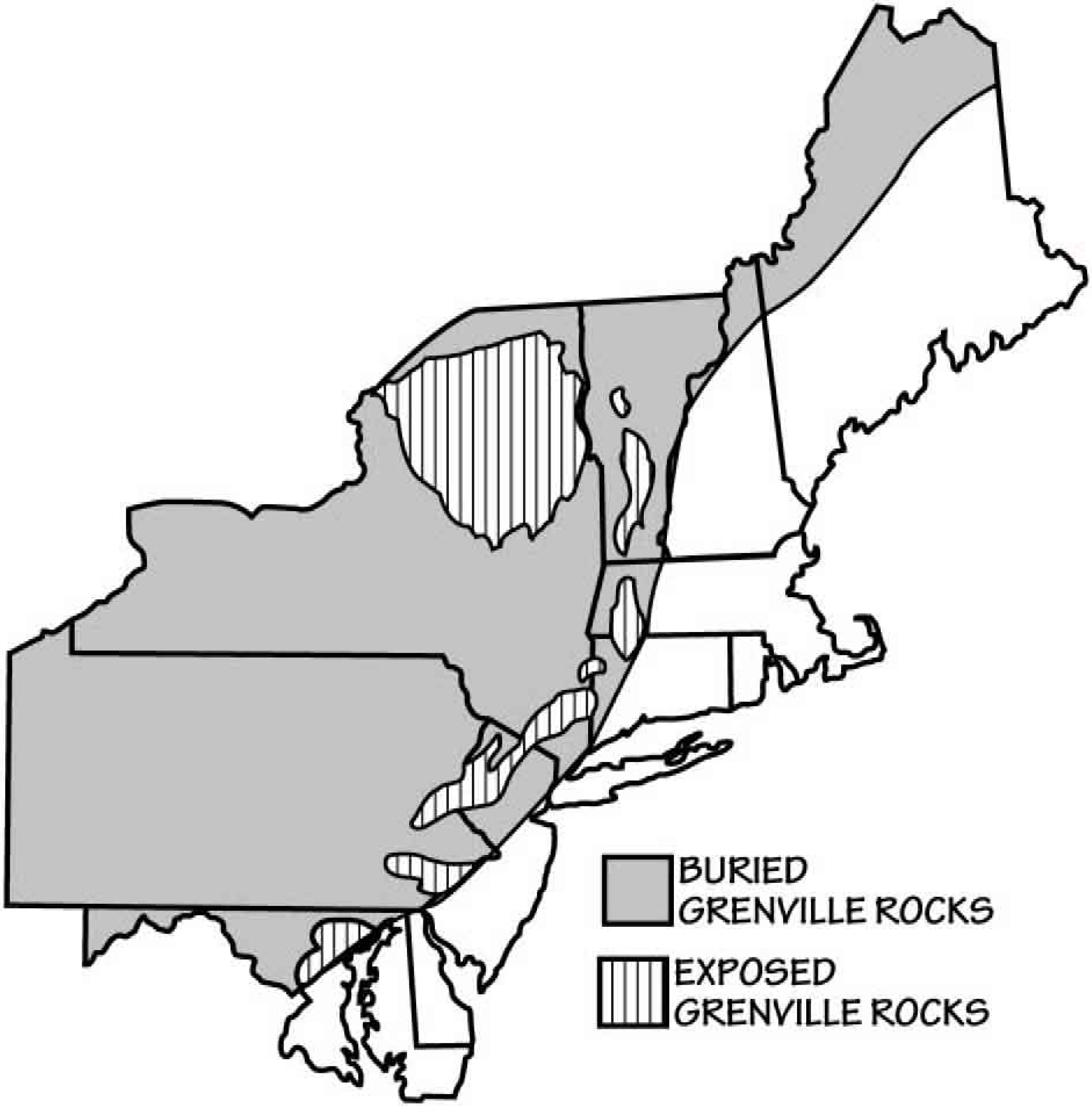


Figure 1.3: Exposures of Grenville-age rocks are found up and down the East Coast and Canada. Figure by J. Houghton.

Grenville Mountain Building

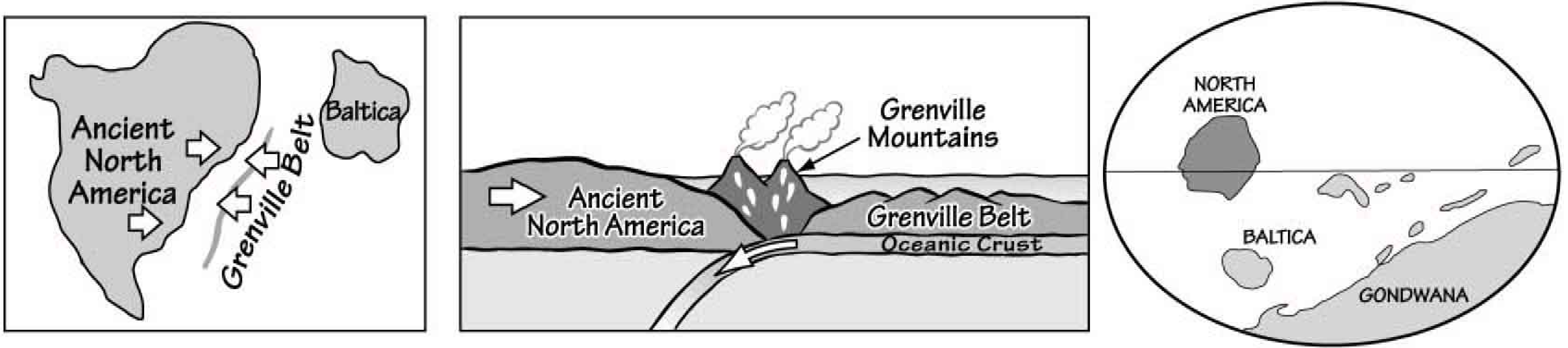
-Baltica approaches and collides with North America

-Grenville belt pushed onto side of ancient North America

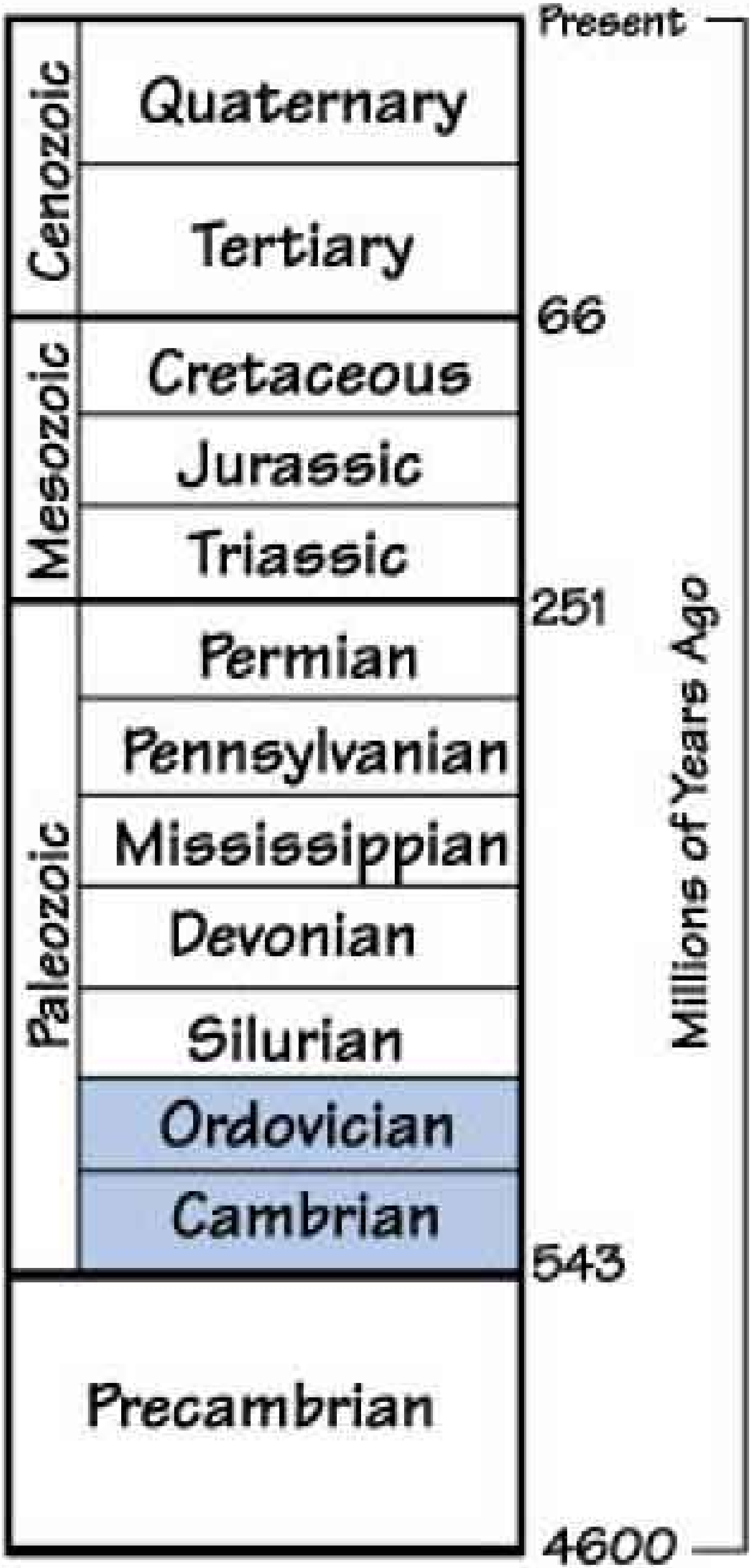
-Grenville Mountains erode away, only roots remain

-North America straddles the equator

Precambrian
(4500-544 mya)



Mountain Building Part II: *the Taconic Mountains*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Mesozoic
Cretaceous
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Paleozoic
Permian
Pennsylvanian
Mississippian
Devonian
Silurian
Ordovician
Cambrian
543
Precambrian
4600
Millions of Years Ago

The rounded Berkshire Mountains of western Massachusetts are the roots of the original **Taconic Mountains**. *Large segments of the Taconic Mountain mass (known as the Taconic Klippe) were thrust westward into eastern New York over younger rocks that had been deposited in the inland ocean.*

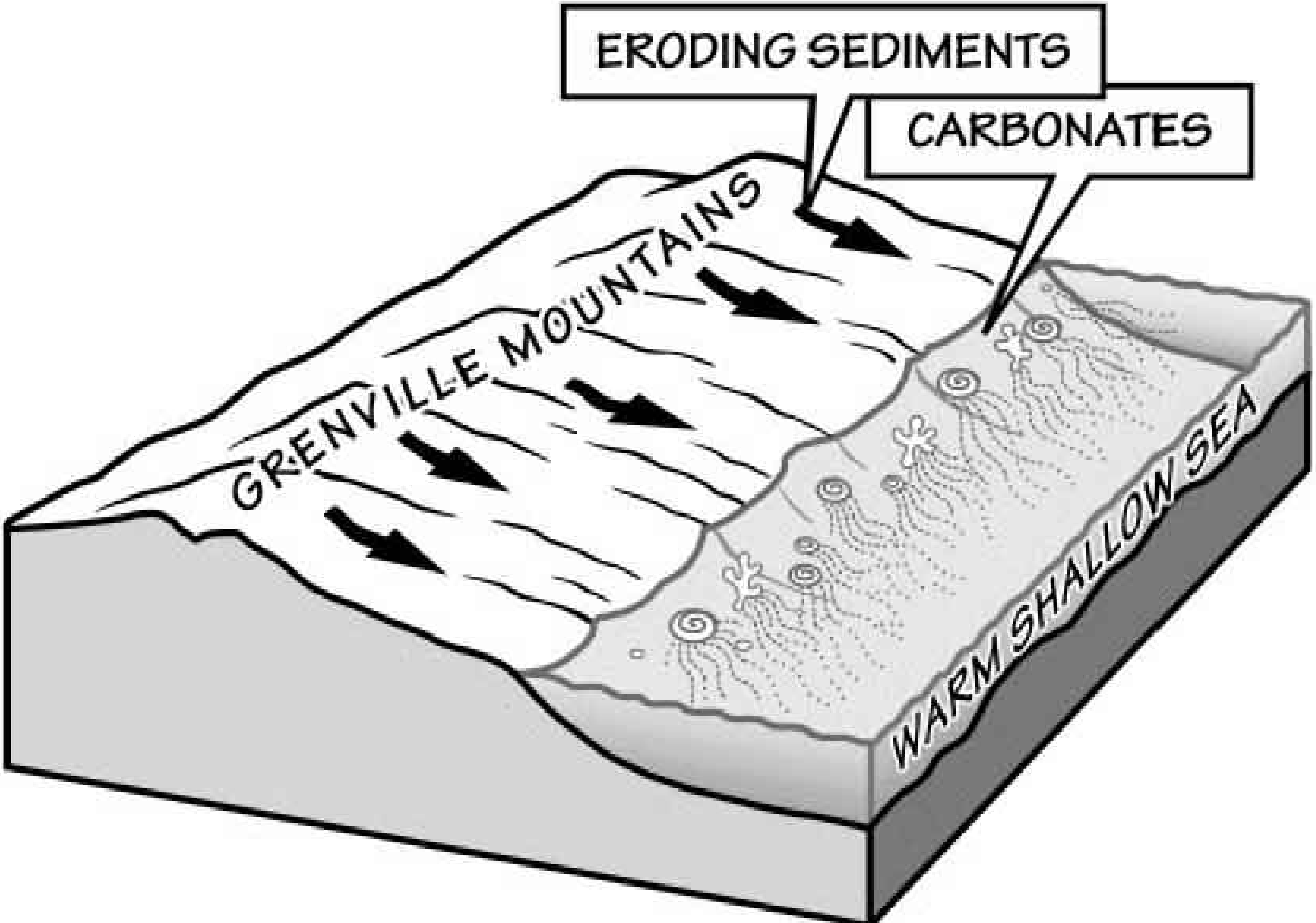


Figure 1.5: The Grenville Mountains gradually eroded over millions of years, depositing sediments on either side of the range, becoming layered with carbonate rocks that were forming in the proto-Atlantic Ocean along the margin of the continent. Figure by J. Houghton.

