Origin of Appalachian Geomorphology

Part I: Erosion by Retreating Floodwater and the Formation of the Continental Margin

Michael J. Oard*

Abstract

The general geology and geomorphology of the Appalachians is summarized. Geological features and the subdued relief of the topography indicate up to 6.5 km of erosion. Erosion can also be estimated by the amount of sedimentary rocks on the offshore continental margin sourced from the west. Assuming that this erosion came from the Appalachians east of the divide, the amount of sediment matches the estimate based on coal rank fairly well. Erosion of the Appalachians and deposition of the continental margin can readily be explained by sheet flow early in the retreating stage of the Genesis Flood, as the land rose up and the continental margin subsided. This is a pattern seen worldwide and is inexplicable by uniformitarianism. This places the Flood/post-Flood boundary in the very late Cenozoic in this region.

Introduction

The Appalachian Mountains of eastern North America form a zone 160 to 500 km wide starting from Newfoundland, southeast Canada, and running 2,400 km southwestward to central Alabama. The Appalachian Mountains include several provinces, including the Blue Ridge Mountains and the Valley and Ridge Province. The highest mountains are in the Smoky Mountains of western North Carolina; Mount Mitchell reaches 2,037 m asl, the highest point east of the Mississippi River, and Grandfather Mountain in the Blue Ridge tops out at 1,810 m asl (Figure 1). "Appalachian" refers not only to the mountains but also to several regions associated with the mountains (Fenneman, 1938; Thornbury, 1965), which are northwest and southeast of the Appalachian Mountains. These regions are divided into provinces of similar geomorphology —the field of geology that studies the features of Earth's surface. This paper is restricted to the central and southern Appalachians. Although there are significant differences between the geomorphology of the central and southern Appalachians, they are similar enough to include in a

* Michael J. Oard, Bozeman, MT, mikeoard@bridgeband.com
Accepted for publication October 12, 2010

Figure 1. Grandfather Mountain in the southern Blue Ridge Mountains at 1,810 m, as seen from the Blue Ridge Parkway at 1,265 m asl.

survey of the general geomorphology. Both areas are combined when describing the geomorphology of the Appalachians (Fenneman, 1938; Thornbury, 1965), as shown in Figure 3 below.

Before proceeding, I must clarify some terms. Many geologists no longer prefer to be called "uniformitarian," having converted to neocatastrophism, rejecting gradualism while maintaining an "actualistic" method. They prefer to be called "actualists." However, Hooykaas (1963) noted that "actualism" can be equally applied to many different historical systems. Reed (2010) noted the redundant use of the two terms and suggested the elimination of "uniformitarian" from the lexicon, since "actualism" has prior precedence. This revolution in geology leaves several problems unresolved; neocatastrophism implies that the physical evidence of the past is much more poorly distributed than was assumed by gradualists, leading to less certainty in interpretation. Also, there has been no wholesale reconstruction of geology as a discipline, that is, no weeding out of the many decades of uniformitarian assumptions that influenced the methods, assumptions, and conclusions of geology. To creationists, it appears that geologists have surrendered to the empirical evidence cited by catastrophists during the past several centuries, while clinging to their metaphysical belief system of naturalism. This, of course, is not science and cannot be justified scientifically. To avoid misunderstanding, I will refer to "secular geologists" as actualists, whether they are either catastrophist or gradualist.

General Geology of the Appalachians

Secular scientists consider the Appalachians to have formed from repeated continental collisions between North America and Europe/Africa (Hatcher, 1989; Plummer and McGeary, 1996, pp. 462–464), citing evidence of "exotic" terranes, supposedly representing slices obducted onto North America, and exposed rare mantle rocks (Miller et al., 2006; Misra and Keller, 1978). Prior to the "last" continental collision, thick Paleozoic sedimentary rocks built up over millions of years along the continental margins of North America and Europe. Then the continents collided to form "Pangea," and the sedimentary rocks were buckled, folded, and faulted. It is believed that multiple thrust faults pushed northwest tens to hundreds of kms up a low slope (Perry, 1978; Simmons, 1983). Some thrusts involved crystalline basement rocks, like those of the Blue Ridge Mountains. The thrusting was related to upward intrusions of mostly granitic rocks. During collisions, the Appalachians were supposedly raised as high as the modern Himalayas (Karle, 2009, p. 76). The mechanism and source of energy for this incredible overthrusting are not known, but it is assumed to be compression.

During the Mesozoic, the last supercontinent, Pangea, split apart. The high mountains in the eastern United States were subsequently eroded to the subdued, rounded mountains of today's Appalachian range. Detritus from that erosion was transported both east and west, possibly as far as the Colorado Plateau (Froede, 2004; Oard, 2009a). This is based on uranium-lead radiometric dates in zircon crystals. Sedimentary rocks dated as upper Precambrian and Paleozoic lie at the base of the Appalachian Basin, which is up to 12 km deep (Way, 1999), a northeast-southwest elongated basis just west of the Blue Ridge Mountains, extending from New York to Alabama.

Except for the very early Paleozoic rocks, which exhibit eastward paleocurrents (Whitaker, 1955), Paleozoic sedimentary rocks were transported toward the west to northwest (Nichelsen, 1958; Pelletier, 1958; Pettijohn, 1970; Schlee, 1963; Yeakel, 1962). This indicates a source from the location of the current Atlantic Ocean, but the sediment could have originated from the area of the Piedmont or coastal plain. Then after the Paleozoic, there was a flow reversal toward the southeast accompanied by significant volumes of erosion (see below). The origin of this drainage reversal remains controversial (Kaktins and Delano, 1999).

General Geomorphology of the Appalachians

Geomorphology is a geological science that studies the general configuration of Earth's surface, especially the classification, description, nature, and origin of landforms and their relationship to the underlying geological structures (e.g., see Neuendorf et al., 2005, p. 267). Other terms for geomorphology are physiography and physical geography. Landforms are features that, taken together, make up the surface of the earth and include broad features such as mountain ranges, plateaus, or plains, and small-scale features such as hills, valleys, slopes, canyons, or alluvial fans.

The Appalachians or Appalachian Highlands can be subdivided into geomorphological provinces. The Blue Ridge Province is the backbone of the Appalachian Mountains and contains the highest elevations. The Valley and Ridge Province, just west of the Blue Ridge Province, is composed of folded sedimentary rocks of the Appalachian Basin. These two provinces show up from space as one large elongated landform (Figure 2). Farther west is the Appalachian Plateaus Province, which includes the Allegheny Plateau in the north and the Cumberland Plateau in the south. Farther west is the Interior Low Plateaus Province. To the east of the Blue Ridge Mountains is the Piedmont Province. These provinces are shown in Figure 3.

The Valley and Ridge and the eastern Appalachian Plateau Provinces are thought to represent thin overthrust slices pushed northwest for long distances along bedding planes. The Blue Ridge and Piedmont are comprised of igneous and metamorphic rocks believed to have been thrusted a short distance northwest (Hatcher, 1972; 1978). Evidence of thrusting, or at least of faulting, of the Blue Ridge Province against the Valley and Ridge Province is shown by fault breccia at the contact in Figure 4.

There are two other geomorphic features of special interest. The first is the Blue Ridge Escarpment of the southern Appalachians, a feature about 500 km long with a face that averages 300 to 600 m high (Figure 5). It is most abrupt in western North Carolina, where it rises vertically about 600 m (Figure 6a and b). Spotila et al. (2004, p. 42) stated:

> In northern North Carolina and southern Virginia the Blue Ridge highlands exhibit low relief, such that the escarpment is a striking boundary between two subdued surfaces, which we refer to as the Upland and Piedmont surfaces.

