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# Origin of Appalachian Geomorphology

# Part II: Formation of Surficial Erosion Surfaces

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## Abstract

Erosion surfaces on the Piedmont and the Appalachian Plateaus are described. Ridges and valleys in the Valley and Ridge Province are probably not erosion surfaces, forming instead due to lithology differences in the underlying rocks. The "cycle of erosion" invented by William Morris Davis was once popular but has many problems. The currently popular weathering hypothesis is also analyzed and found wanting. The formation of the erosion surfaces with monadnocks and veneers of gravels transported over long distances is best explained by mechanisms associated with the retreating stage of the Flood.

## Introduction

In part I, I summarized the general geomorphology of the Appalachians, which includes the Piedmont, Blue Ridge Mountains, Valley and Ridge, and Appalachian Plateaus provinces (Figure 1). Several lines of evidence suggest that up to 6.5 km of erosion occurred, probably as a result of sheet-flow erosion during the retreating stage of the Flood. Although there are several crude methods of estimating the amount of erosion, the most reliable indicator is probably the amount of sediment and sedimentary rock in the offshore area.

During the great erosion episode in the Appalachians, rocks were sometimes planed to flat or nearly flat surfaces, called erosion or planation surfaces. These surfaces have proven controversial among secular geologists but can be readily explained by the mechanisms of the Flood.

## Surficial Erosion Surfaces

An erosion surface is defined as: "A land surface shaped and subdued by the action of erosion, esp. by running water. The term is applied to a level or nearly level surface" (Neuendorf et al., 2005, p. 217). A planation surface is generally considered a flat to nearly flat erosion surface. The definition includes erosion by water because many surficial erosion and planation surfaces are capped by a veneer of generally rounded rocks attributed to aqueous action.

Gravel-capped planation surfaces are found all over the Earth. Good examples are found in the northern High Plains of western North America. There are typically four planation surfaces in this area in Montana and Canada (Alden, 1932). Figure 2 shows the flat surface of the highest planation surface, the Cypress Hills of southeast Alberta and southwest Saskatch-

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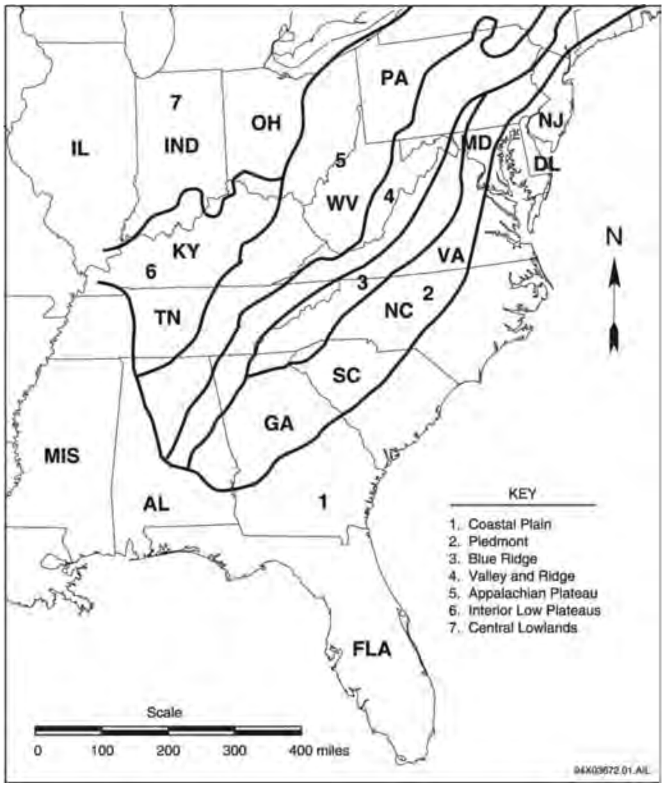