Carbonates *include limestone and dolostone, formed by the accumulation of calcium carbonate ($CaCO_3$) shells and outer skeletons from aquatic organisms , such as corals, clams, snails, bryozoans and brachiopods. These organisms thrive in warm, shallow waters common to tropical areas. It is not surprising that modern carbonates are observed forming in places such as the Florida Keys and the Bahamas.*

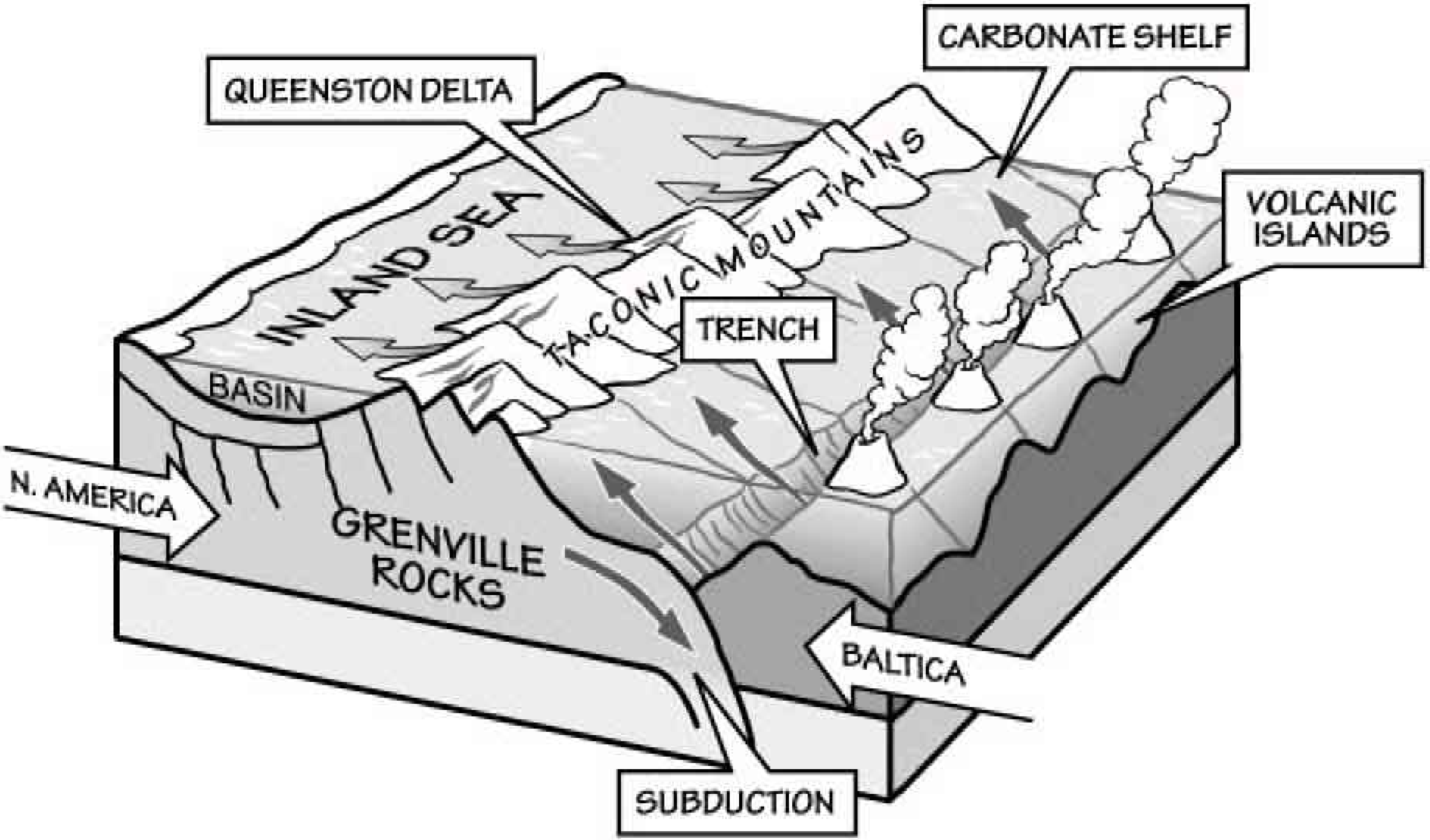


Figure 1.7: Volcanic islands formed where the plates were forced together as the Iapetus Ocean closed. The compression crumpled the crust to form the Taconic Mountains and a shallow inland sea. Figure by J. Houghton.

Volcanic islands *are common at subduction zones between colliding oceanic plates. As the plates smash together, one plate is pulled under the other (or subducted). The friction between the plates generates enough heat and pressure to melt some of the crust. The molten rock rises upwards through the crust and creates a string of volcanoes along the edge of the plate.*

The Aleutian Islands are a modern example of volcanic islands forming at a subduction zone.

A **delta** *forms as sediment is eroded from mountains and transported downward by streams. Deltas typically form a wedge-shaped deposit as sediments fan out across the lower elevations.*

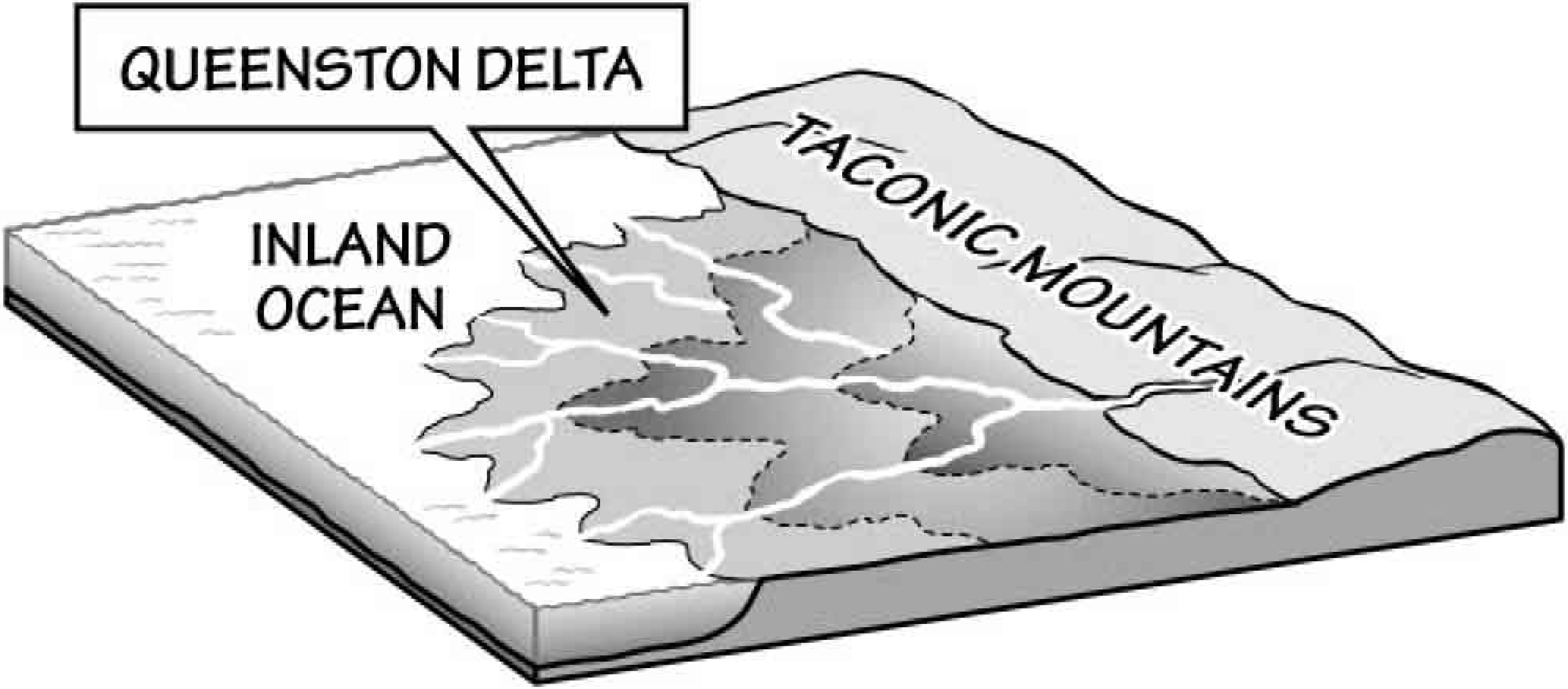


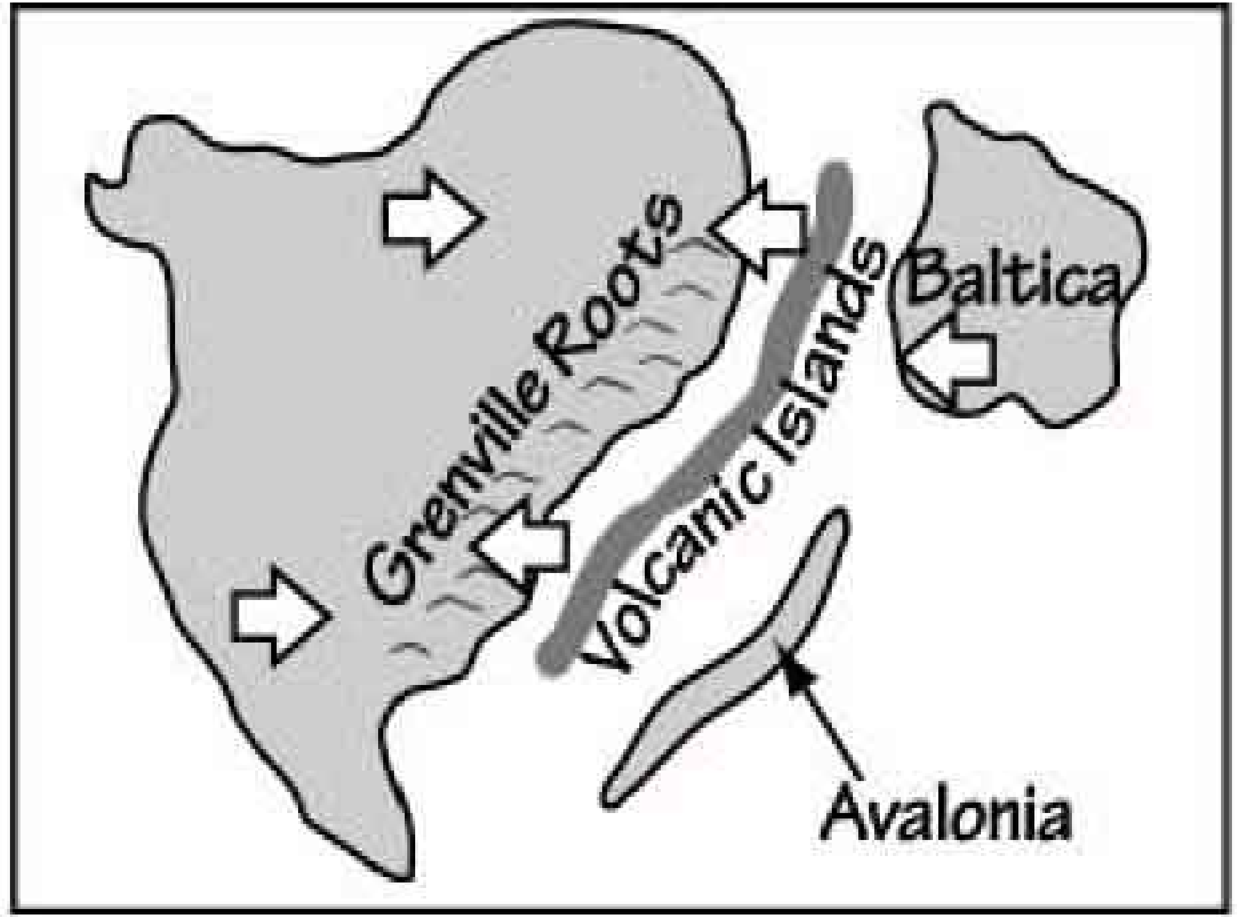
Figure 1.8: The Queenston Delta formed as sediments eroded from the Taconic Highlands and were transported downward by streams, forming the characteristic wedge-shaped delta deposits. Figure by J. Houghton.

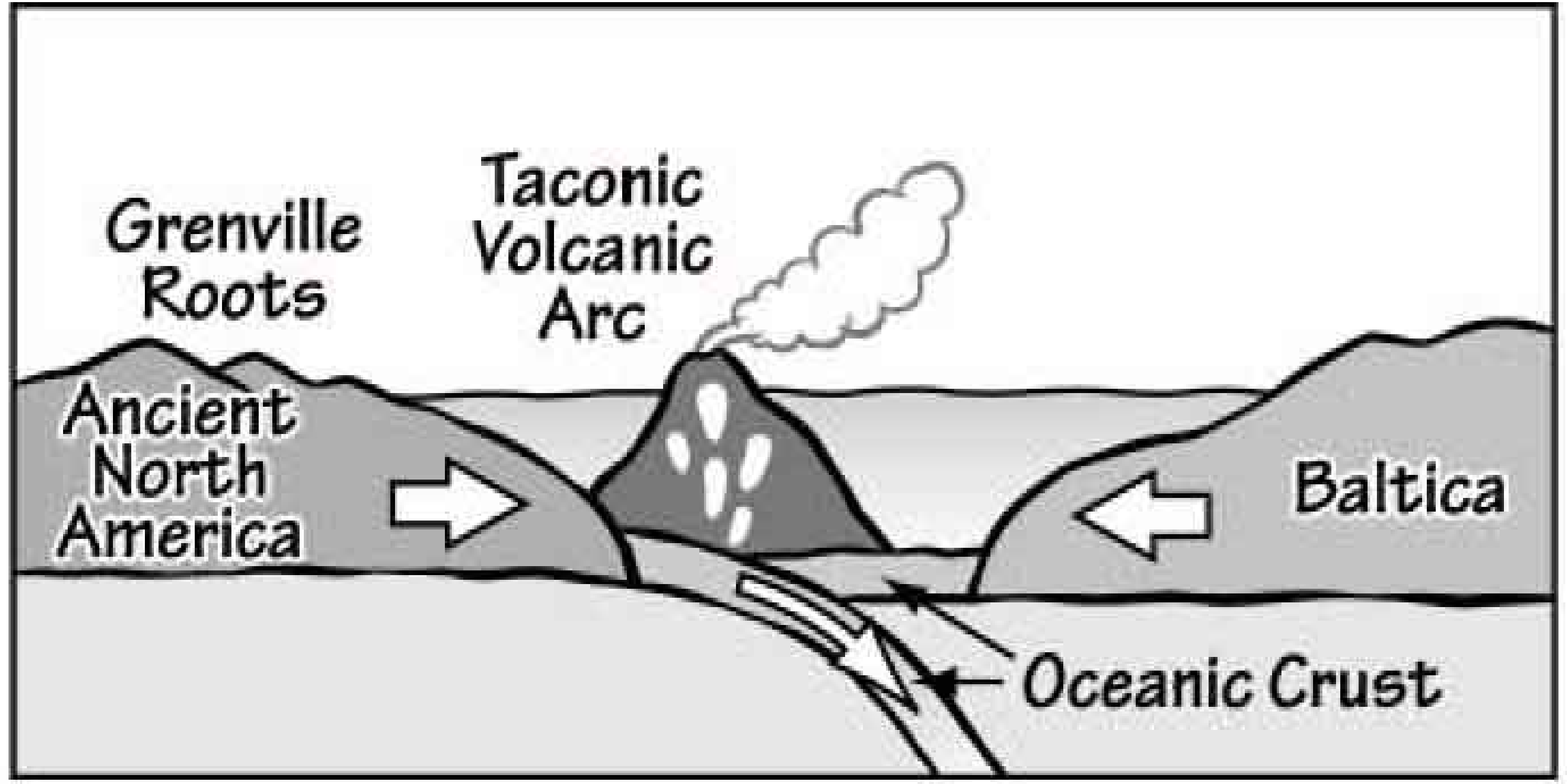
The **Queenston Delta** *formed from sediments eroding off of the Taconic highlands. With the rise of the Acadian Mountains, erosion of sediments was renewed and the Catskill Delta deposits covered over the Queenston delta.*