The Blue Ridge Escarpment is not as high or well defined as the Great Escarpments along eastern Brazil, eastern Australia, western India, and around Southern Africa (Oard, 2008, pp. 53–54; Ollier, 1985), but it is still considered a Great Escarpment (Battiau-Queney, 1989; Pazzaglia and Gardner, 2000), similar in some respects to other Great Escarpments (Spotila et al., 2004). It is primarily an abrupt topographic rise across high-grade metamorphic and granite rocks from the Piedmont Province to the east to the Blue Ridge Mountains to the west (Figure 7). It is not a fault and is believed to have slowly eroded westward (Spotila et al., 2004). The fault at Caesar's Head eroded northwest in granite (Figure 8). The deduction of a northwest-eroding escarpment is reinforced by the existence of outliers of the Blue Ridge Province on the Piedmont. The amount of lateral erosion is uncertain (Battiau-Queney, 1989) but significant. Thornbury (1965, p. 105) stated: "These [Blue Ridge] outliers suggest that the front of the scarp may have been considerably farther east in Tertiary time." He places the erosional retreat of the Blue Ridge Escarpment in the Tertiary. The location of the escarp-

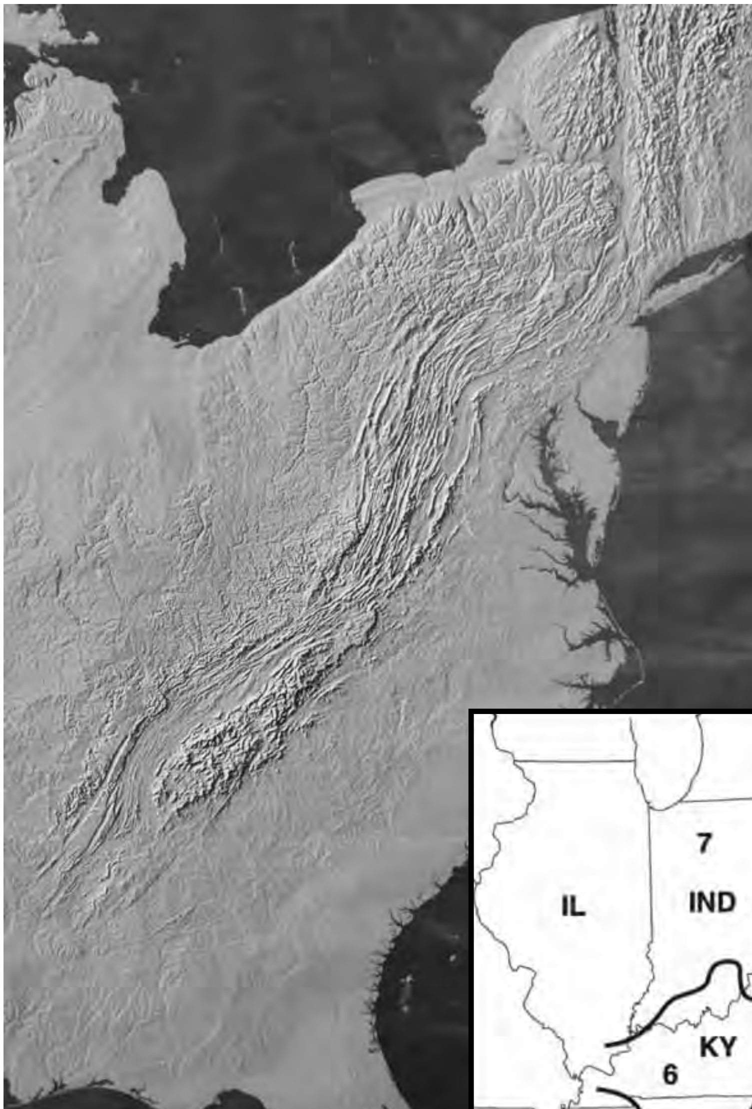


Figure 2 *(left)*. **The distinctive geomorphology of the Appalachian Mountains, the Blue Ridge and Valley and Ridge Provinces, as seen from space (from Thelin and Pike, 1991).**

Figure 3 *(below)*. **Map of the Appalachian provinces and the two provinces to the west. Modified from Aadland et al. (1992).**

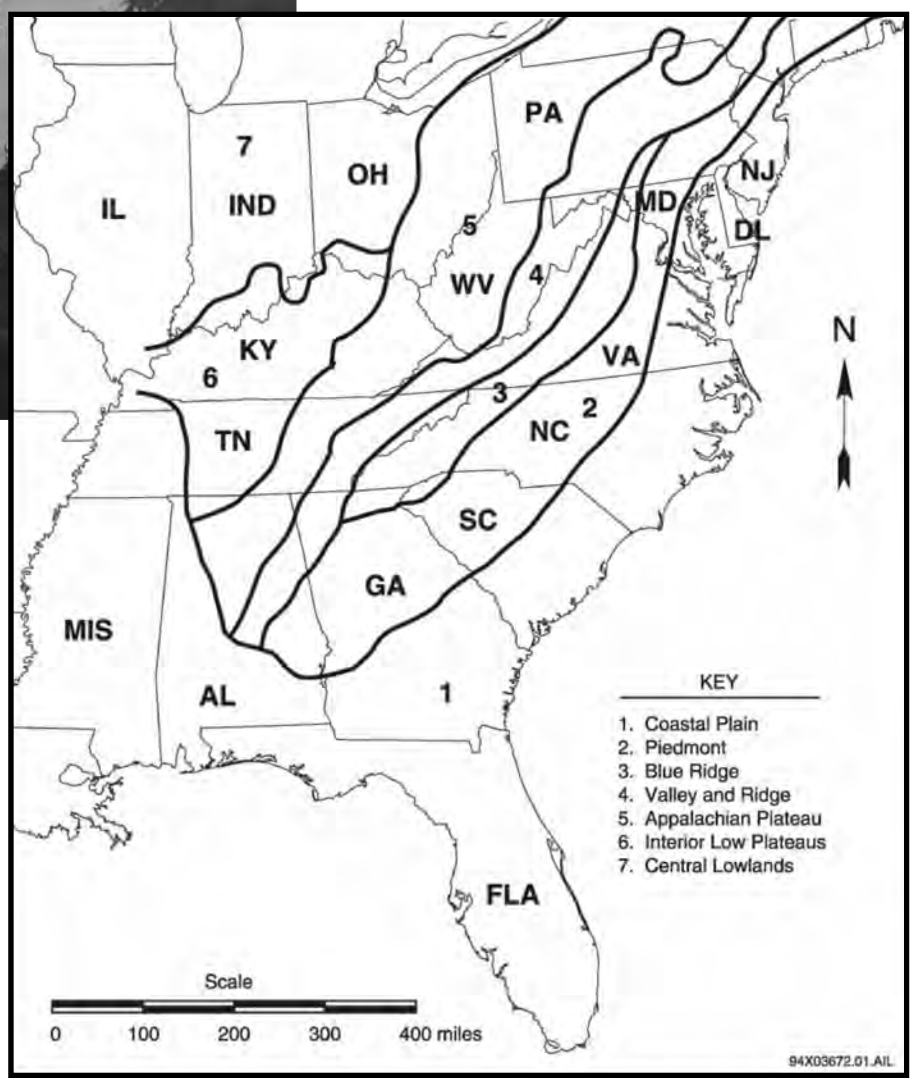


Figure 4. Fault breccia of Antietam quartzite in Blue Ridge Thrust Fault zone, Rt 340, Virginia. Note angularity and freshness of clasts. From Bentley (2010).

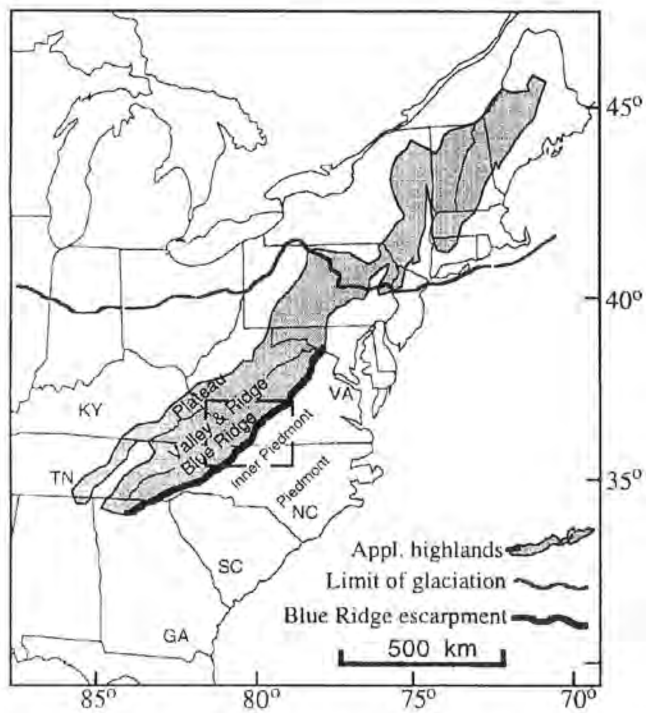


Figure 5. Location of the Blue Ridge Escarpment. From Spotilla et al. (2004, p. 42).