**Figure 1. Map of the Appalachian provinces and the two provinces to the west. From Aadland et al. (1992).**

**Figure 2. The flat top of the Cypress Hills planation surface near Reser Lake.**

**Figure 3. Quartzite conglomerate cap at Conglomerate Cliffs, western Cypress Hills.**

**Figure 4. Close up of the quartzite conglomerate at Conglomerate Cliffs, western Cypress Hills.**

ewan (Oard and Klevberg, 1998). Before dissection, probably by glacial meltwater, this surface covered an area of about 2,500 km$^2$. Its western end stands about 300 m above the next planation surface, the Flaxville surface, and about 700 m above the rivers to the north and south. The top of the Cypress Hills surface is capped by an average 23-m-thick veneer of rounded quartzite cobbles and boulders (Figures 3 and 4). Quartzite is not exposed on the High Plains, and the rocks atop the Cypress Hills surface likely originated in the western Rocky Mountains of central and northern Idaho and western Montana, based on paleocurrent directional indicators, representing a total travel distance of over 500 km *across* the present continental divide (Oard et al., 2005). The minimum current velocity, based on the slope between the eastern Rocky Mountains and the top of the Cypress Hills, the size of the rocks, and the ubiquitous percussion marks on the rocks (Figure 5), is an incredible 30 m/sec at a minimum depth of 55 m (Klevberg and Oard, 1998). These numbers were based on the fact that percussion marks on hard quartzite rocks are ubiquitous, implying highly turbulent flow in which small- to medium-sized rocks are carried up into suspension for a short time and crash down into other quartzites. The minimum horizontal velocity and depth were calculated by estimating the fall velocity of a maximum size,

**Figure 5. Large percussion marks on a quartzite boulder from the Cypress Hills gravel cap.**

bullet-shaped rock of 15 centimeters diameter. The distribution of the gravels indicates these conditions existed in a sheet flow across the entire area.

In the Appalachians, there are three possible erosion surfaces. Due to their rolling morphology, they are not planation surfaces. From east to west, these include: (1) the Piedmont Province, (2) the accordant mountaintops of the Valley and Ridge Province, and (3) the Allegheny and Cumberland Plateaus. I include the Interior Low Plateaus Province to the west in the last.

## The Piedmont Erosion Surface

The Piedmont Province starts just east of the Blue Ridge Mountains from the Hudson River in the north to Alabama in the south (Figure 6). It is 200 km at its widest point near the Virginia-North Carolina border. The Piedmont is bordered on the east by the Atlantic Coastal Plain Province, the boundary being the fall line. The Piedmont is relatively flat (Figure 7) with many erosional remnants called monadnocks (Figure 8). Stone Mountain, Georgia, is probably the best known (Figure 9) (Froede, 1995). It rises 240 m above the surrounding terrain. The Piedmont's elevation gradually rises westward to the Blue Ridge Mountains.

The highly deformed rocks of the Piedmont are predominantly igneous and metamorphic rocks with several distinct