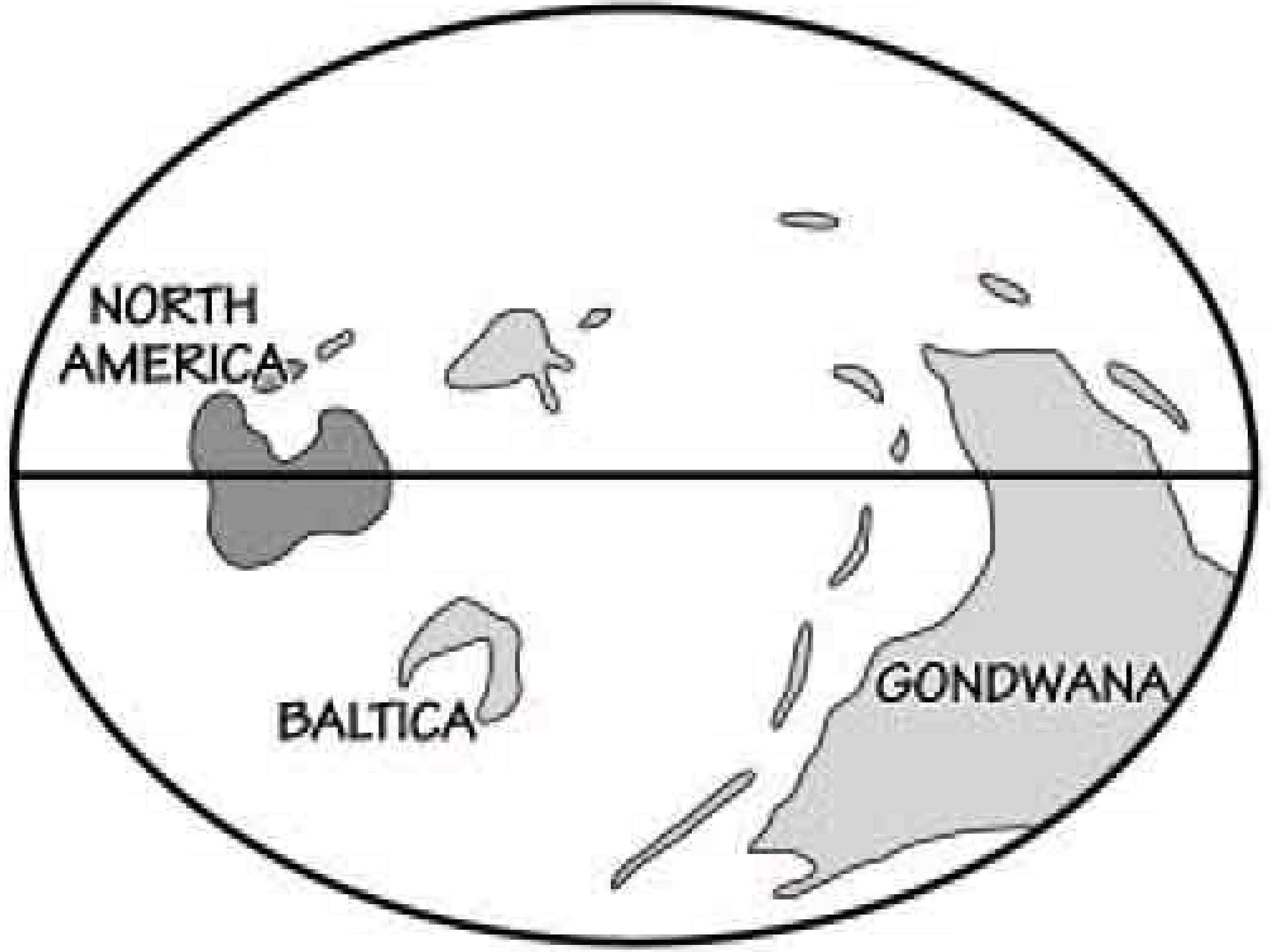
Taconic Mountain Building

-Baltica approaches North America after breaking away earlier
-volcanic islands form over subduction trench
-volcanic islands collide with North America, form Taconics
-inland sea forms to the west of Taconics
-Taconic Mountains erode
-Queenston Delta deposited west of Taconics

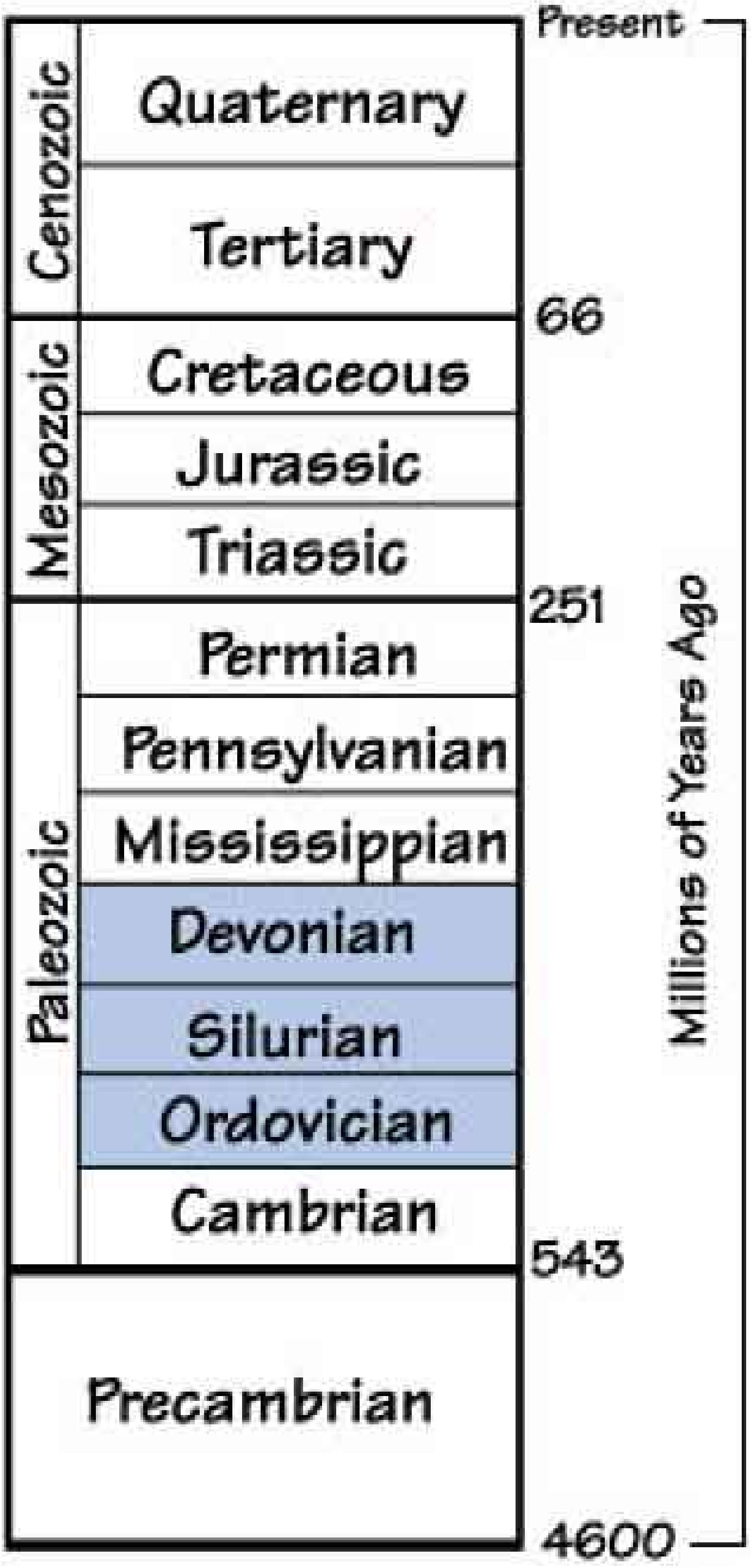
Cambrian/ Ordovician (544-440 mya)







Exotic Terranes:
the making of New England



Present
Cenozoic
Quaternary
Tertiary
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Mesozoic
Cretaceous
Jurassic
Triassic
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Paleozoic
Permian
Pennsylvanian
Mississippian
Devonian
Silurian
Ordovician
Cambrian
543
Precambrian
4600
Millions of Years Ago

Due to their origin from far away, 'exotic' places, **exotic terranes** *have distinctly different geologic characteristics than the surrounding rocks.*

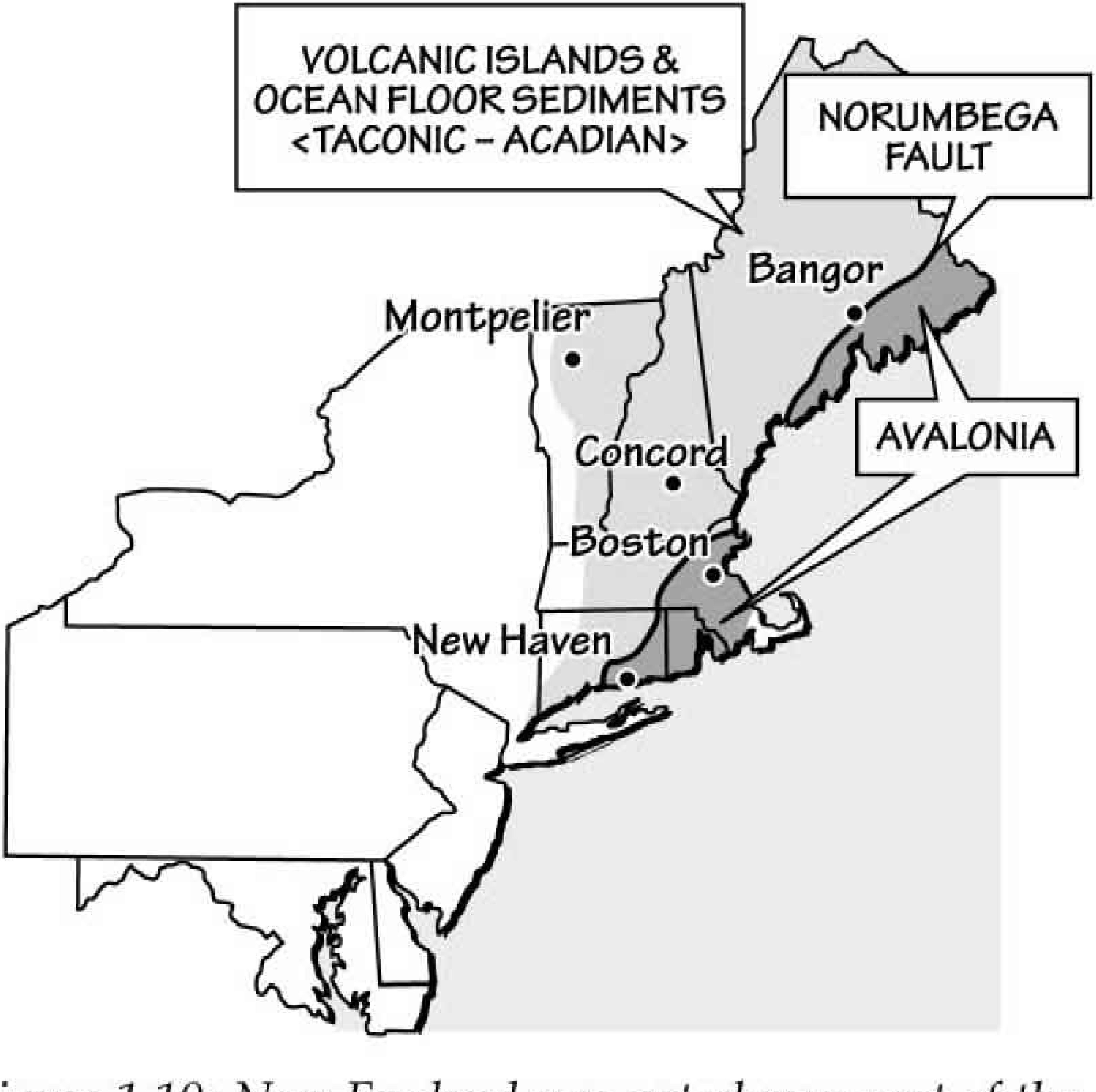
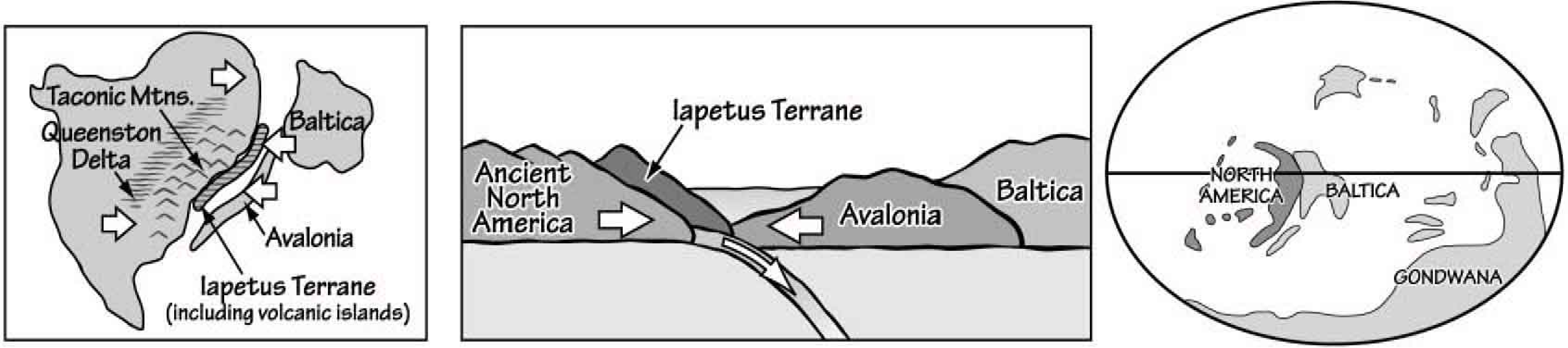


Figure 1.10: New England was not always part of the North American continent. Slices of land known as exotic terranes, collided with North America during the Taconic and Acadian orogenies. Figure by J. Houghton.