Figure 6a. Blue Ridge Escarpment, a 600-m cliff, at Caesar's Head State Park, South Carolina (view southeast).

Figure 6b. View northwest of the Blue Ridge Escarpment from the rolling Piedmont erosion surface, North Carolina.

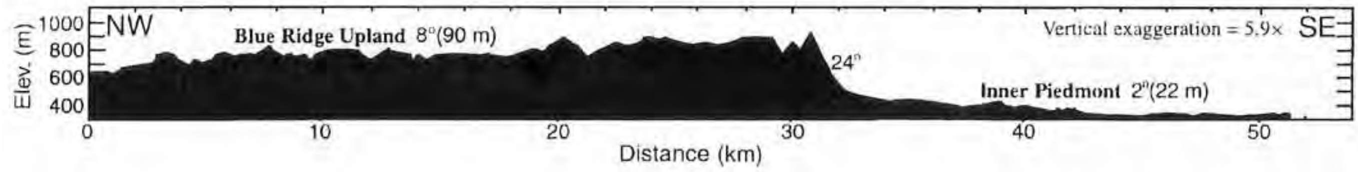


Figure 7. Cross-section with vertical exaggeration 5.9 across the Blue Ridge Escarpment with a 24° slope on a northwest—southeast line. From Spotilla et al. (2004, p. 43).

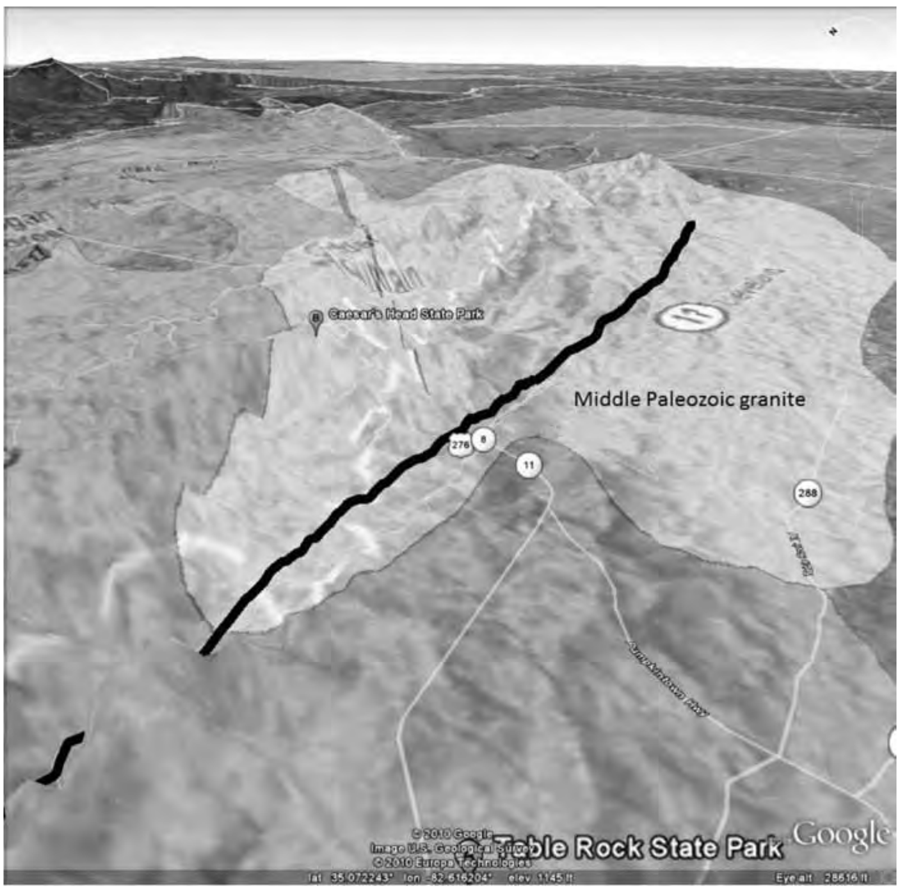


Figure 8. Google Earth/Google Map image of Caesars Head State Park area, showing base of Great Escarpment (black line) cutting across Middle Paleozoic granite as shown in Schruben et al. (2006). North is to top right of picture; 3x vertical exaggeration.

ment cannot be correlated to lithology (i.e., soft or hard rocks); the lack of preferential erosion (Spotila et al., 2004) is a conundrum to most geologists. So, the Blue Ridge Escarpment is believed to have formed erosionally, like other Great Escarpments, but the cause is unknown (Spotila et al., 2004).

A second major geomorphic feature is the Great Valley (Figure 9), a prominent valley (see Figure 2) on the eastern edge of the Valley and Ridge Province. It extends the full length of the Appalachians, from the St. Lawrence Lowland to Alabama, varying in width from 3.5–80 km. The Great Valley can be considered the first valley of the Valley and Ridge Province, but it is much wider than those to the west. It is 3.5 km wide just north of Roanoke, Virginia, but 80 km wide at its southern end. It goes by many local names, such as Coosa, Shenandoah, Cumberland, Lebanon, Hudson, and Champlain Valleys. The sedimentary rocks below the Great Valley are deformed and folded like the rest of the Valley and Ridge Province yet have been planed into a long, narrow erosion surface (Perry, 1978). Along its length, there are low passes creating segments. Many cities and towns have been built within the Great Valley, and Interstate 81 runs almost its entire length.

Appalachians Deeply Eroded

For many decades, geologists have believed that the Appalachian Mountains are "old" because they have been deeply eroded. They present a rounded appearance (Figures 10a and 10b) in many areas. Early estimates of Cenozoic erosion were 2 km from eastern North America (Mathews, 1975), with much less during the Mesozoic. Clearly, significant erosion has occurred, as witnessed by the erosional remnants, near-surface coal, and eroded anticlines. Surrounding provinces have also been eroded significantly into erosion and planation surfaces.

Some plutonic rock masses in the Appalachians (Figure 11) indicate a few

Figure 9. View northwest of the Great Valley from Rocky Top Overlook, Shenandoah National Park.

Figure 10a. The Blue Ridge Mountains, showing an eroded, rounded appearance (view southeast from exit 55 on Interstate 64 Virginia.

Figure 10b. The Great Smoky Mountains of the southern Blue Ridge Mountains, showing an eroded, rounded appearance (view southeast from Sevierville, Tennessee).

thousand feet of erosion as a minimum, namely of the rocks surrounding the pluton. Plutonic rocks were once under the ground and only have been exposed by erosion.

Coal is commonly found in the sedimentary rocks in the Valley and Ridge Province west of the Blue Ridge Mountains (Figure 12). It includes high-rank anthracite and medium-rank bituminous coal; the rank is typically higher toward the southeast (Hower and Rimmer, 1991). If rank was a result of heat and pressure just from burial, several km of overlying sedimentary rock was eroded at one time. The exact volume of rock varies with assumptions, which are speculative. Friedman and Sanders (1982) believed that the anthracite coal in the Catskill Mountains of New York required an overburden of rock about

Figure 11. Exposed granite seen from Log Hallow Overlook on the Blue Ridge Parkway.

Figure 12. Area of the Appalachian coal of Pennsylvanian age within the uniformitarian geological column. From Eble and Grady (1993, p. 122).

6.4 km thick, implying this much erosion occurred since the coal is near the surface. This depth was estimated based on a normal geothermal gradient and no local heat sources. However, a higher gradient in the past or some other thermal source would have required less sedimentary overburden (Hower and Rimmer, 1991). Although Friedman and Sanders (1982) studied anthracite coal in the Catskill Mountains, their deductions based on the existence of anthracite coal would also apply to the coal of Valley and Ridge Province, since their depth estimate is simply based on estimated overburden and the geothermal gradient. The lower-rank bituminous coal would require less heat and pressure. So if there were no other heat sources and the geothermal gradient were normal, the removal of between 4 and 6.5 km of sedimentary rock from the Valley and Ridge Province is a reasonable estimate based on coal rank.

In regard to the Blue Ridge and Piedmont Provinces, erosion could have been tens of km, but this assumes the grade of metamorphic rocks, now on the surface, formed at depths of tens of kms and pushed up to the surface with the rock above eroded off. There could be other ways to form metamorphic rocks besides depth, so the deduction of tens of kms of erosion is uncertain. Regardless, a huge volume of rock was eroded off these provinces during uplift.