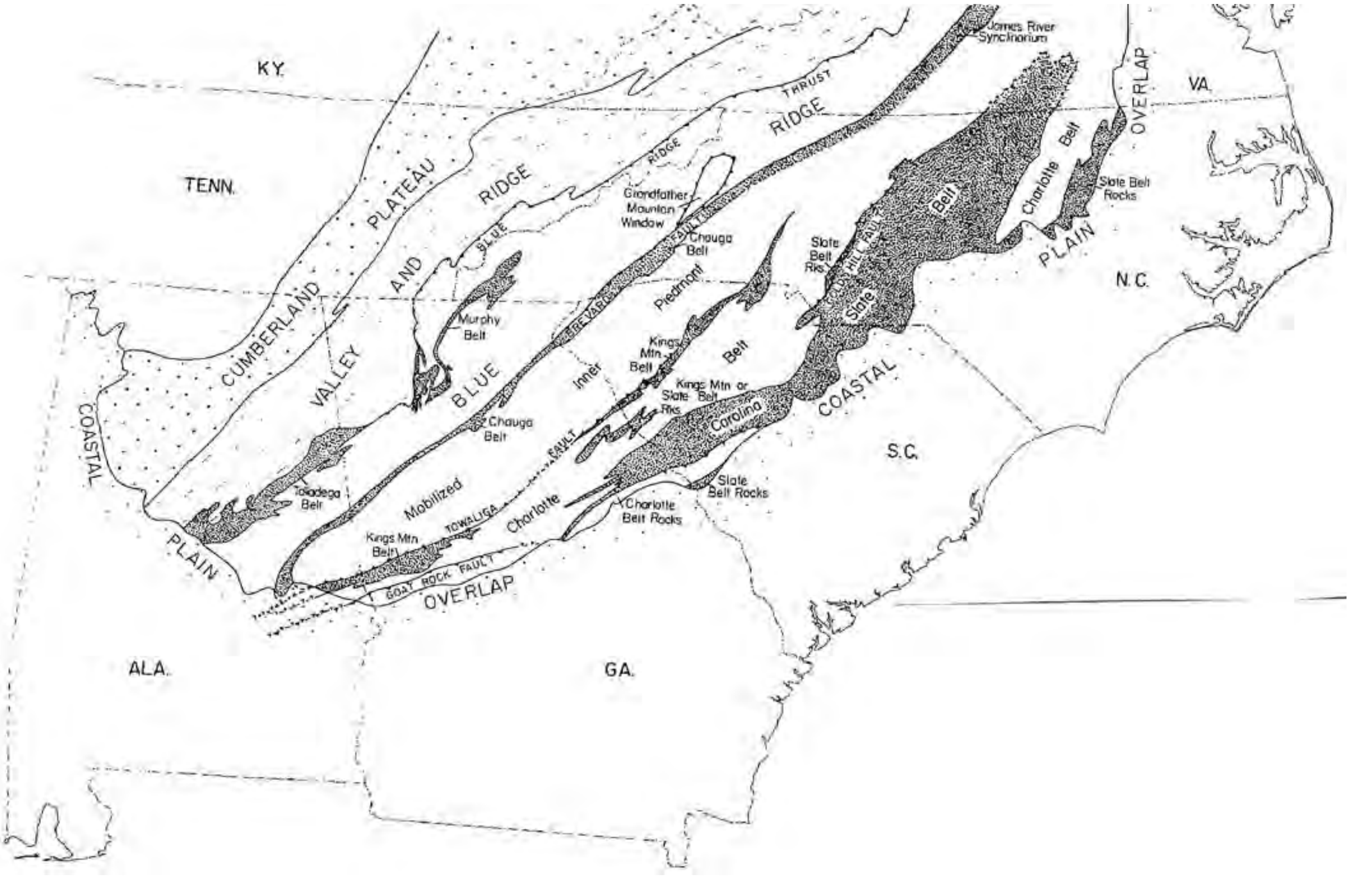

**Figure 6. Map of the subprovinces (belts) on the Piedmont from Alabama to Virginia. After Hatcher (1972, p. 2,737).**

**Figure 7. Lake on the Piedmont near Parkersville showing general flatness of the terrain.**

**Figure 8. Monadnock on the Inner Piedmont close to Caesar's Head State Park, South Carolina.**

**Figure 9. Stone Mountain, Georgia, monadnock. Photo courtesy of Carl Froede.**

tectonic zones and lithologic belts parallel to the Blue Ridge Escarpment, such as the Brevard Fault zone, the Charlotte Belt, and the Carolina Slate Belt. Granitic bodies locally intrude the Piedmont. The type of rock varies widely; there are even some mantle-sourced rocks in spots (Farrar, 1985).

Nevertheless, the Piedmont has been planed fairly smooth across its entire area. The presence of rolling hills and monadnocks (see below) make it an erosional, rather than a planation, surface. Because of the lithology variations, erosion by modern processes over millions of years would have resulted in a more uneven surface, with hard rocks eroded less than soft rocks. By now, erosion over millions of years should have resulted in the harder rocks being mountains and the softer rocks being deep valleys. But both hard and soft rocks have been planed generally the same by erosion. Geomorphologist Nevin Fenneman (1938, p. 122) stated that the Blue Ridge Mountains and the Piedmont used to be called the "Older Appalachians," but the eastern part was planed:

> At a much later time the older belt became two physiographic provinces by the reduction of its seaward side of a relatively late peneplain (Piedmont province), while the higher belt on its western side (Blue Ridge province) was not destroyed.

Figure 10 is a shaded relief image of the central Appalachians around Ceasar's Head State Park at the Blue Ridge Escarpment, showing the rough, mountainous look of the Blue Ridge Province and the smoother look of the Piedmont to the southeast.

Because the Blue Ridge Escarpment between the two provinces shows evidence of significant headward erosion toward the west (see Oard, 2011), the scale of that event makes it likely that the Piedmont planation occurred at the same time. Fenneman's "peneplain" was the old name for an erosion surface; today, it is simply called an "erosion surface."