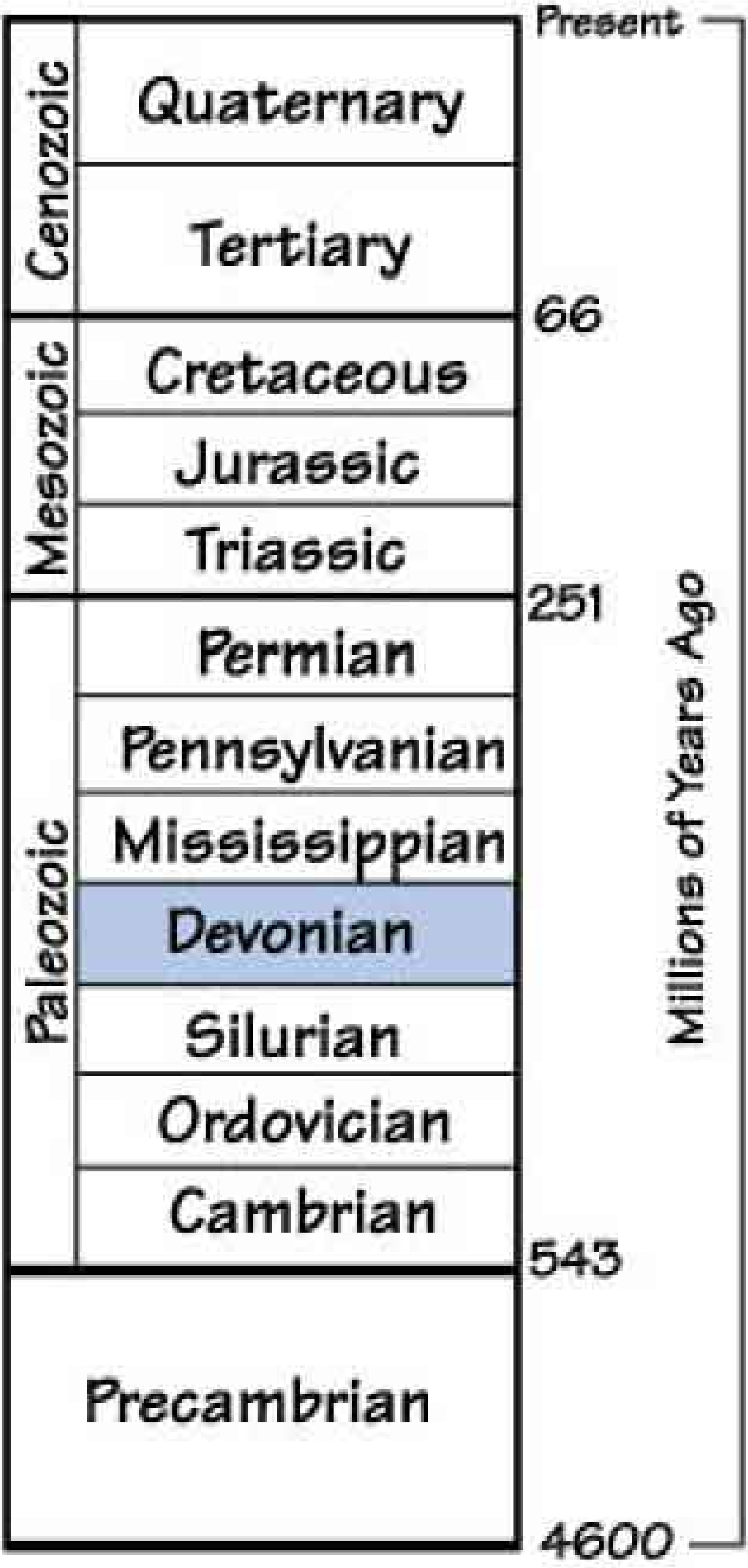
Exotic Terranes

-Taconic volcanic island arc collides with North America
-Iapetus Ocean sediments collide with North America
-Avalonia (origin uncertain) collides with North America

Silurian/ Devonian (440-360 mya)



Mountain Building Part III:
the Acadian Mountains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Precambrian
4600
Millions of Years Ago

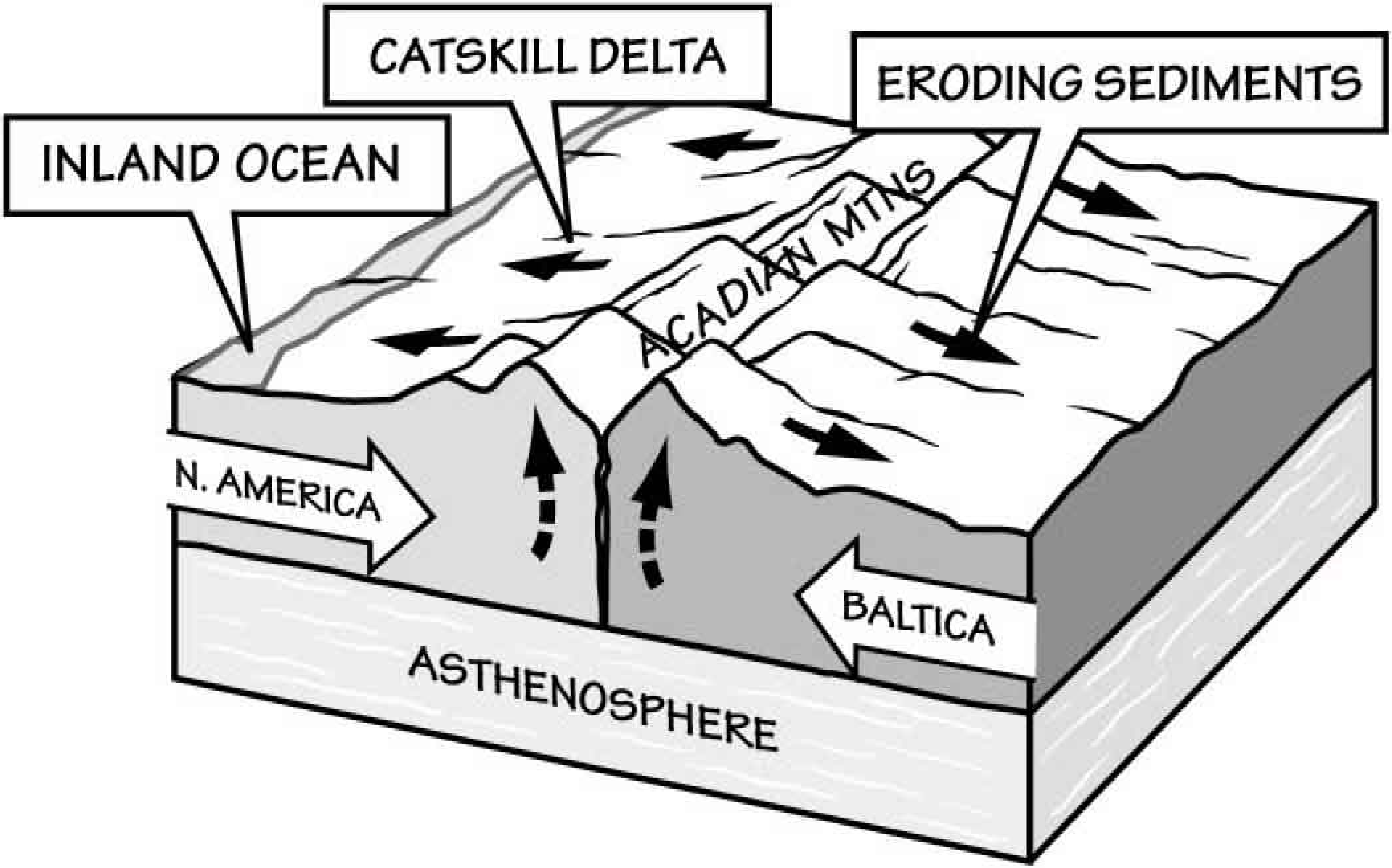


Figure 1.13: North America and Baltica collided finally in the mid-Devonian, crumpling the crust to form the Acadian Mountains. Sediments eroded from the highlands formed

The sediments of the **Catskill Delta** *are over 1.2 km thick in some places, indicating intense erosion and the enormity of the Acadian Mountains. Close to the source of erosion (the Acadian highlands) the delta sediments are coarser grained and thicker. As the sediments spread west across New York and Pennsylvania, they became finer grained and thinner deposits.*

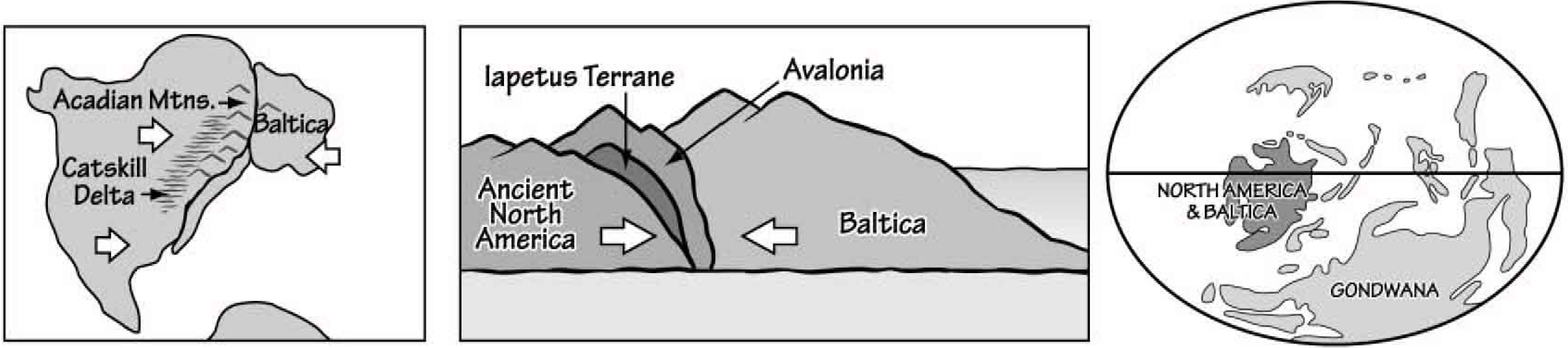
Between mountain-building events: ***deposition in the inland ocean***

The Northeast was not continuously experiencing dynamic mountain-building events. There were quieter times as well between the rise of great mountains and crushing crusts of colliding plates. The quiet times were marked by erosion of the highlands and very little plate movement and compression within the Northeast region. The building of the Taconic Mountains was over by the late Ordovician. Throughout the following Silurian period, the Northeast experienced a quiet time in which erosion from the Taconic highlands and deposition in the inland sea were the main events. Huge thicknesses of sedimentary rocks accumulated in and on the margins of the inland sea during part of the Silurian. The inland ocean, which spread across much of New York, Pennsylvania and western Maryland, was similar to the modern Persian Gulf, becoming very salty because of the shallow water, high rates of evaporation and poor circulation.

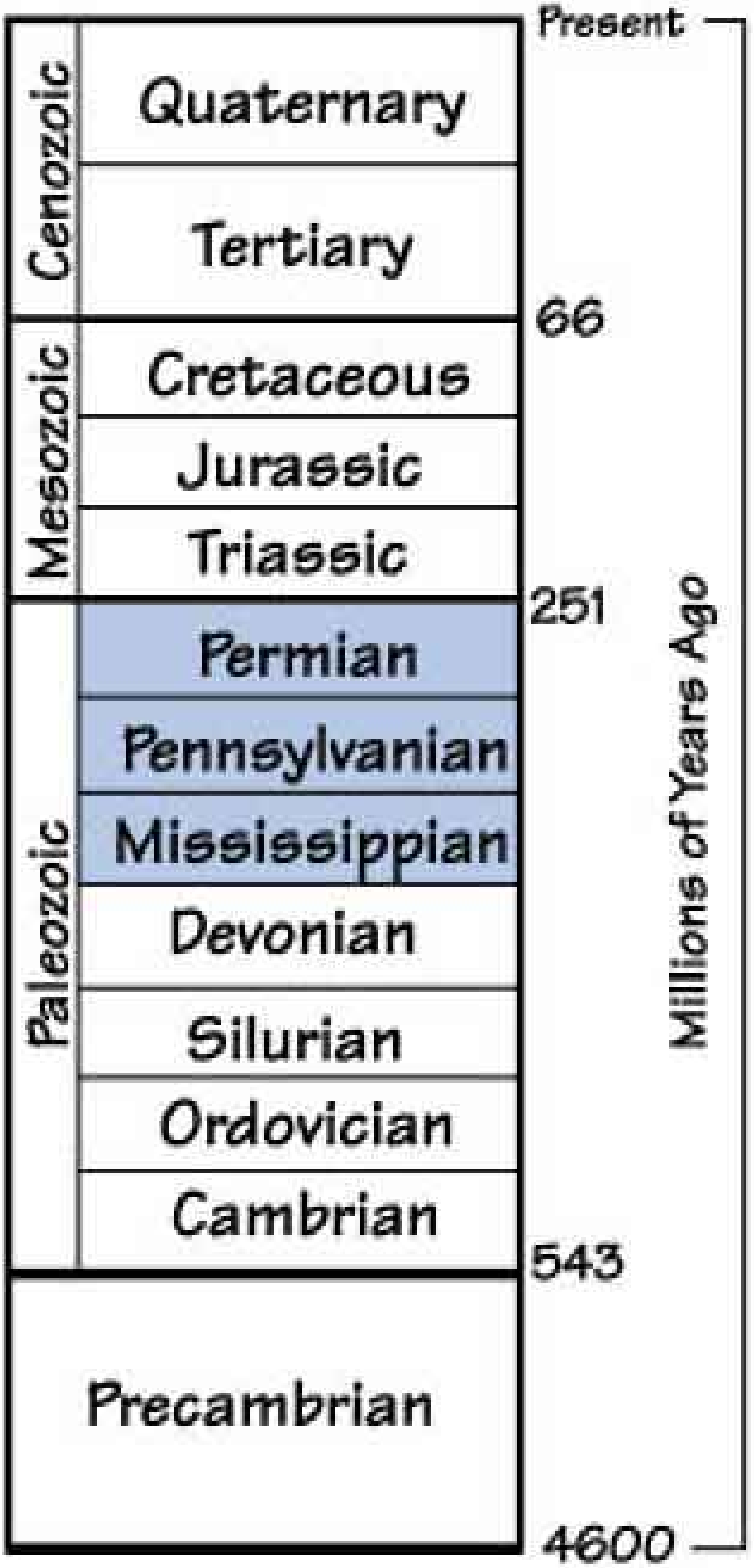
Acadian Mountain Building

-Baltica collides with North America
-Acadian Mtns form (northern Appalachian Mtns)
-similar to Taconic mountain building
-inland sea forms west of Acadian Mountains
-Acadian Mountains erode
-Catskill Delta deposited west of Acadian Mountains

Devonian (410-360 mya)



Mountain Building Part IV: *the formation of Pangea and the Appalachian Mountains*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Precambrian
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Millions of Years Ago