Amount of Erosion Based on Offshore Sediments

Another, more accurate, method of estimating the amount of erosion is to determine the volume of sediment, presumably derived from the Appalachians, deposited in the offshore continental margin system and its associated basins. The continental margin includes the continental shelf, slope, and rise. These sediments form a wedge, thickening seaward, and beginning near zero at the "fall line," a small topographical

Figure 13. Exposed rapids at the fall line after a dam was built, Savannah River, Augusta, Georgia.

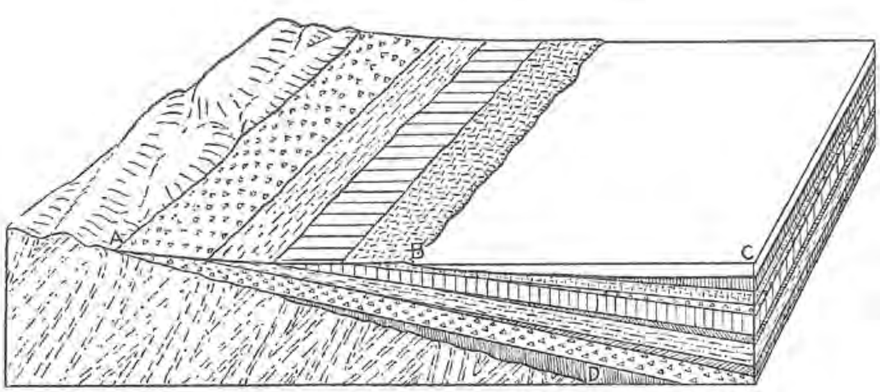


Figure 14. Seaward prograding wedge of sedimentary rocks after Fenneman (1938, p. 7). A to D represents the original surface, A to B is the coastal plain, and B to C is the ocean on top of the continental shelf.

drop between the Piedmont and Coastal Plain provinces. As the limit of upstream navigation, many large cities in the southeast are built on the fall line. Its topography varies. Major rivers crossing the fall line form either waterfalls or a series of rapids (Figure 13). The coastal plain sedimentary wedge thickens out across the continental shelf, slope, and rise (Figure 14) (Klitgord et al., 1988; Poag and Valentine, 1988).

Though typically only about 1000 m, the thickness of continental margin sedimentary rocks is quite impressive in basins. Extensive deep-sea boreholes and seismic reflection profiles have shown great thicknesses of sedimentary rocks offshore, and there are many buried rifts or basins caused by extension and subsidence east of the Blue Ridge Mountains (Hack, 1989; Schlische, 1993; Pazzaglia and Gardner, 1994, p. 12,153). These basins parallel the coast and the Blue Ridge Mountains (Figure 15), indicating that they are related to differential uplift between the land and the sea (see below).

One of the deepest of these basins is the Baltimore Canyon Trough. It extends some 400 km from Cape Hatteras to Long Island (Pickering et al., 1989, pp. 263–269) with a maximum fill thickness of 18 km (Pazzaglia and Gardner, 2000, p. 287) and a total area of 200,000 km^2. A similar deep basin off Newfoundland—the Jeanne d'Arc Basin—contains up to 20 km of sedimentary rock (Deptuck et al., 2003).

This vast amount of sediment was likely sourced from the Appalachians. The cause of erosion and sedimentation was the concomitant uplift of eastern North America and sinking of the Atlantic basin. Poag and Sevon (1989, p. 119) stated that "the primary forcing mechanisms considered have been tectonic and isostatic uplift and subsidence." Tectonic uplift of the eastern United States is believed to have caused the erosion, while the total amount of subsidence along the continental margin is believed to be 14 km (Poag, 1992; Poag and Sevon, 1989). In other words, the continent rose up and the adjacent ocean sank down.

Given the extensive data available along the margin of eastern North America, Poag and Sevon (1989) calculated the total volume of sedimentary rock for each period from the Jurassic to the Quaternary. The amount of sedimentary rocks per period depends upon assumptions of dating (primarily by index fossils), so I will simply examine the total volume of sediments and sedimentary rocks. The total volume of non-carbonate and non-"evaporite" sedimentary rocks is 1.377 million km^3 over an area of about 500,000 km^2 between

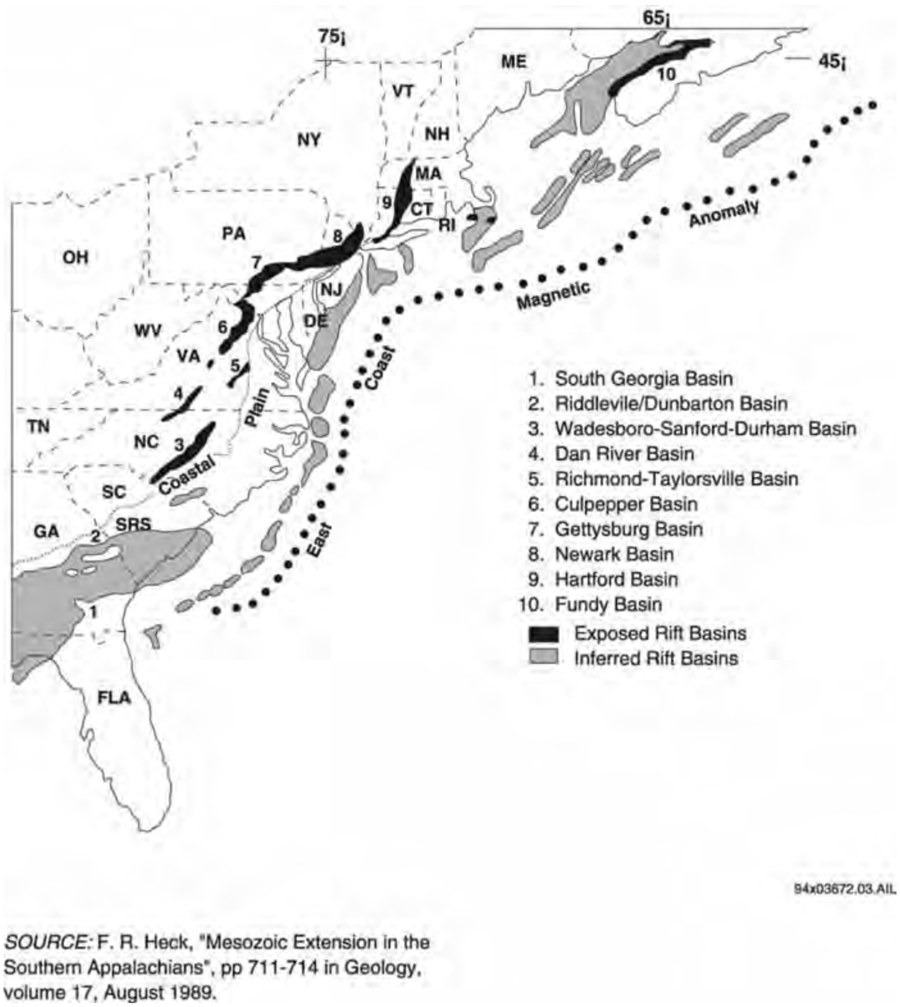


Figure 15. Exposed and inferred rift basins, east of the Blue Ridge Mountains and offshore along the continental margin. After Heck (1989).

latitudes 36° and 42° N and longitudes 39° 30′ and 78° W. The average depth of this sediment over that area is 2.7 km, and if carbonates and evaporites are included, it may exceed 3 km.

The central Appalachians, including the Valley and Ridge, Blue Ridge, and Piedmont Provinces, cover an area of around 315,000 km^2 (Poag, 1992). Based on the total volume and assuming that the sediment originated from these provinces, the average thickness of rock removed by erosion would have been 4.37 km, ignoring issues of compaction, etc. However, it is probable that these sediments were mostly eroded from east of the Appalachian divide, reducing the area by nearly 30%, and increasing the thickness of overburden removed to approximately 6 km. That is close to Pazzaglia and Gardner's (2000) estimate of about 7 km and to that derived from coal studies on the Valley and Ridge Province (4 to 6.5 km) but less than that assumed to have eroded from the Blue Ridge and Piedmont Provinces.