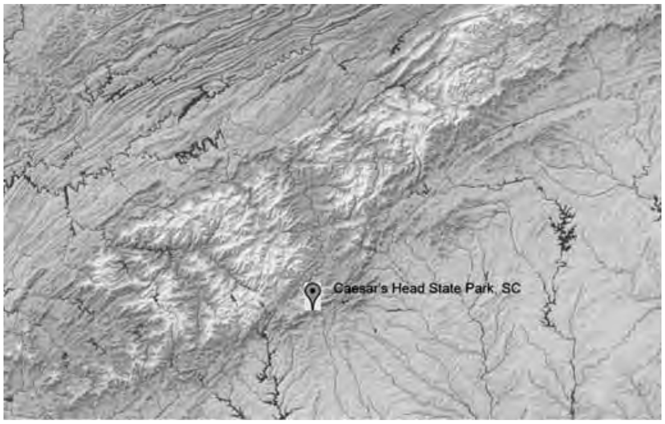

**Figure 10. Shaded relief image of the central Appalachians around Caesar's Head State Park, South Carolina, at the Blue Ridge Escarpment showing the rough, mountainous look of the Blue Ridge Province and the smoother look of the Piedmont. The parallel ridges and valleys can also be seen to the northwest.**

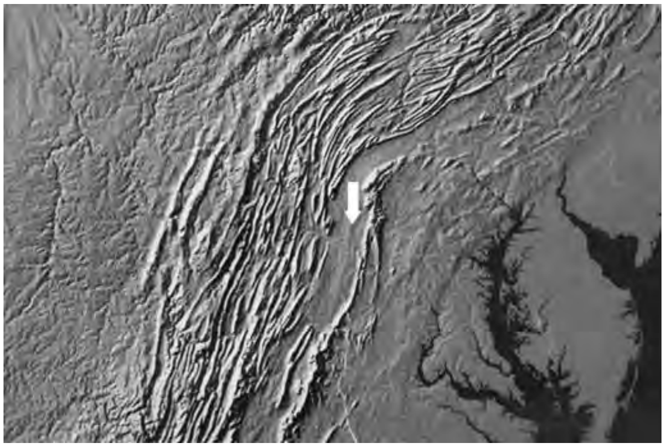

**Figure 11. The distinctive geomorphology of the Appalachian Mountains in southern Pennsylvania, Maryland and eastern Virginia (from Landforms of the Conterminous United States). The Great Valley is shown by an arrow.**

**Figure 12a. Vertical strata in one of the water gaps on the Susquehanna River north of Harrisburg, Pennsylvania.**

**Figure 12b. Conglomerate in near vertical sedimentary rock in one of the water gaps on the Susquehanna River north of Harrisburg, Pennsylvania.**

## Are the Ridges in the Valley and Ridge Province an Erosion Surface?

The Valley and Ridge Province, on the opposite side of the Blue Ridge Mountains from the Piedmont (Figure 1), extends a distance of about 1,900 km from the St. Lawrence Lowland to Alabama (Fenneman, 1938; Thornbury, 1965). Its width varies from about 22 km along the New York-New Jersey state line to 125 km between Harrisburg and Williamsport, Pennsylvania. The province is thought to have formed by folding and thrusting toward the northwest of mostly early Paleozoic strata followed by erosion over millions of years. The ridges and valleys have a marked parallelism in a northeast-southwest direction (Figures 10 and 11). The Great Valley (see Oard, 2011) is usually considered the first valley, as it borders the Blue Ridge Mountains to the east.

The crests of the ridges are generally hard sandstone or conglomerate (Figure 12a and b), and are moderately even or level, and of similar elevation, but rarely are any ridges wide enough to be topped by a flat surface. The valleys are mostly underlain by softer shales. Lithological differences probably explain the highs and lows. This is different from the erosion

Figure 13. Monadnocks above flat floor of the Great Valley as seen to the northwest from Rocky Top Overlook, Shenandoah National Park, Virginia.

Figure 14. The dissected erosion surface on the border of Virginia and Kentucky at Breaks Interstate Park.

of the Piedmont, also with lithological differences but planed generally flat, while the Valley and Ridge were not. The level tops of many of the ridges suggested to some, such as William Morris Davis (Hack, 1989), that their crests represented an extensive erosion surface. It was named the "Schooley Peneplain" by William Morris Davis (Johnson, 1954, p. 489). A lower peneplain, developed in the valleys, was called the Harrisburg Peneplain. However, the accordant tops of the ridges need not represent a single regional erosion surface, but merely differential erosion of hard and soft folded rocks (Hack, 1989). Thornbury (1965, p. 127) suggested:

> We must, of course, always keep in mind the possibility that the topography of the Ridge and Valley province can be interpreted reasonably without resort to erosion cycles and peneplains.

Therefore, I will not treat the accordant tops of the Valley and Ridge Province as a regional erosion surface.

However, the bottom of the Great Valley likely is a linear erosion surface, since in many areas the valley floor is flat and has truncated sedimentary rocks of different hardness. Also, monadnocks occur in the Great Valley (Figure 13). This erosion surface can be equated with the Harrisburg peneplain of Davis's cycle of erosion.