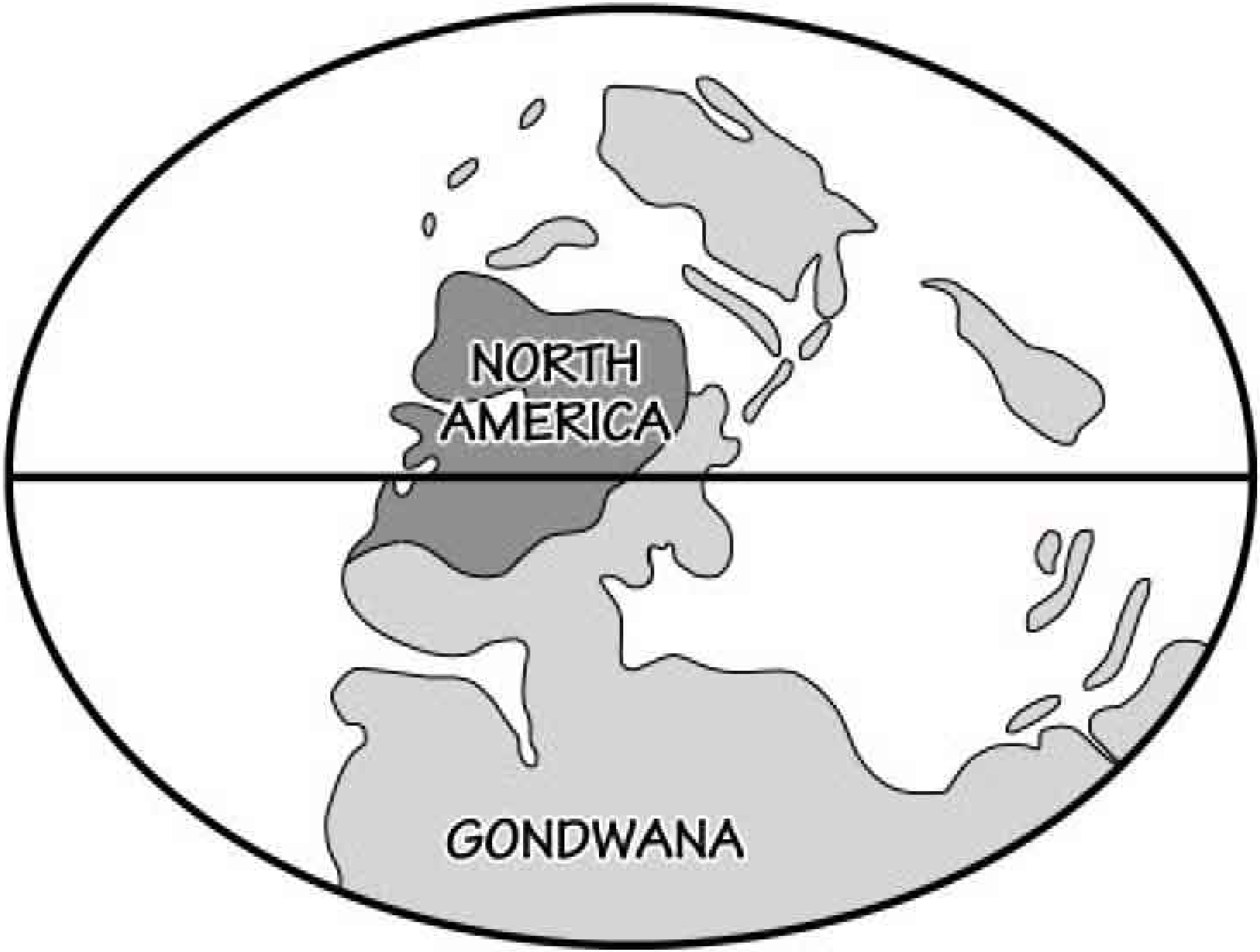


Figure 1.17: Late Pennsylvanian: 306 million years ago.

Pangea, *meaning 'all Earth,' formed over 250 million years ago and lasted for almost 100 million years. All of the Earth's continents were literally joined as one to form a giant super-continent.*

Evidence For Pangea

How do we know that Pangea existed 250 million years ago? Fossil evidence and mountain belts provide some of the clues. The Permian-age 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, indicating that the continents at one time were joined as Pangea. The discovery of* Glossopteris *and the evidence in the rocks helped geologists to formulate the theory of Continental Drift, which, when the processes of continental movement were later discovered, was reformulated under the modern theory of Plate Tectonics.*

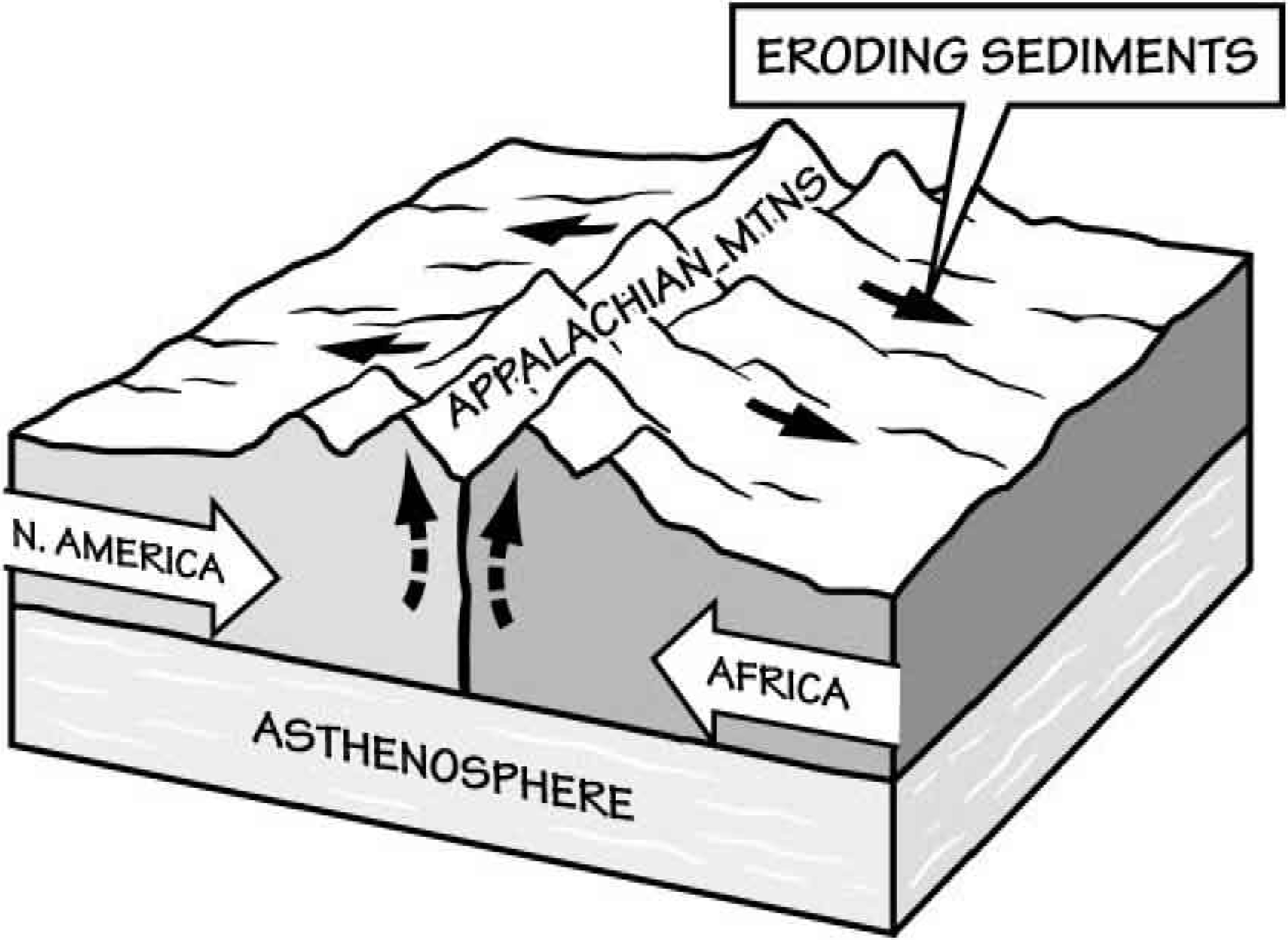


Figure 1.16: When ancestral Africa collided with North America, the Appalachian mountains were formed. Figure by J. Houghton.

Why are the Appalachians still here?

Although the Appalachian Mountains were formed over 250 million years ago, they are still around today. The forces of erosion and weathering have worn down the Appalachians over time; periodic uplift of the range, however, has prevented them from completely eroding away.

Though the Appalachian Mountains do not look as tall and rugged as the Himalayas of India, the Appalachians formed through esentially the same geologic processes. The collision of the Indian and Asian plates that is taking place today is raising the Himalaya Mountains, similar to the collision over 250 million years ago between Africa and North America created the Appalachian Mountains.