It is not possible to calculate the volume of erosion over the Appalachian Plateaus and interior Low Plateaus Provinces west of the continental divide. Because of the potential energy generated by the uplifting Appalachians and the adjacent sinking ocean basins, it is likely that erosion was much stronger east of the divide than west of the divide. The eroded debris west of the divide should have been much less than east of the divide and transported into the Gulf of Mexico.

From the standpoint of geomorphology, it is clear that the Appalachians have been heavily eroded, probably by as much as 6 km or more. What caused the erosion, transport, and redeposition of these rocks? Many clues point to the deduction that erosion had to be catastrophic and not by slow erosion over millions of years as provided by the details of the geomorphology of the Appalachians, described more fully in Parts II and III. Since planation and erosion surfaces, erosional remnants (monadnocks), long transported rocks, and water and wind gaps are inimical to the model of slow erosion over millions of years, a catastrophic mechanism is favored (Oard, 2008). Evidence of rapid erosion exists in the hundreds of erosional remnants, especially the monadnocks on the Piedmont (see Part II). If the erosion were slow and gradual over millions of years, these monadnocks also would have eroded and would be very small today.

Another clue to the erosional history comes from the late timing of the erosion—after a huge amount of sediments had been laid down. Most geologists date the erosion during the late Mesozoic and Cenozoic. Such powerful catastrophic erosion and deposition of the Coastal Plain and offshore sediments late in geological history strongly points that the erosion occurred during the latter stage of the Genesis Flood.

Erosion by the Flood

Clearly, the erosion and deposition was caused by the combined uplift of the Appalachians and subsidence of the

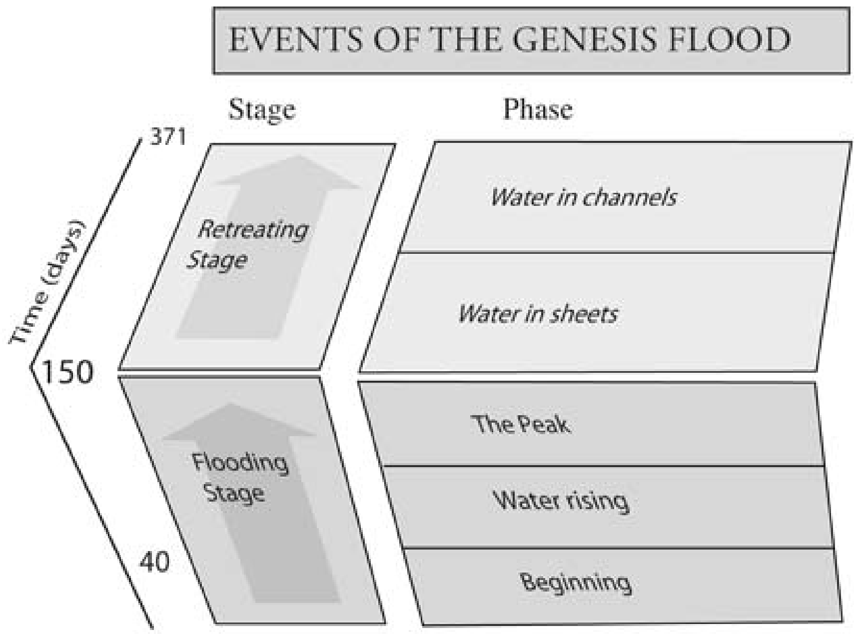


Figure 16. Walker's classification of the Flood into the 150-day flooding stage and 221-day retreating stage with five phases.

continental margin. This fits both Biblical and scientific data from other parts of the world. Uplift and deposition in the rifts along the coastal plain and offshore began before Day 150 based on dinosaur tracks in these sediments (Froede, 2010), since tracks imply a live vertebrate that had to be dead by Day 150. The majority of the thick offshore sediment probably occurred during the retreating stage of the Flood (Oard, 2008; Walker, 1994) as the Appalachians continued to uplift. Psalm 104:6–9 describes the latter part of the Flood, speaking of the simultaneous rising of the mountains and sinking of valleys. Figure 16 shows the two stages and five phases of the Flood.

Because the Blue Ridge Escarpment likely represents a northwestward retreating erosional escarpment, like a 500-km long retreating waterfall, erosion of the Appalachians likely was caused by currents flowing generally from the northwest, perpendicular to the mountain chain. Moreover, if erosion were by currents parallel to the Appalachians, many pediments would have been formed (Oard, 2004; 2008). Based on work done in the western U.S. (Oard, 2008; Ranney, 2005), it appears that there was an initial episode of sheet-flow erosion along the entire length of the Appalachians. That current would have transported the detritus to the coastal plain and offshore regions, depositing the sediment as a sheet where the water depth increased and as the current velocity decreased.

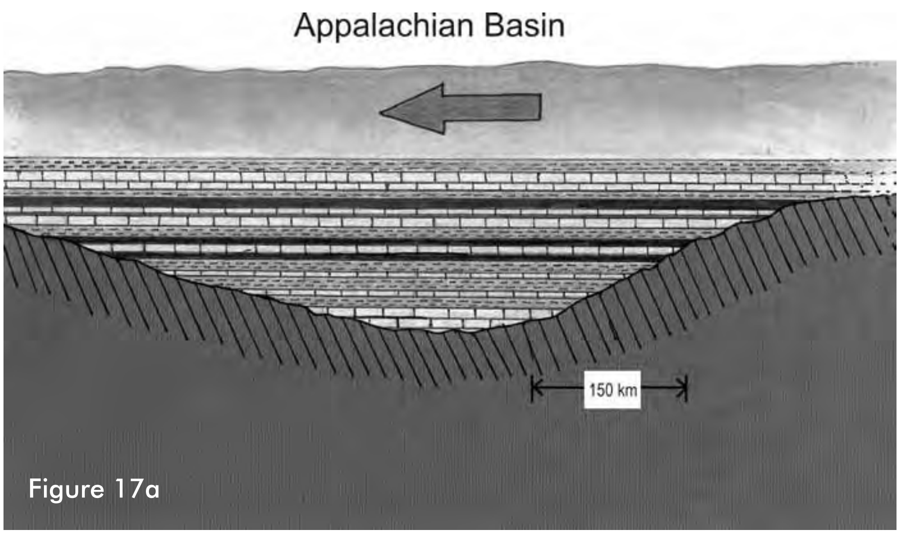
Ongoing uplift and falling water levels during this sheet flow episode would eventually divert the flow around the Blue Ridge Mountains. Figure 17 shows a series of schematics showing the uplift and erosion of the Appalachians during the sheet-flow phase of the retreating stage of the Flood. Very thick sediments were laid down early in the huge northeast-southwest Appalachian Basin early in the Flood from currents mostly coming from the east (Figure 17a). Then the Appalachians uplifted late in the flooding stage and early in the retreating stage with the future Blue Ridge and Piedmont Provinces overthrust toward the northwest and buckling the Appalachian Basin sedimentary rocks (Figure 17b). Such uplift with the adjacent sinking ocean basin to the east causes the sheet flow to reverse east of the major uplift. Sheet flow continues in Figure 17c, eroding the whole area.

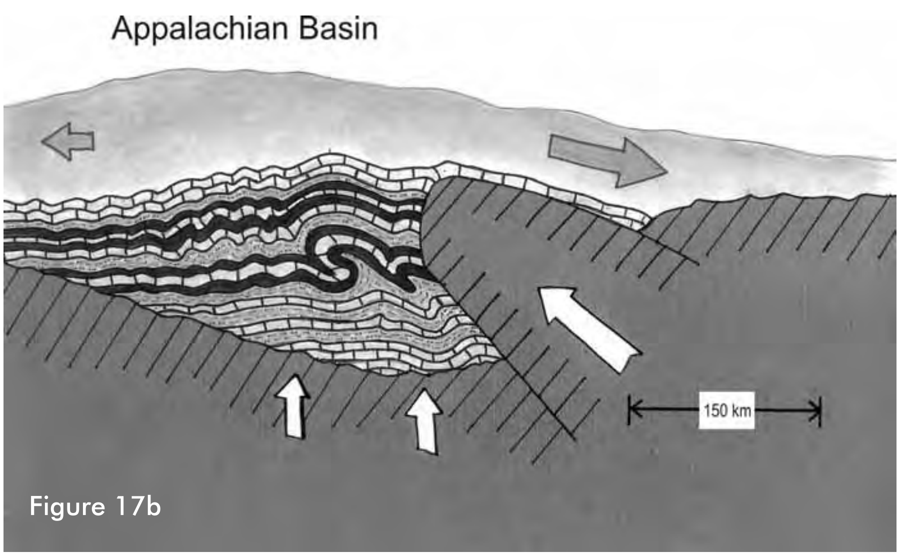
The strongest currents would be expected east of the divide because of the rising Appalachians and greatly sinking continental margin to the southeast rapidly increasing the potential energy for gravitational acceleration. The greater the differential change in elevation, the faster the water runoff. Water diverted toward the west, on the other side of the Appalachians, would have been accelerated to moderate speeds by the sinking of the Gulf of Mexico, which is far away.