## Erosion Surfaces West of the Valley and Ridge Province

Immediately west of the Valley and Ridge Province is the Appalachian Plateau Province, which stretches from northwestern New York to northeastern Alabama (Fenneman, 1938, pp. 279–342). It attains a maximum width of 320 km in the Ohio-Pennsylvania-West Virginia area (Thornbury, 1965) and occupies more than 66,000 km$^2$. The Appalachian Plateau consists of the Allegheny Plateau in the north and the Cumberland Plateau in the south. The boundary between the two is rather arbitrary. Most of the Appalachian Plateau is significantly dissected by streams, and thus different from many plateaus found in the western United States. Briggs (1999) subdivided this area into miniprovinces.

The rocks below the Appalachian Plateau are relatively undeformed, except in the east (Dennison, 1976). The highest point of the plateau is along the eastern border of West Virginia and Kentucky, where the plateau edge exceeds 1,200 m (Figure 14). Although the altitude of the plateau varies, it is generally higher than the Valley and Ridge Province and the Low Plateaus Province to the west and is bounded on most sides by outfacing escarpments. One exception is the northwest part of the plateau, from a point east of Columbus to near Cleveland, Ohio. This could have been caused by glaciation, which reached the northern Allegheny Plateau (Oard, 2004), as evidenced by glacial debris, and the loss of the escarpment in the northwestern plateau.

The Appalachian Plateau Province is considerably dissected by channelized erosion, the type that forms canyons and valleys (Figure 15). It is so dissected along its eastern margin that the topography is designated as mountainous—the Allegheny Mountains or Allegheny Front. Relief in the Allegheny Mountains reaches about 300 m, but it is 600 m in the Cumberland Mountains along the eastern Cumberland Plateau called the Cumberland Front (Figures 16 and 17). The New River deeply incises the Appalachian Plateau (Figure 18). Although localized erosion cuts the Appalachian Plateau Province, the plateau once was a large erosion surface (Figure 19). The Allegheny Plateau, the northern Appalachian Plateau, is rolling and has also been more severely eroded (Figures 20 to 22) than the Cumberland Plateau, which is quite flat and less dissected (Figures 23 and 24).

In the western part of the Appalachian Plateau Province, there is a bench about 100 m above the major river valleys (Figure 25) cut into hard rock. It is considered a strath terrace and named the Parker Strath in many places. A strath terrace

**Figure 15. View southwest of an erosional remnant of the Allegheny Plateau showing considerable dissection around it (view southwest from Welcome Center Rest Stop, I-15, north central Pennsylvania).**

**Figure 16 *(left)*. Cumberland Front at the edge of the Cumberland Mountains, looking west from I-40 in Tennessee.**

**Figure 17 *(below)*. Google map image of Cumberland Front (solid line). The Cumberland Front is the boundary between the subdued relief of the Cumberland Plateau to the northwest and the Valley and Ridge Province to the southeast. The Blue Ridge Province can be seen in the lower, right corner.**