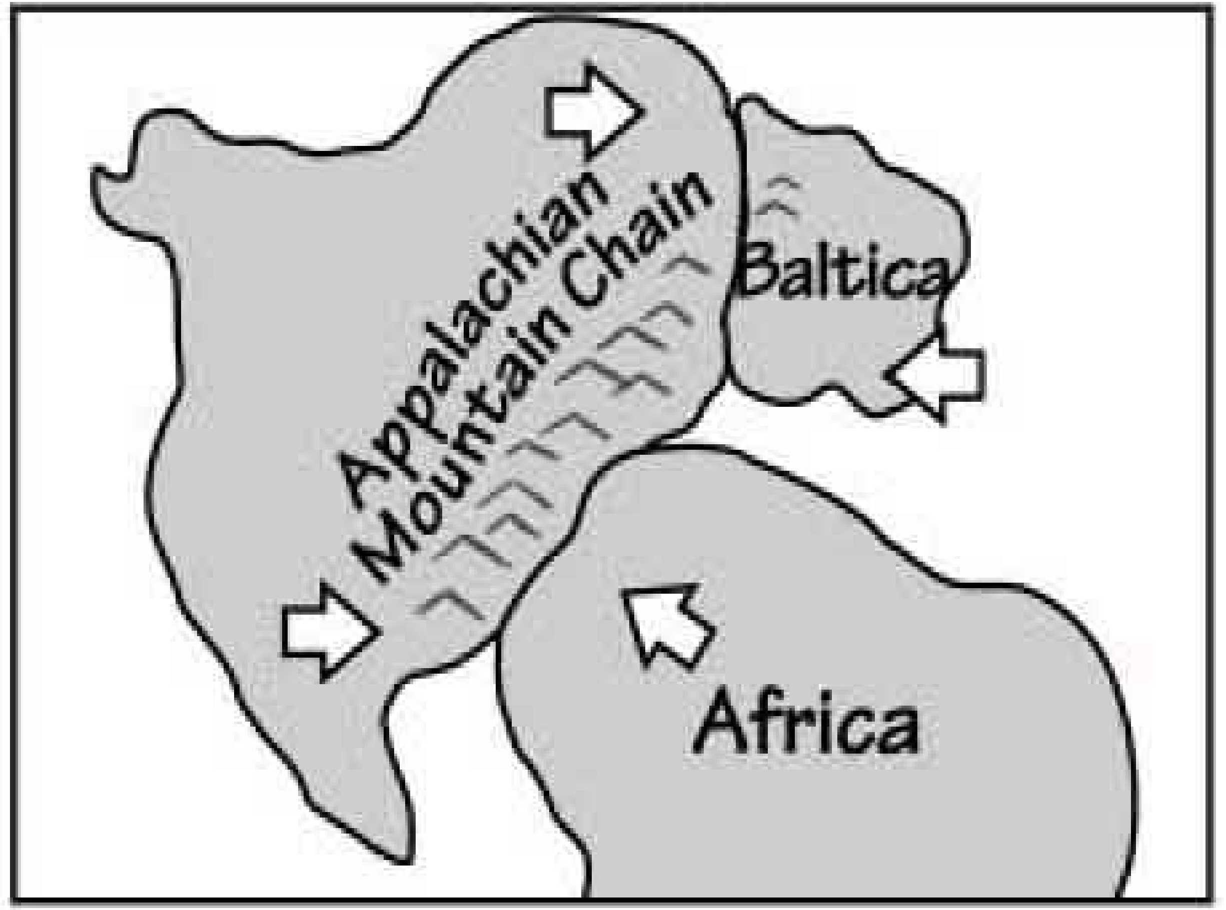
Alleghanian Mountain Building

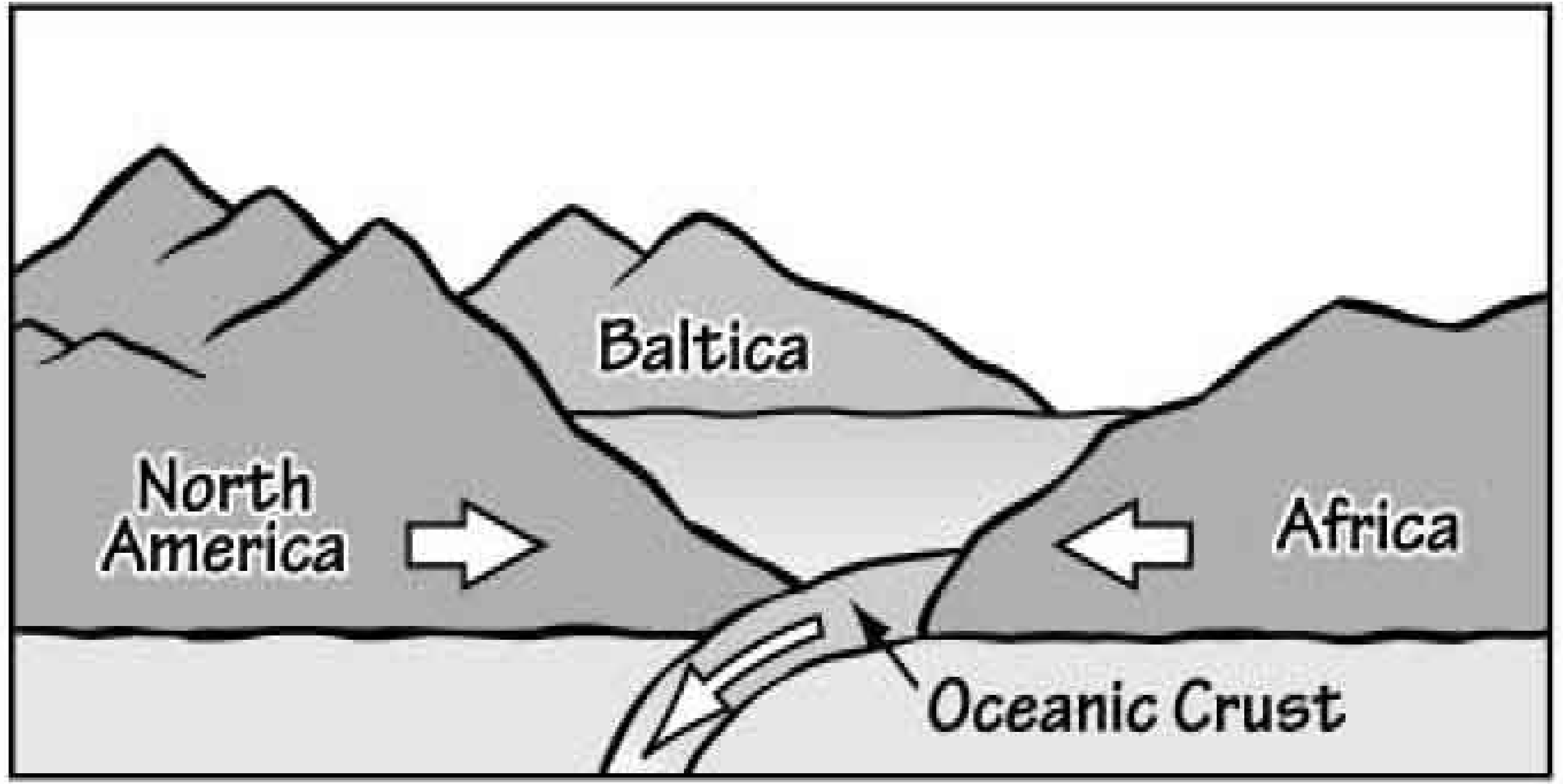
-Africa collides with North America

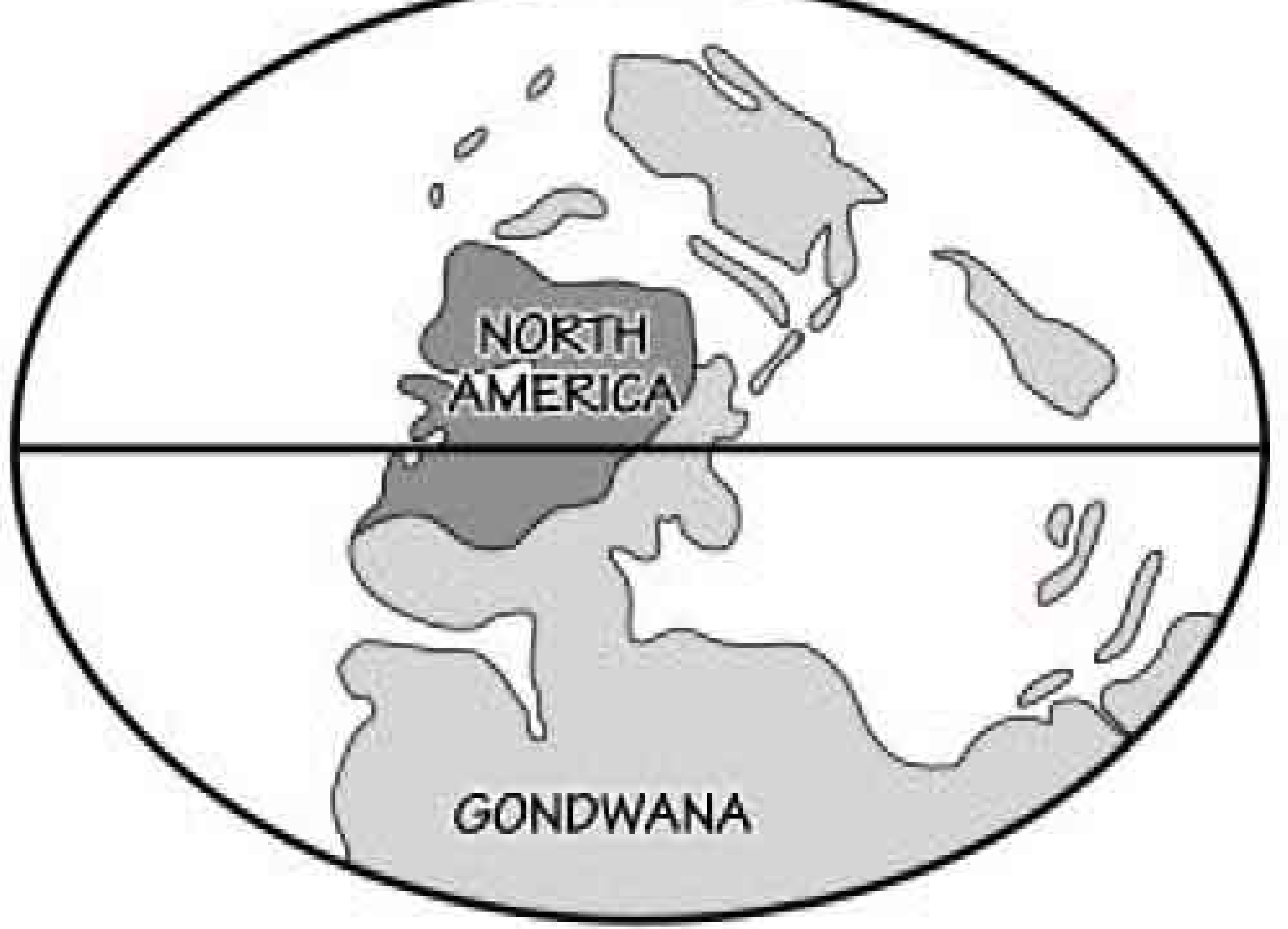
-central/southern Appalachians form

-Pangea assembled, one supercontinent on Earth

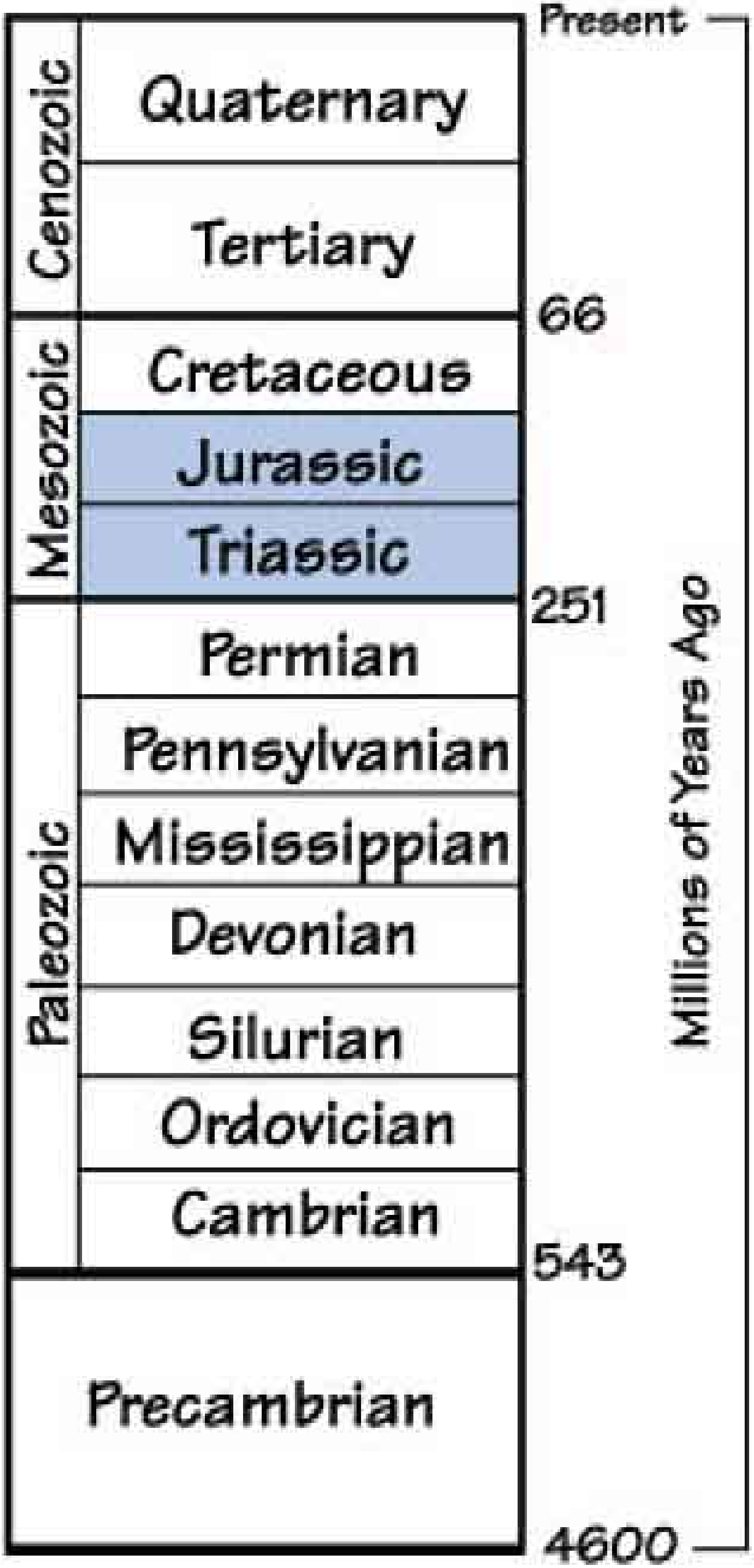
Mississippian
Pennsylvanian
Permian
(360-245 mya)







The Breakup:
Pangea comes apart


Present
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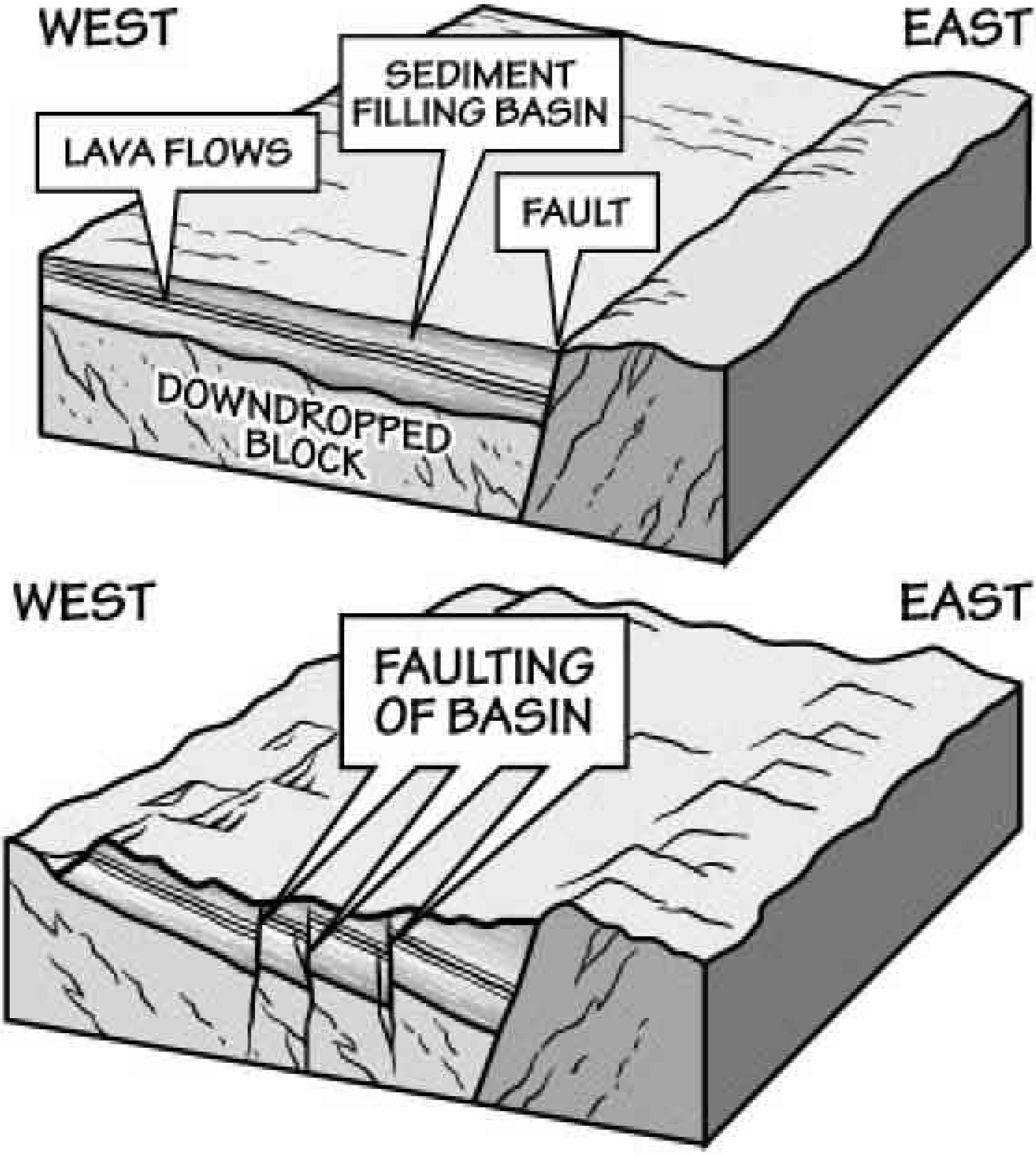
Mississippian
Devonian
Silurian
Ordovician
Cambrian
543
Precambrian
4600
Millions of Years Ago

Rifts *are breaks or cracks in the crust which can be caused by tensional stress as a landmass breaks apart into separate plates.*

The same processes that are today tearing apart **East Africa**, *were tearing apart Pangea 180 million years ago. In East Africa, the African plate is pulling away from the Arabian plate, stressing the crust to the point of breaking apart.*



Figures 1.19 and 1.20: As rifting occurred, blocks of crusts slid down faults to form a basin. The basin was filled with sediments and lava flows. Eventually, the entire basin was tilted and faulted. Figure by J. Houghton.