The Formation of the Continental Margin

The eroded debris would have been deposited as soon as the current energy dropped, which would have been at the transition to deeper water at the subsiding continental margin and its associated basins. Thus, the coastal plain and continental margin sediments were deposited in the same event that eroded the Appalachians. The scale of the event is supported by the nature of the sedimentary strata. Pitman (1978, p. 1,393) stated:

> The general structure of Atlantic-type margins is that of a seaward-thickening mass of systematically stratified sediment overlying a deeply subsided, faulted basement platform … The sedimentary strata consist of seaward-thickening wedges separated, at least in the shallower sections, by remarkably undisturbed planar horizons. The deepest strata are often disturbed by basement horsts and grabens, reefal structures, and diapirs.





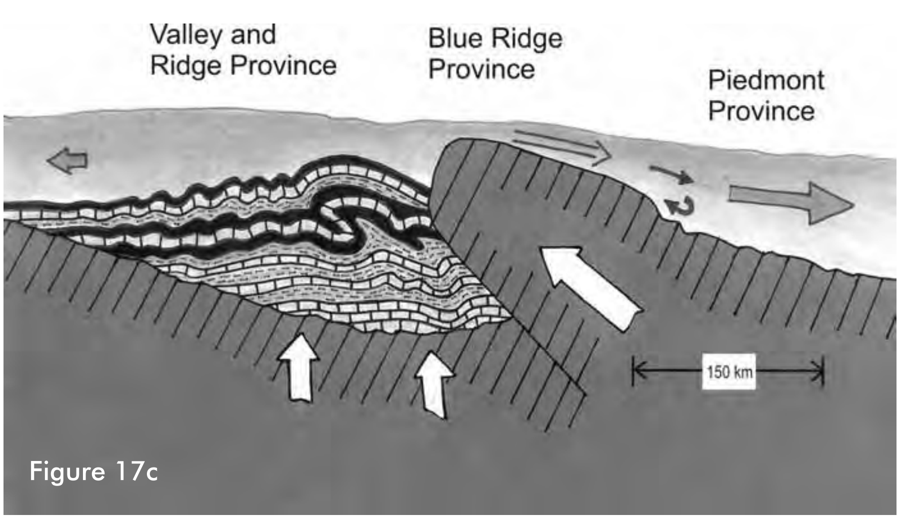


Figure 17. Schematic of suggested tectonic and erosional features for the Appalachians. Illustration by Melanie Richard.

A. Very thick sediments collect in the Appalachian basin early in the Flood from currents coming mostly from the east.

B. Appalachians uplift early in the retreating stage with the future Blue Ridge and Piedmont Provinces overthrust toward the northwest and buckling the Appalachian Basin sedimentary rocks.

C. Sheet flow continues and erodes the whole area.

A horst is an uplifted block, and a graben is a downfaulted block. Reefal structures are rare. Diapirs are intrusions of salt, mud, or sand that are squeezed upward from beds below by density differences. Such diapirs are an indication of rapid deposition in that the soft material did not have a chance to dewater before the next layer was deposited. Like the Gulf of Mexico basin, the Atlantic margin diapirs are believed to be mostly salt from the deepest layers of the continental margin.

During subsidence, many rift basins opened due to extension and block faulting (see above). Figure 15 shows these basins elongated parallel to the coast and the trend of the Appalachians.

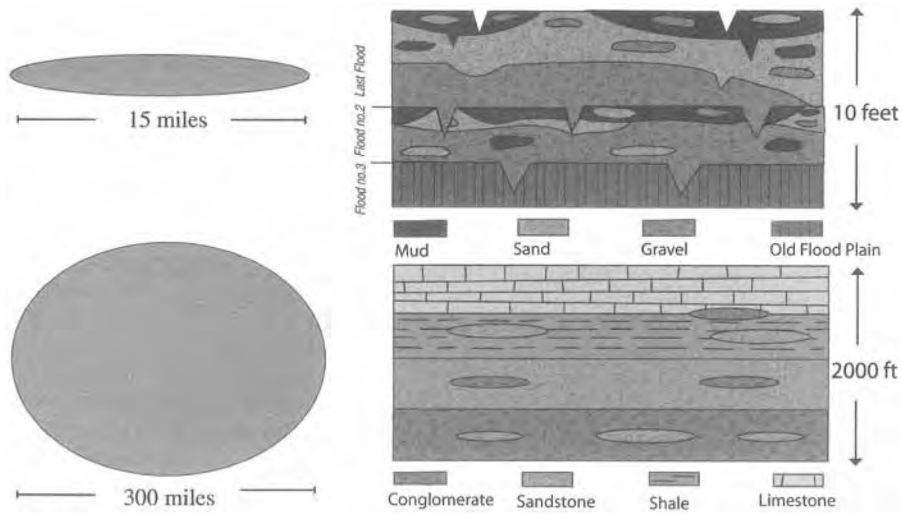


Figure 18. Schematic comparing the scale and character of uniformitarian sedimentation in local floods (top) contrasted with the Genesis Flood (bottom). The left side is an aerial view, while the right side is a vertical cross-section. Note the much larger aerial and vertical scale of flood deposition with little or no erosion at the contacts between types of sedimentary rock. From Oard (2008, p. 26).

These basins have been cited as evidence of the breakup of Pangea in the plate tectonics paradigm, but simple extension as the Appalachians uplifted while the continental margin greatly subsided can account for them. These basins were quickly filled with sediments.

The broad sheets of sediment that form the continental margin are typically flat with a slight seaward dip, decreasing from the basement upward through the sediment wedge. But sometimes, the dip increases seaward, forming unconformities and delta-like features that indicate that the current flow was perpendicular to the shoreline and not parallel as expected by wind generated currents. Hedberg (1970, p. 11) stated that the "reflection profiling has shown that many slopes in their present form are the result of prograding sedimentation." This prograding wedge of sedimentation is perpendicular to the coast.

The dip of the sedimentary rocks of the coastal margin is steeper where they are buried deeper (Steckler et al., 1999), reinforcing the role of differential vertical tectonics. King (1982, p. 45) commented in regard to the continental margin sedimentary rocks off southeast Africa:

> We note that all the formations drilled dip offshore. The oldest and deepest formations dip at several degrees, the youngest and upper most dip at less than one degree.

Such a profile of the subsurface sedimentary rocks of the continental margin indicates a broad scale uplift of the adjacent continental area and sinking of the continental margin, probably along with the ocean basins farther seaward (Uchupi and Emory, 1967; Pazzaglia and Gardner, 1994). This is consistent with the subsidence of guyots far from land that were probably planed off close to sea level but whose tops are now at an average of 1,500 m below sea level (King, 1983). The hinge line for this uplift and subsidence is near the coast. King (1983, p. 200, emphasis added) summarized:

> The formations and unconformities have been tilted seaward (monoclinally) at intervals during the later Cenozoic. There have been repeated tectonic episodes: *always in the same sense—the lands go up and the sea floor down.*

King indirectly quoted Psalm 104:8! He believed that stepwise tectonic movements caused the unconformities, but others believe such unconformities could be caused by other processes, such as the change in the amount of sedimentation (Steckler et al., 1999). King also believed that the vertical tectonics occurred quite late in geological time, which would correspond to the late Flood differential vertical tectonics.

This pattern, seen in the Appalachians, is also observed worldwide. Differential vertical tectonics explains features at a variety of scales, from interior mountain basins (Oard, 2008) to the megaregional continental margins. This also answers the common canard about the relationship between the Flood and marine strata found on high mountains; the difference in elevation was once much less during the Flood (Oard, 2009b). The same features are seen in ocean basins, as shown by fracture zones and the ubiquitous abyssal hills (Oard, 2008).