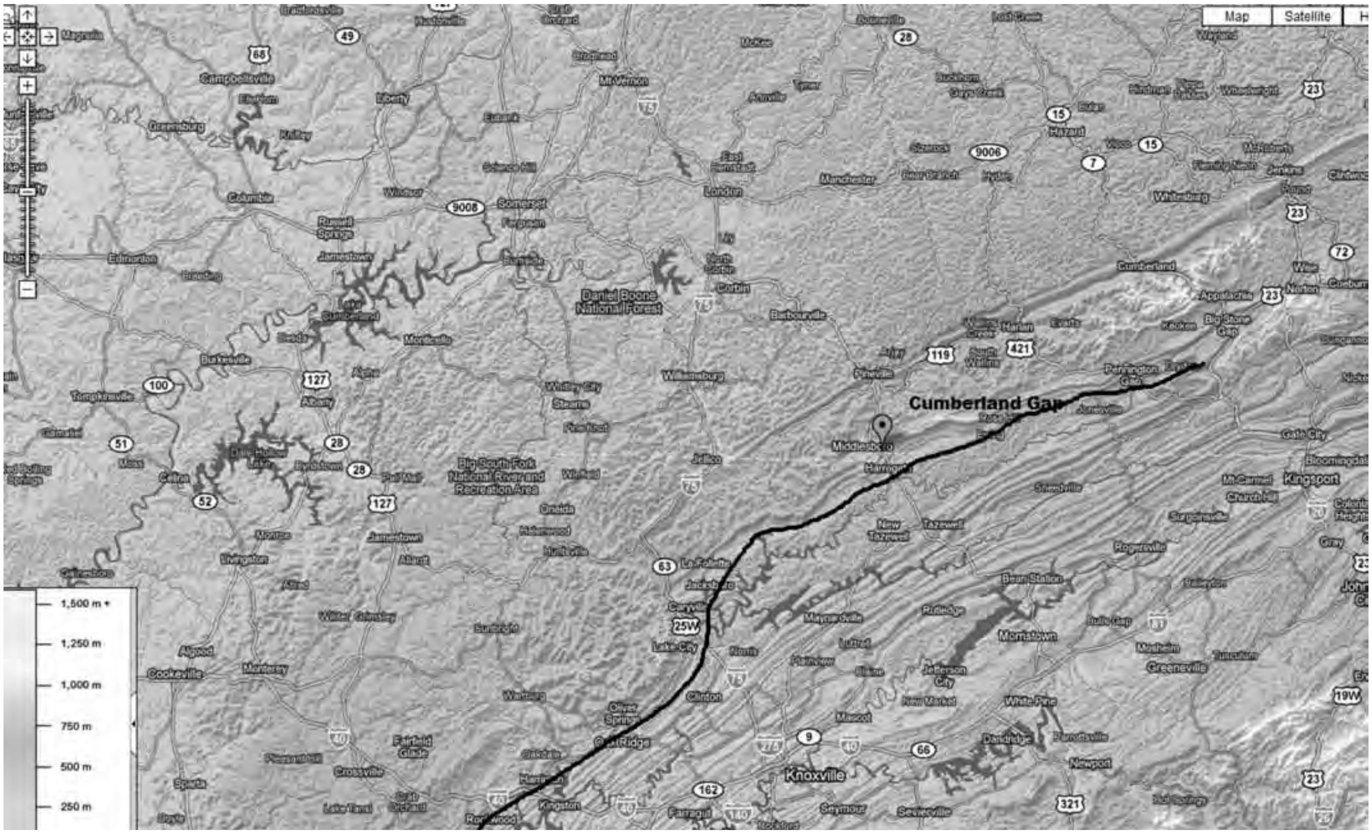

**Figure 18. New River Gorge near the New River Bridge, West Virginia.**

**Figure 19. Dissected erosion surface, north central Pennsylvania. Vertical exaggeration = 1.5.**

**Figure 20. Top of rolling, dissected erosion surface of the Allegheny Plateau north central Pennsylvania.**

**Figure 21. Top of fairly flat erosion surface of the Allegheny Plateau east central Pennsylvania.**

**Figure 22. Top of rolling erosion surface of the Allegheny Plateau, southeast West Virginia.**

is a narrow erosion surface formed during dissection of the valleys and gorges.

To the west of the Appalachian Plateau Province lies the Interior Low Plateaus Province (Fenneman, 1938, pp. 411–448; Thornbury, 1965, pp. 185–211). The Interior Low Plateaus Province represents a lower erosion surface, called the Lexington Plain (Figure 26). Fairly flat and rolling, it is more a plain than a plateau (Figures 27 to 29). Its eastern boundary is the escarpment up to the Appalachian Plateau in eastern Kentucky and Tennessee (Figure 30). It extends north to the edge of Ice Age glaciation and west into western Kentucky and Tennessee (Figure 1). Gravels from the Appalachian Mountains cover parts of this surface, especially in western Kentucky (see below). The Lexington Plain is less severely dissected than the Appalachian Plateau Province.

## Erosional Remnants

Erosional remnants are common on Appalachian erosion surfaces. They are typically hills or even mountains that survived

**Figure 23. View northwest of the top of the nearly flat erosion surface of the Cumberland Plateau, Sequatchie Valley, southeast Tennessee.**

**Figure 24. Nearly flat erosion surface of the Cumberland Plateau, southeast Tennessee.**

**Figure 25. Rolling strath terrace (left arrow) west of the nearly flat erosion surface of the Cumberland Plateau (right arrow).**