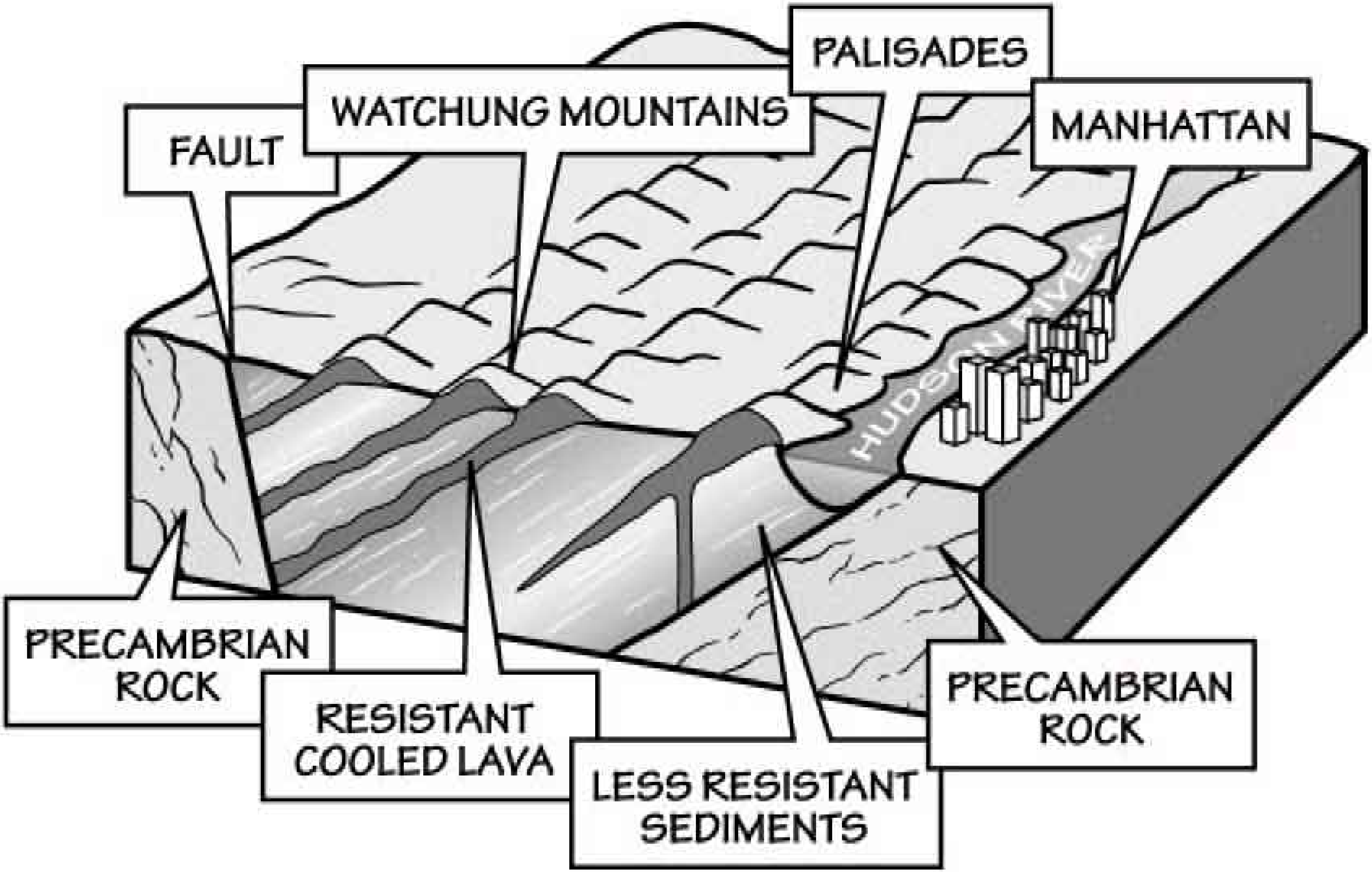


Figure: 1.22: The softer sediments of the Newark Rift basin were quickly worn away, forming valleys between the more resistant ridges of hardened lava flows. Figure by J. Houghton.

Rocks that form ridges

Some rocks wear down relatively quickly, while others can withstand the power of erosion for much longer. Softer, weaker rocks such as shale and poorly cemented sandstone and limestone are much more easily worn away than hard, crystalline igneous and metamorphic rocks, or well cemented sandstone and limestone. Harder rocks are often left standing alone as ridges because surrounding softer, less resistant rocks were quickly worn away.

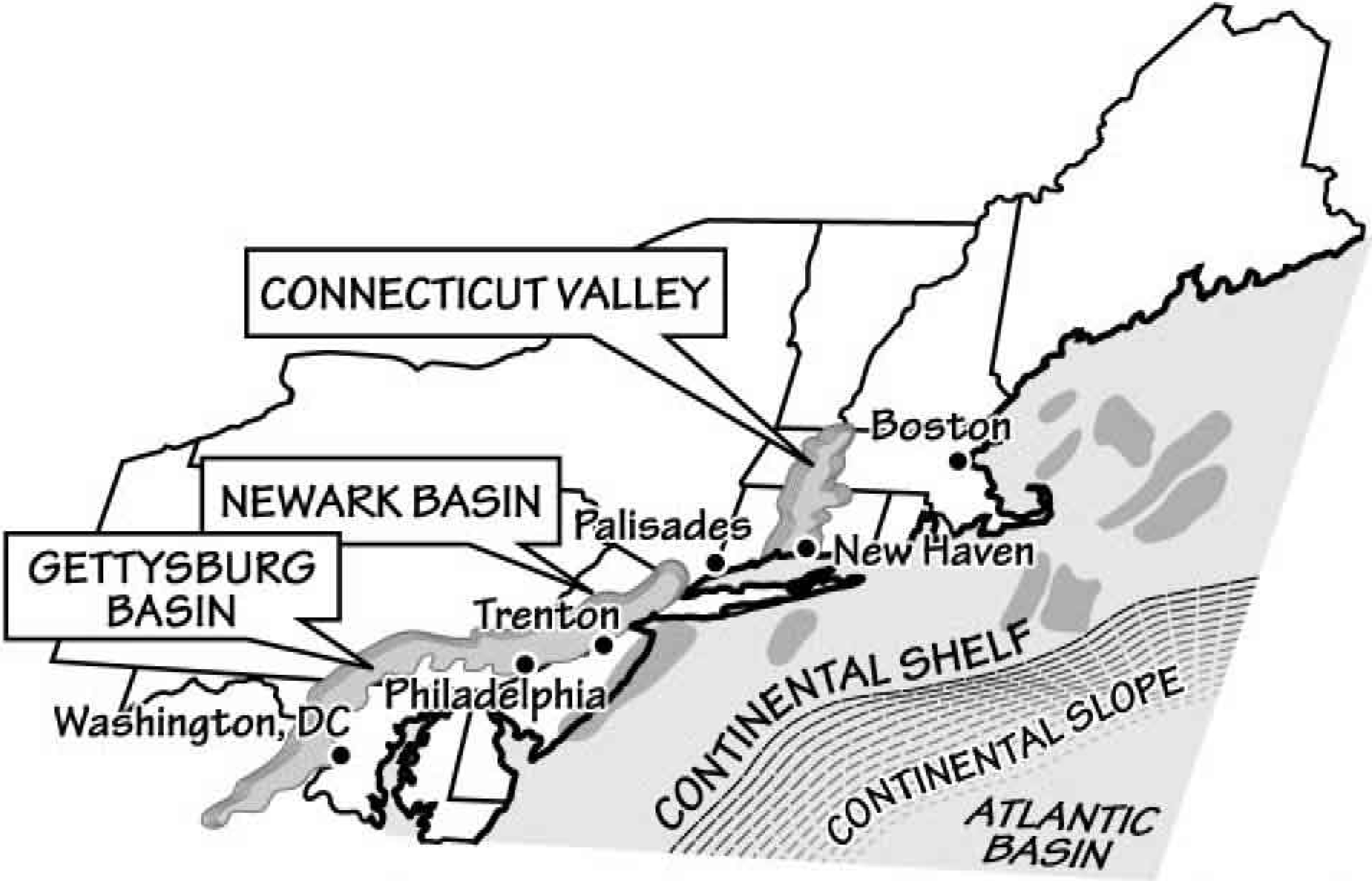


Figure 1.21: The Triassic Rift Basins of the Northeast formed as North America broke away from Pangea during the Triassic and Jurassic. Figure by J. Houghton.

Pangea Breaks Up

-Pangea begins to split

-rifts are created in the crust

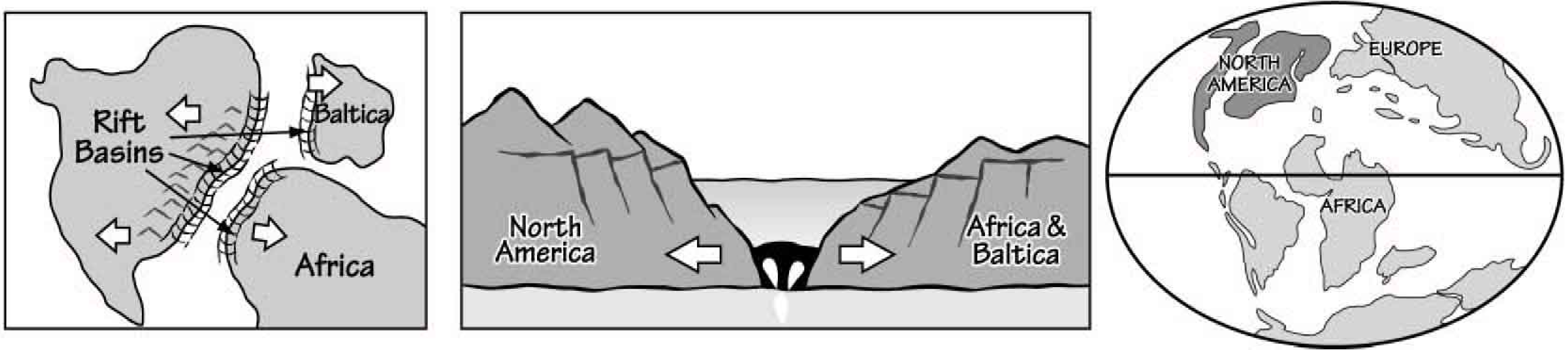
-Triassic/Jurassic Rift Basins form

-Rift Basins filled with sediments and lava flows

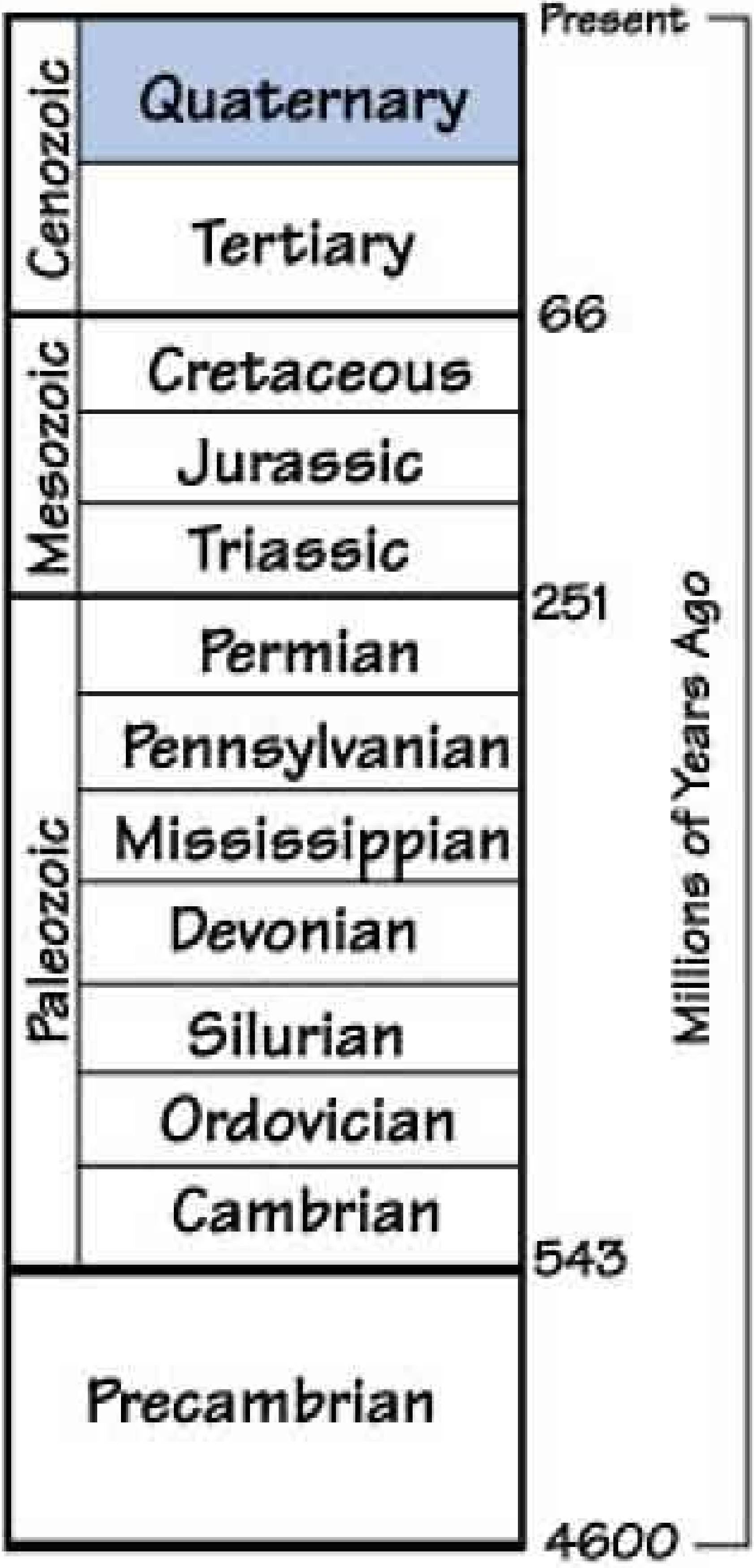
-Rift Basins later tilted, faulted and eroded

-long period of erosion

Triassic/ Jurassic Cretaceous (245-65 mya)



The Ice Age: *mountains of ice*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543
Precambrian
4600
Millions of Years Ago

Throughout the Earth's history, the continents have been periodically plunged into an ice age, dependent upon the climate and position of the continents. Over the last million years, North America has experienced glaciation approximately **once every 100,000** *years and once every 40,000 years during the previous two million years.*