The timing of the erosional and depositional event that formed the current Appalachian geomorphology and the sedimentary wedge of the continental margin clearly was relatively late. Geologists date these events mostly in the Cenozoic. Thus, in this region, the end of the Flood coincides with the late Cenozoic, similar to many other features found around the planet (Oard, 2007).

Implications for Actualism

The large-scale, uniform sedimentation finds no place within classical gradualism and is hard-pressed to be explained by neocatastrophist concepts. Uniformitarian erosion and sedimentation is generally linear and small scale (Figure 18). But the continental shelf and slope sediments are mostly planar.

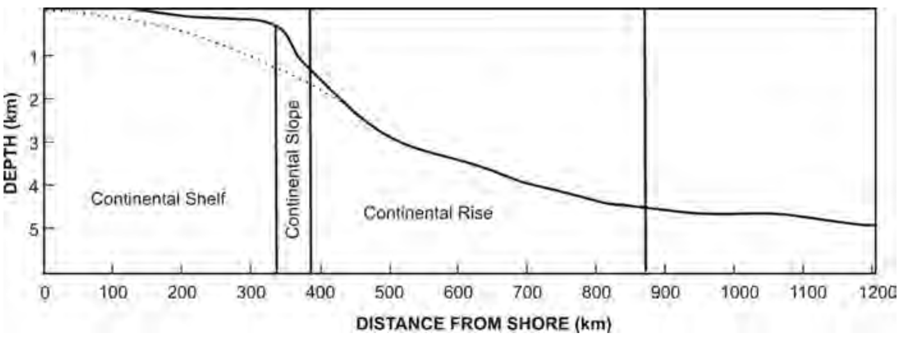


Figure 19. Principle features of a wide Atlantic-type margin with a continental rise (vertical exaggeration 50x). The dashed line represents the expected profile of the continental margin if formed over millions of years according to King (1983). Modified from Kennett (1982, p. 27)

The surface profile of the continental margin is also contrary to expectations of gradualists. Natural processes operating at lower energy levels over longer periods would generate a steady slope from continent to abyssal plains; there should be no continental shelf or slope. Figure 19 shows the current profile of the continental margin with the dashed line showing the slope predicted by gradual processes. King (1983, p. 199, emphasis added) described this puzzle:

> There arises, however, the question as to what marine agency was responsible for the leveling of the shelf in early Cenozoic time, a leveling that was preserved, with minor modification, until the offshore canyon cutting of Quaternary time? Briefly *the shelf is too wide, and towards the outer edge too deep*, to have been controlled by normal wind-generated waves of the ocean surface.

At the time King wrote these words, many scientists believed that submarine canyons were young features formed by the lower sea level of the "Quaternary" Ice Age. However, researchers now realize that submarine canyons must have taken much more time to erode in their paradigm (Oard, 2008).

Ocean currents are commonly parallel to the coast, and such is the case here, with the Gulf Stream (Kennett, 1982). Sediments today are mainly supplied to the continental margin by rivers. These rivers create deltas, with shore-parallel currents spreading the sediment along the continental margin. Slumping and other mass movements cause the sediment to slide down to the deep ocean basins. If these processes operating over millions of years had formed the continental margin, we would expect quite different features from those actually observed.

Summary

The Appalachian Mountains include (from east to west) the Piedmont, Blue Ridge Mountains, Valley and Ridge, and Appalachian Plateaus provinces. Geological features, such as near-surface high-rank coal, geomorphologic features, and the volume of derivative sediment generally agree in suggesting comprehensive erosion averaging 4–6.5 km in depth from the entire region. The best explanation of the geomorphology of the mountains and adjacent continental margin is erosion along the entire length of the mountains by sheet flow perpendicular to the Appalachian axis. Eroded detritus was transported, sorted, and deposited along the adjacent subsiding continental margin, creating a unique continental shelf and slope system that cannot be explained by the long-term work of present-day processes, even granting higher rates of energy. Instead, these features support the work of the early retreating stage of the Genesis Flood. The Flood/post-Flood boundary in this region is clearly in the very late Cenozoic since the uplift, huge erosion, and the thick sedimentation of the continental margin predominantly occurred during the Cenozoic of the uniformitarian timescale.

Acknowledgments: I thank those people who helped with this project, especially John Reed, who suggested that I check the amount of sedimentary rocks offshore of the Appalachians, and Doug Dunbar, who showed me the geomorphology of western Kentucky. I also thank two anonymous reviewers for significantly improving the manuscript and for providing two of the figures. I appreciate the work of artist Mrs. Melanie Richard, who drew the schematic shown in Figure 17. This work was supported by a grant from the Creation Research Society.

References

CRSQ: Creation Research Society Quarterly

JoC: Journal of Creation, *Technical Journal*, *or Creation Ex Nihilo Technical Journal*

Aadland, R.K., A.D. Smits, and P.A. Thayer. 1992. Geology and hydrostratigraphy of the A/M Area, Savannah River Site (SRS), South Carolina, USDOE Report WSRC-RP-92–440, Westinghouse Savannah River Company, Savannah River Site, Aiken, SC.

Battiau-Queney, Y. 1989. Constraints from deep crustal structure on long-term landform development of the British Isles and Eastern United States. *Geomorphology* 2:53–70.

Bentley, C. 2010. http://mountainbeltway.wordpress.com/2010/05/17/geology-of-skyline-drive-jmu/ (accessed June 2, 2010).

Deptuck, M.E., R.A. MacRae, J.W. Shimeld, G.L. Williams, and R.A. Fensome. 2003. Revised Upper Cretaceous and lower Paleogene lithostratigraphy and depositional history of the Jeanne d'Arc Basin, offshore Newfoundland, Canada. *AAPG Bulletin* 87:1,459–1,483.

Eble, C.F., and W.C. Grady. 1993. Palynologic and petrographic characteristics of two Middle Pennsylvanian coal beds and a probable modern analogue. In Cobb, J.C., and C.B. Cecil (editors), *Modern and Ancient Coal-Forming Environments*, GSA Special paper 286, pp. 119–138. Geological Society of America, Boulder, CO.

Fenneman, N.M. 1938. *Physiography of Eastern United States*. McGraw-Hill Book Company, Inc, New York, NY.

Friedman, G.M., and J.E. Sanders. 1982. Time-temperature-burial significance of Devonian anthracite implies former great (~6.5 km) depth of burial of Catskill Mountains, New York. *Geology* 10:93–96.

Froede, C.R. Jr. 2004. Eroded Appalachian Mountain siliciclastics as a source for the Navajo Sandstone. *JoC* 18(2):3–5.

Froede, C.R. Jr. 2010. Fossilized animal tracks and trackways date uplift of the Appalachian Mountains. *Creation Matters* 15(4):1, 6, 7.

Hack, J.T. 1989. Geomorphology of the Appalachian Highlands. In Hatcher, R.D. Jr., W.A. Thomas, and G.W. Viele (editors), *The Geology of North America*, Volume F-2, *The Appalachian-Ouachita Orogen in the United States*, pp. 459–470. Geological Society of America, Boulder, CO.

Hatcher, R.D. Jr. 1972. Development model for the Southern Appalachians. *GSA Bulletin* 83:2,735–2,760.

Hatcher, R.D. Jr. 1978. Tectonics of the western Piedmont and Blue Ridge, Southern Appalachians: review and speculation. *American Journal of Science* 278:276–304.

Hatcher, R.D. Jr. 1989. Tectonic synthesis of the U.S. Appalachians. In Hatcher, R.D. Jr., W.A. Thomas, and G.W. Viele (editors), *The Geology of North America*, Volume F-2, *The Appalachian-Ouachita Orogen in the United States*, pp. 511–535. Geological Society of America, Boulder, CO.

Heck, F.R. 1989. Mesozoic extension in the southern Appalachians. *Geology* 17:711–714.

Hedberg, H.D. 1970. Continental margins from viewpoint of the petroleum geologist. *AAPG Bulletin* 54 (1):3–43.

Hooykaas, R. 1963. *The Principle of Uniformity in Geology, Biology, and Theology*, second impression. E.J. Brill, London, UK.

Hower, J.C., and S.M. Rimmer. 1991. Coal rank trends in the central Appalachian coalfields: Virginia, West Virginia, and Kentucky. *Organic Geochemistry* 17(2):161–173.