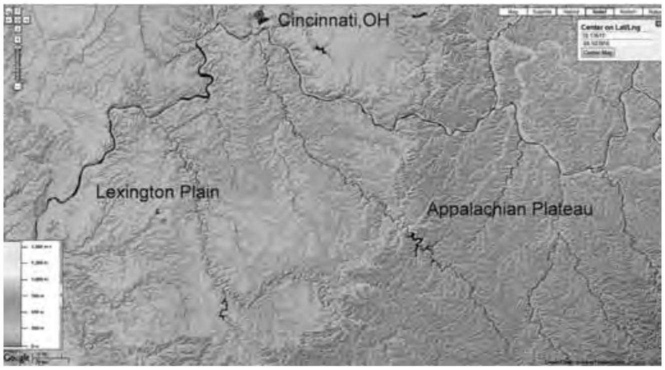

**Figure 26. Shaded relief map of Cincinnati, Ohio, region and south, showing the Lexington Plain and the higher Appalachian Plateau with a sharp boundary (escarpment) between them. From shaded-relief.com.**

**Figure 27. Erosion surface of the Interior Low Plateaus Province northeast of Cincinnati, Ohio.**

**Figure 28. Erosion surface of the Interior Low Plateaus Province, south central Kentucky.**

erosion, although reduced in elevation (Small, 1978). Any proposed erosional mechanism must account for these remnants. Most are inselbergs, defined as "a prominent isolated residual knob, hill, or small *mountain of circumdenudation*, usually smoothed and rounded, rising abruptly from and surrounded by an extensive lowland erosion surface" (Neuendorf et al., 2005, p. 328, emphasis his). *Inselberg* is a German word meaning a hill or an island jutting up from a flat sea, or more simply an "island mountain" (Faniran, 1974, p. 151). They are associated with hot, dry environments but occur in many different climates.

**Figure 29. Erosion surface of the Interior Low Plateaus Province, western Kentucky.**

**Figure 30. The western escarpment of the Cumberland Plateau looking northwest. The flat surface in the background is the continuation of the Cumberland Plateau that wraps around the valley below.**

**Figure 31. Monadnocks on the Inner Piedmont as seen from High Piney Spur, Blue Ridge Parkway, looking east.**

A synonym often used in the eastern United States is "monadnock"; the same as the African "bornhardt." Stone Mountain, Georgia, is a famous monadnock on the Piedmont (Figure 9), but only one of hundreds (Figure 31, and see Figure 8). The distribution of monadnocks on the Piedmont approaching the Blue Ridge Mountains indicates a northwest erosional retreat of the Blue Ridge Escarpment (Hack, 1989).

The origin of inselbergs is one of many puzzles in geomorphology (Twidale, 1982) and has generated considerable controversy for many years. Their mere existence, towering over planation and erosion surfaces, is problematic, but that is multiplied by their supposed duration from tens to over 100 million years (Oard, 2008). Aspects of structure and lithology seem to control their development, but those correlations appear weak (Twidale and Bourne, 1998; Römer, 2005), following King's (1966) observation of a lack of any structural control on many inselbergs. Some researchers have noticed a correlation between fracture patterns in inselbergs and the surrounding land. Inselbergs seem to be less fractured or jointed (Twidale, 1981; Twidale and Bourne, 1998), but the question is far from settled (Römer, 2005). Thomas (1978, p. 3, emphasis his) stated:

> Enquiry into the origins and development of the prominent and generally isolated hills described as *inselbergs* continues to arouse controversy after many decades of research.

## Long-Distance Transport of Resistant Rocks

Resistant rocks eroded from the Appalachians have been transported long distances out onto the surrounding lowlands. Remnants of what was probably once a widespread gravel deposit are often found at the highest elevations and have been given different names at different locations.

That west of the Appalachian Mountains is generally called the Lafayette Gravel. It is found in scattered upland locations over a wide area east of the Mississippi River valley, from the Ohio River in the north into the southern states (Autin et al., 1991; Ehlers, 1996; Thornbury, 1965). Its original extent is unclear since so much of it has been eroded (Bresnahan and Van Arsdale, 2004). The larger clasts are typically iron-stained and composed mostly of brown chert (Figures 32 and 33), a hard silicate. Figure 34 is a close-up view of the Lafayette Gravel in Figure 33. Quartzite, sandstone, and vein quartz are minor constituents of this gravel. Vein quartz forms by hydrothermal deposition in cracks and is generally white. The gravels are rounded to subrounded and up to 10 cm in diameter. A significant amount of finer-grained sediment is mixed in with the gravel.