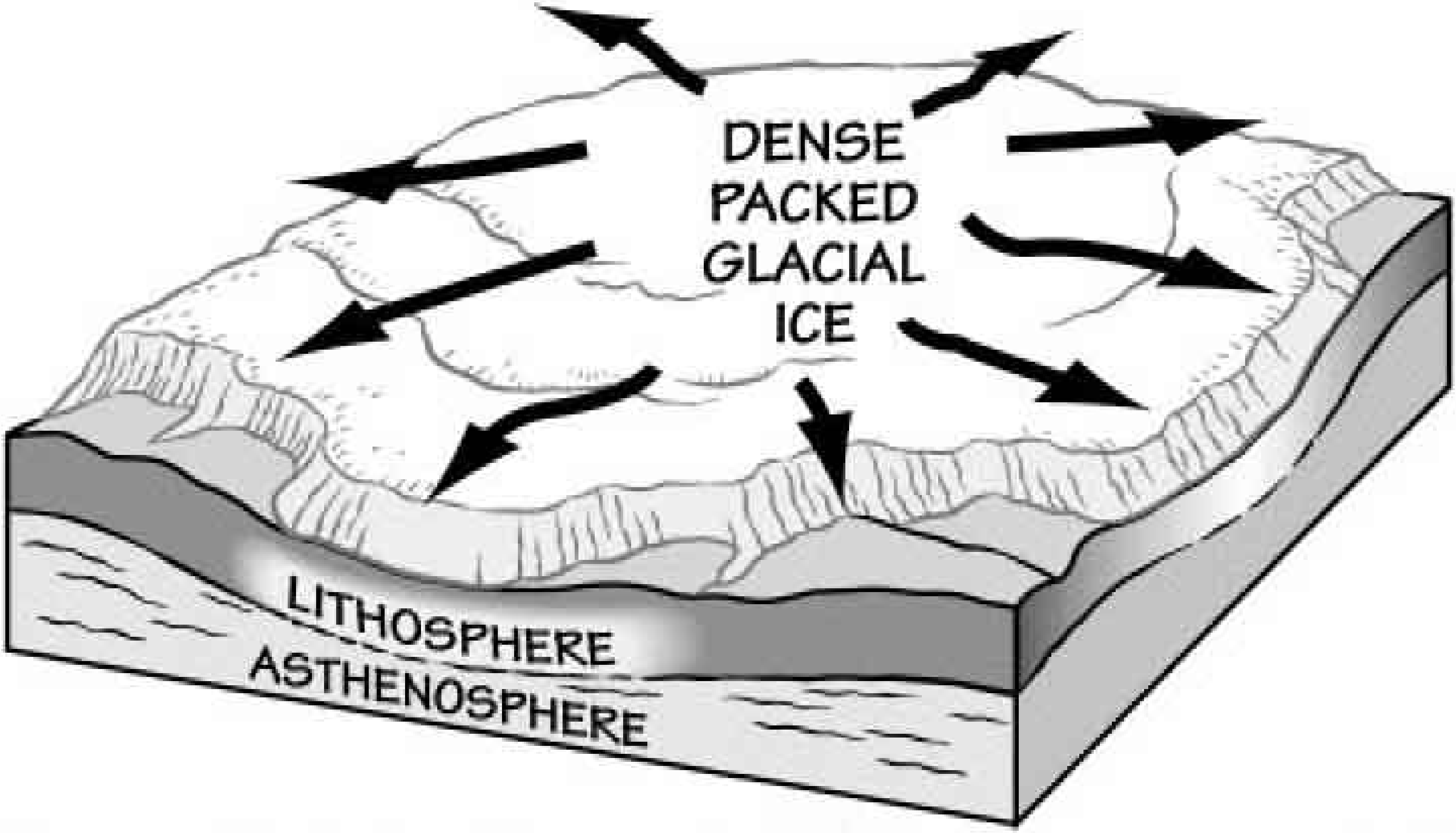


Figure 1.26: As dense glacial ice piles up, a glacier is formed. The ice begins to move under its own weight and pressure. Figure by J. Houghton.

Figure 1.27: The movement of the ice sheet over North America. Figure by J. Houghton.

What happened between the breakup of Pangea and the ice age?

The Northeast gradually rifted away from the rest of Pangea during the Mesozoic. Throughout the Tertiary period (which followed the breakup of Pangea) a warm climate promoted chemical weathering and erosion of rocks of the Northeast. Periodic uplift and significant erosion of the land shaped much of the topography of the Northeast. Though Tertiary deposits are thick along the continental shelf and parts of the Coastal Plain (evidence of significant erosion during this time), there are very few Tertiary deposits on much of the Northeast coast. This is because as the climate began to cool and the ice age set in, glaciers scraped up most of the sediments deposited during the Tertiary and pushed them southward. Uplift during the Tertiary created the Adirondack Mountains of New York.

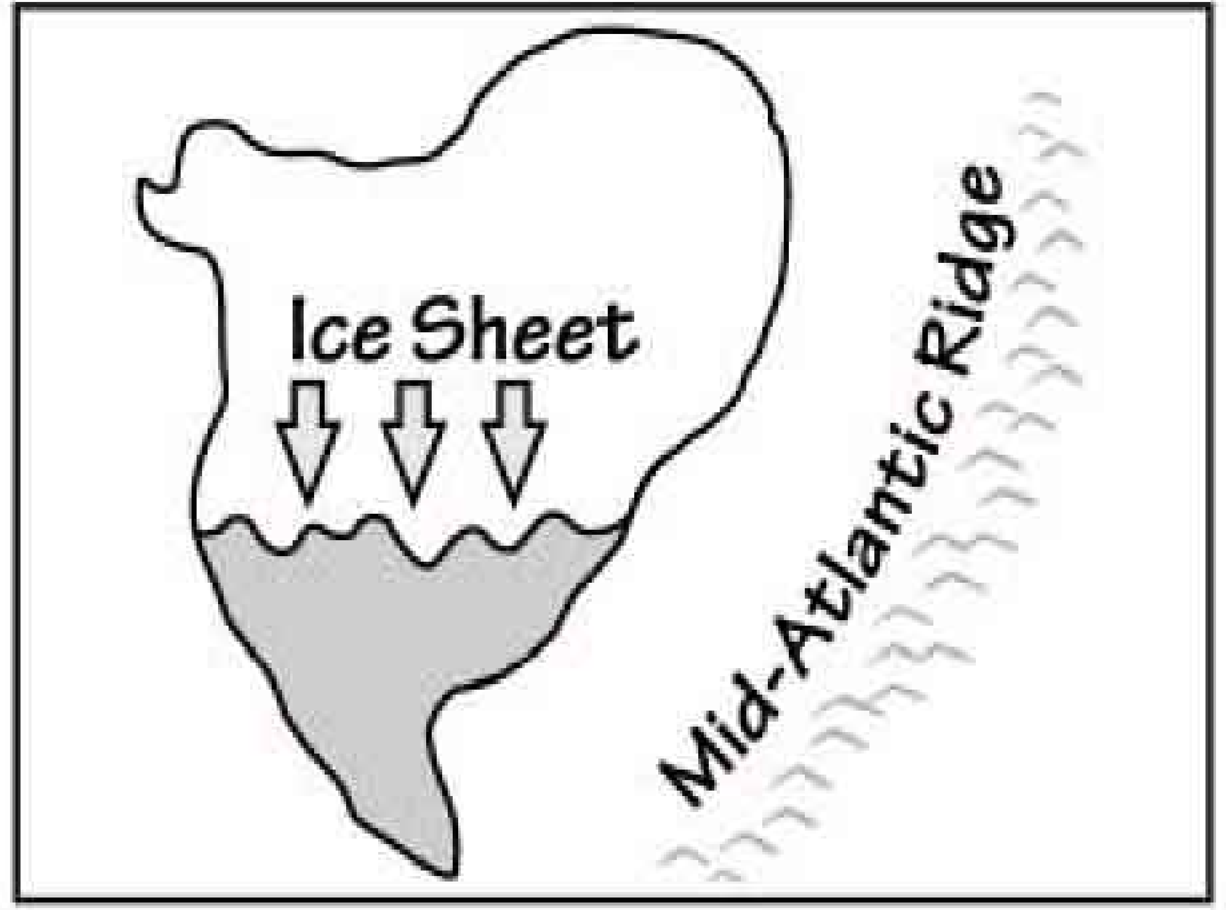
Ice Age

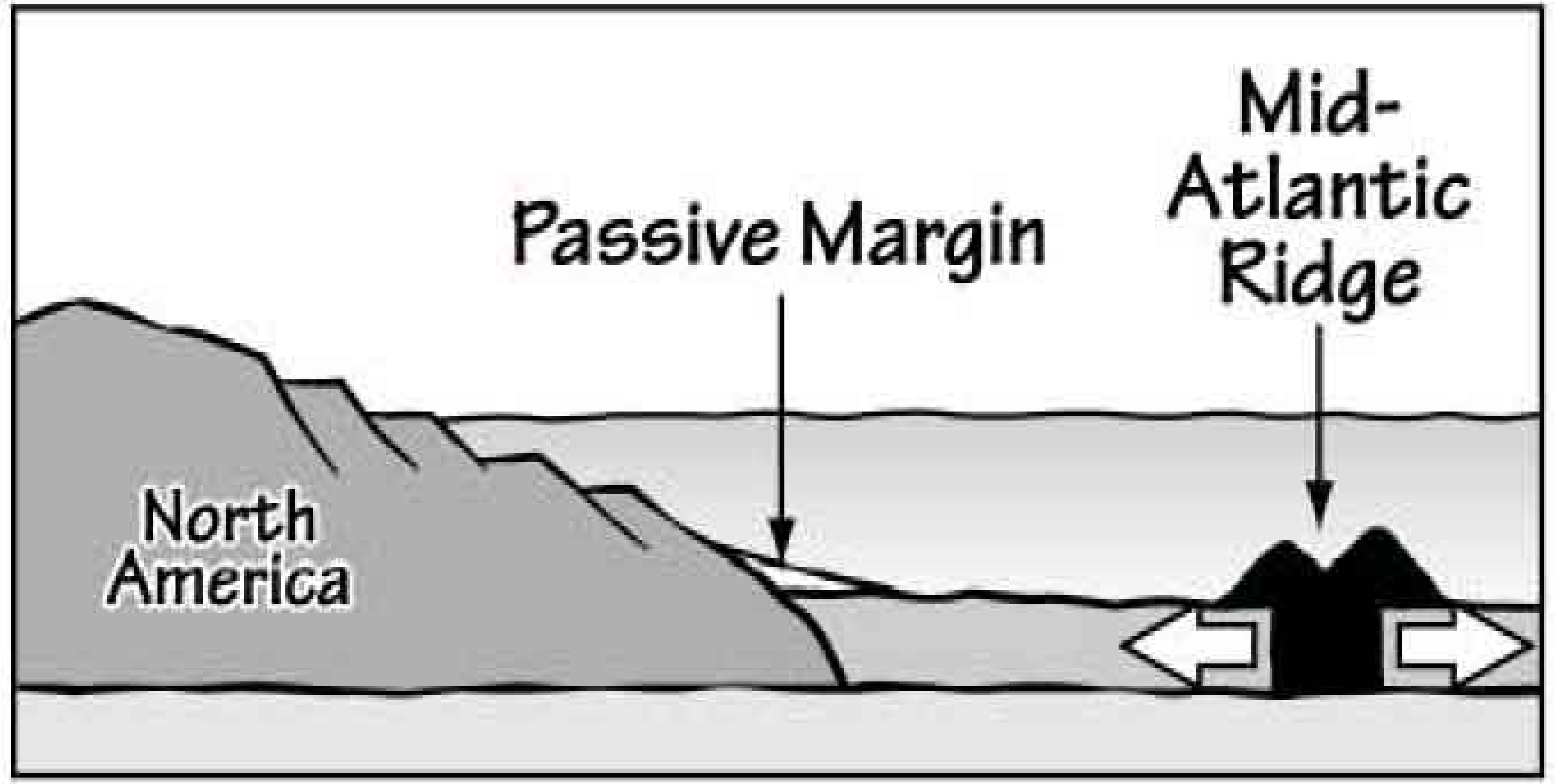
-Northern Canadian ice sheet forms

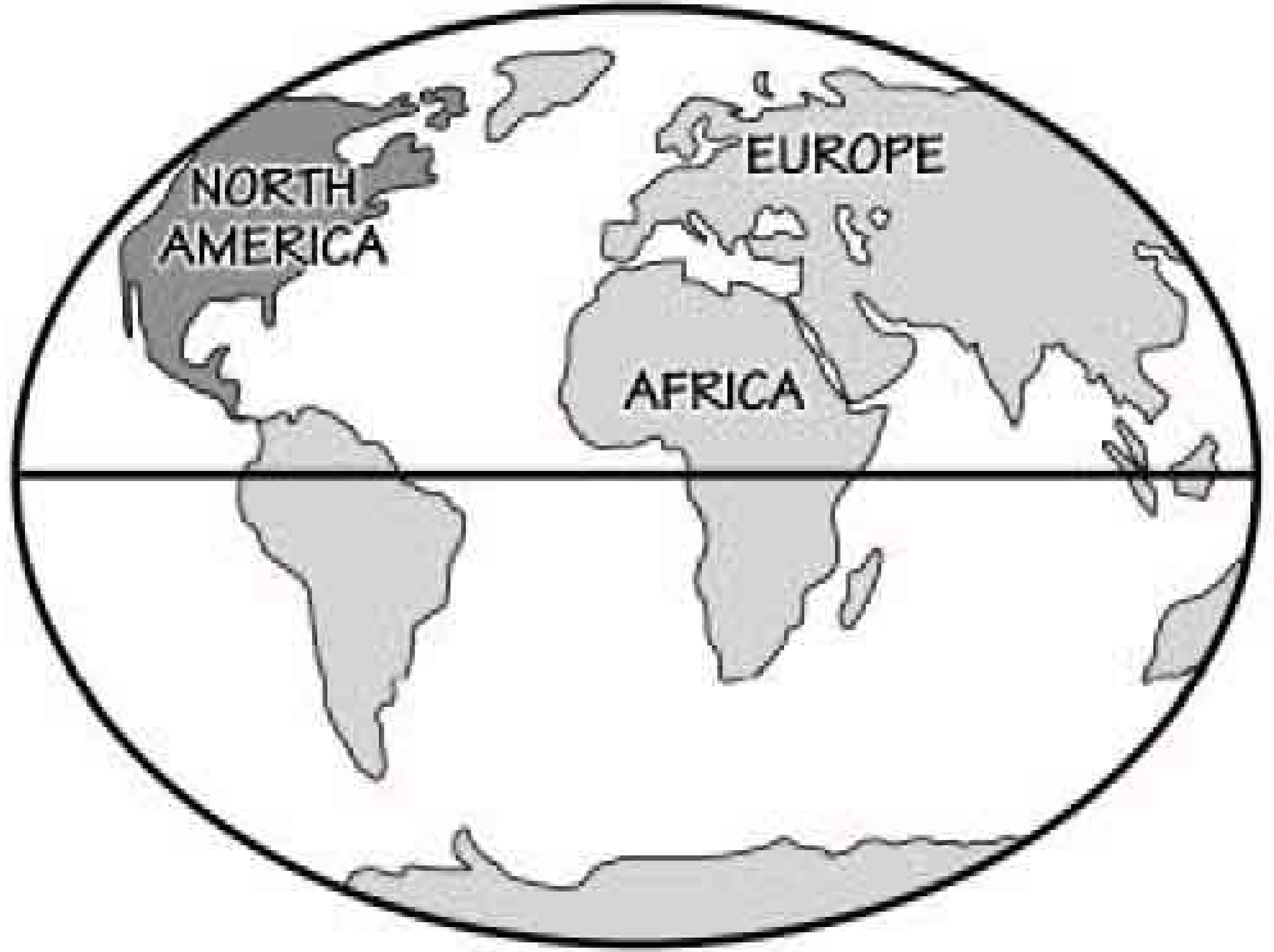
-repeated advances and retreats of ice sheet over the Northeast

-put the finishing touches on the topography of the Northeast

Quaternary
(1.8 mya-present)







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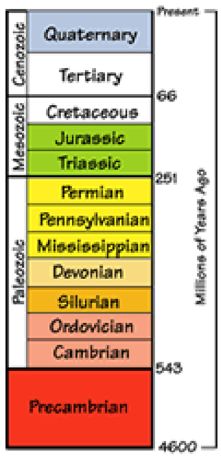

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