Kaktins, U., and H.L. Delano. 1999. Drainage basins. In Shultz, C.H. (editor), *The Geology of Pennsylvania*, pp. 379–390. Pennsylvania Geological Survey, Harrisburg, PA, and Pittsburgh Geological Society, Pittsburgh, PA.

Karle, K.H. 2009. Young evidences in an ancient landscape: part 1—the Eastern Structural Front of the Appalachian Mountains. *JoC* 23(3):76–83.

Kennett, J. 1982. *Marine Geology*. Prentice-Hall, Englewood Cliffs, NJ.

King, L.C. 1982. *The Natal Monocline*, second revised edition. University of Natal Press, Pietermaritzburg, South Africa.

King, L.C. 1983. *Wandering Continents and Spreading Sea Floors on an Expanding Earth*. John Wiley & Sons, New York, NY.

Klitgord, K.D., D.R. Hutchinson, and H. Schouten. 1988. U.S. Atlantic continental margin; structural and tectonic framework. In Sheridan, R.E., and J.A. Grow (editors), *The Geology of North America*, Volume I-2: *The Atlantic Continental Margin: U.S.*, pp. 19–55. Geological Society of America, Boulder, CO.

Mathews, W.H. 1975. Cenozoic erosion and erosion surfaces of eastern North America. *American Journal of Science* 275:818–824.

Miller, B.V., A.H. Fetter, and K.G. Stewart. 2006. Plutonism in three orogenic pulses, Eastern Blue Ridge Province, southern Appalachians. *GSA Bulletin* 118:171–184.

Misra, K.C., and F.B. Keller. 1978. Ultramafic bodies in the southern Appalachians: a review. *American Journal of Science* 278:389–418.

Neuendorf, K.K.E., J.P. Mehl, Jr., and J.A. Jackson. 2005. *Glossary of Geology*, 5th ed. American Geological Institute, Alexandria, VA.

Nickelsen, R.P. 1958. Cross-bedding in Pennsylvanian sandstones of central Pennsylvania: a preliminary study. *GSA Bulletin* 69:791–796.

Oard, M.J. 2004. Pediments formed by the Flood: evidence for the Flood/post-Flood boundary in the Late Cenozoic. *JoC* 18(2):15–27.

Oard, M.J. 2007. Defining the Flood/post-Flood boundary in sedimentary rocks. *JofC* 21(1): 98–110.

Oard, M.J. 2008. *Flood by Design: Receding Water Shapes the Earth's Surface*. Master Books, Green Forest, AR.

Oard, M.J. 2009a. Colorado Plateau sandstones derived from the Appalachians? *JoC* 23(3):5–7.

Oard, M.J. 2009b. Dinosaur tracks, eggs, and bonebeds. In Oard, M.J., and J.K. Reed (editors), *Rock Solid Answers: The Biblical Truth Behind 14 Geological Questions*, pp. 245–258. Master Books, Green Forest, AR, and Creation Research Society Books, Chino Valley, AZ.

Ollier, C.D. 1985. Morphotectonics of passive continental margins: introduction. *Zeitschrift für Geomorphologie N. F.* 54:1–9.

Pazzaglia, F.J., and T.W. Gardner. 1994. Late Cenozoic flexural deformation of the middle U. S. Atlantic passive margin. *Journal of Geophysical Research* 99 (B6):12,143–12,157.

Pazzaglia, F.J., and T.W. Gardner. 2000. Late Cenozoic landscape evolution of the US Atlantic passive margin: insights into a North American Great Escarpment. In Summerfield, M. A. (editor), *Geomorphology and Global Tectonics*, pp. 283–302. John Wiley & Sons, New York, NY.

Pelletier, B.R. 1958. Pocono paleocurrents in Pennsylvania and Maryland. *GSA Bulletin* 69:1,033–1,064.

Perry, W.J. Jr. 1978. Sequential deformation in the central Appalachians. *American Journal of Science* 278:518–542.

Pettijohn, F.J. 1970. Introduction. In, Fisher, G.W., F.J. Pettijohn, J.C. Reed Jr., and K.N. Weaver (editors), *Studies of Appalachian Geology: Central and Southern*, pp. 1–4. John Wiley & Sons, New York, NY.

Pickering, K.T., R.N. Hiscott, and F.J. Hein. 1989. *Deep-Marine Environments*. Unwin Hyman, London, U.K.

Pitman W.C. III. 1978. Relationship between eustacy and stratigraphic sequences of passive margins. *GSA Bulletin* 89:1,389–1,403.

Plummer, C.C. and D. McGeary. 1996. *Physical Geology*, 7th edition. Wm C. Brown Publishers, Dubuque, IA.

Poag, C.W. 1992. U.S. middle Atlantic continental rise: provenance, dispersal, and deposition of Jurassic to Quaternary sediments. In Poag, C.W., and P.C. de Graciansky (editors), *Geological Evolution of Atlantic Continental Rises*, pp. 100–156. Van Nostrand Reinhold, New York, NY.

Poag, C.W., and W.D. Sevon. 1989. A record of Appalachian denudation in postrift Mesozoic and Cenozoic sedimentary deposits of the U.S. middle Atlantic continental margin. *Geomorphology* 2:119–157.

Poag, C.W., and P.C. Valentine. 1988. Mesozoic and Cenozoic stratigraphy of the United States Atlantic continental shelf and slope. In Sheridan, R.E., and J.A. Grow (editors), *The Geology of North America*, Volume I-2: *The Atlantic Continental Margin: U.S.*, pp. 67–85. Geological Society of America, Boulder, CO.

Ranney, W. 2005. *Carving Grand Canyon: Evidence, Theories, and Mystery*. Grand Canyon Association, Grand Canyon, AZ.

Reed, J.K. 2010. Untangling uniformitarianism, level I: a quest for clarity. *Answers Research Journal* 3:37–59.

Schlee, J. 1963. Early Pennsylvanian currents in the southern Appalachian Mountains. *GSA Bulletin* 74:1,439–1,452.

Schlische, R.W. 1993. Anatomy and evolution of the Triassic-Jurassic continental rift system, Eastern North America. *Tectonics* 12 (4):1,026–1,042.

Schruben, P.G., R.E. Arndt, and W.J. Bawiec, 2006. Geology of the Conterminous United States at 1:2,500,000 Scale — A Digital Representation of the 1974 P.B. King and H.M. Beikman Map. http://pubs.usgs.gov/dds/dds11/ (accessed June 2, 1010).

Simmons, H. 1983. Old rock on young rock. *Mosaic* 16(2):24–31.

Spotila, J.A., G.C. Bank, R.W. Reiners, C.W. Naeser, N.D. Naeser, and B.S. Henika. 2004. Origin of the Blue Ridge escarpment along the passive margin of Eastern North America. *Basin Research* 16:41–63.

Steckler, M.S., G.S. Mountain, K.G. Miller, and N. Christie-Blick. 1999. Reconstruction of Tertiary progradation and clinoform development on the New Jersey passive margin by 2-D backstripping. *Marine Geology* 154:399–420.

Thelin, G.P., and R.J. Pike. 1991. Landforms of the Conterminous United States: A Digital Shaded-Relief Portrayal. Miscellaneous Investigations Series Map I-2206, U.S. Geological Survey, Washington, DC.

Thornbury, W.D. 1965. *Regional Geomorphology of the United States*. John Wiley & Sons, New York, NY.

Uchupi, E. and K.O. Emery. 1967. Structure of continental margin off Atlantic coast of United States. *AAPG Bulletin* 51(2):223–234.

Walker, T. 1994. A Biblical geological model. In Walsh, R.E. (editor), *Proceedings of the Third International Conference on Creationism*, technical symposium sessions, pp. 581–592. Creation Science Fellowship, Pittsburgh, PA.

Way, J.H. 1999. Appalachian Mountain section of the Ridge and Valley Province. In Shultz, C.H. (editor), *The Geology of Pennsylvania*, pp. 353–361. Pennsylvania Geological Survey, Harrisburg, PA, and Pittsburgh Geological Society, Pittsburgh, PA.

Whitaker, J.C. 1955. Direction of current flow in some lower Cambrian clastics in Maryland. *GSA Bulletin* 66:763–766.

Yeakel, L.S. Jr. 1962. Tuscarora, Juniata, and Bald Eagle paleocurrents and paleogeography in the central Appalachians. *GSA Bulletin* 73:1,515–1,540.