It appears that a regional gravel sheet once covered the Appalachian plateaus and extended across much of the area west of the Appalachians—in some places even beyond the Mississippi River (Autin et al., 1991; Ehlers, 1996; Potter, 1955b; Thornbury, 1965). The Lafayette Gravel shows paleocurrent directions toward the northwest. Potter (1955a, 1955b) noted that the sand and some of the larger clasts originated from the Blue Ridge Mountains, while others are local. It is interesting

Figure 32. The Lafayette Gravel in the Milby pit, western Kentucky. Except for a surficial layer, the in situ gravel extends from top to bottom of the pit with the lower gravel obscured with talus.

Figure 34. Close up of the Lafayette Gravel shown in Figure 33.

Figure 33. The Lafayette Gravel along a road in western Kentucky.

Figure 35. Black chert within the limestone of western Kentucky, which is a different color than the overwhelmingly tan cherts of the Lafayette Gravel.

that the chert within the limestones of western Kentucky is black (Figure 35) while the Lafayette Gravel is tan, supporting the allochthonous origin of the Lafayette Gravel. The distance from the Mississippi River in western Kentucky eastward to the Blue Ridge Mountains is about 800 km. Thus, it is likely that a widespread sheet of gravel and sand was deposited over a low slope, probably during planing. After its deposition, the area was dissected by channelized erosion, eroding and redepositing some of the gravel.

Resistant gravels were also deposited east of the Appalachian Mountains, and surviving remnants cap the highest terrain. A sheetlike gravel around 7 to 9 m thick covers approximately 1,530 km$^2$ of the coastal plain of southern Maryland (Schlee, 1957). There are also some isolated upland gravels on the Virginia coastal plain. Upland surfaces near the coast in northeastern Maryland, Delaware, southeastern Pennsylvania, and New Jersey are also covered by the Brandywine and Bryn Mawr Gravels (Owens, 1999; Owens and Minard, 1979; Pazzaglia, 1993; Stose, 1928).

Sand with quartzite pebbles has also been found as far south of the Appalachian Mountains as Florida (Froede, 2006, 2009), extending down to the northern Keys, where they are found in drill holes in the subsurface. Such quartzites are widespread and contain clasts that are over 7.5 cm in their long axis. The evidence shows these Florida quartzites were derived from the Appalachians, more than 1,000 km away.

## Uniformitarian Hypotheses on Formation of Erosion Surfaces

In the 1800s, many geologists believed that erosion and planation surfaces were caused by marine planation during sea level rises. Then in about 1900, William Morris Davis developed the "cycle of erosion" or the "geographical cycle" for the formation of erosion surfaces called peneplains. Davis and his cycle of erosion exerted considerable influence upon geomorphology that still continues, though diminished, today.

### The Rise and Fall of Davis's "Cycle of Erosion"

Davis was born into a liberal Quaker home, but the Quakers influenced him little, since his father was expelled from the church. Davis's religious views ended up as mainly moral sentiments, which eventually led him into unitarianism and an unshakeable faith in the hypothesis of evolution. His real interest was geology. He joined the geology department at Harvard University despite having *no* field experience (Chorley et al., 1973). After an inauspicious start, he was given a strong hint by the president of Harvard University that he should look for employment elsewhere. He might have disappeared into obscurity, except for one lucky break.

In 1883, he conducted a geological survey of the route for the Northern Pacific Railway in Montana. Davis described his summer on the High Plains as a lifesaver, for it was there that he conceived the idea for his cycle of erosion (Chorley et al., 1973, p. 135; Crickmay, 1974, p. 171). Chorley et al. (1973, p. 160) described his revelation:

> Although Davis constantly acknowledged his debt to such predecessors as Powell, Jukes, Dutton and Gilbert, in later life he came to refer to his first notion of the cycle of erosion, while working on the Northern Pacific Railroad Survey in Montana in 1883, as rather like the blinding flash of understanding experienced by a prophet in the wilderness.

Davis recognized the enormous denudation of the plains of Montana, as indicated by igneous mesas and dikes in bold relief (Chorley et al., 1973, p. 136). Davis imagined that the many erosion and planation surfaces there were caused by ancient rivers and streams sweeping back and forth, smoothing the land over millions of years. He took special note of the comparative smoothness of the plain between Fort Benton and Great Falls, Montana (Chorley et al., 1973, pp. 162–163). This plain is the eastern Fairfield Bench (Figures 36 and 37). Back at Harvard the next fall, Davis developed his theory and applied it to erosion surfaces of the Appalachians. From then on, he published extensively on this subject into the early 1900s.

Davis' idea was strongly influenced by the theory of evolution (Flemal, 1971). Summerfield (1991, p. 457) summarized its influence on Davis' views:

> The model of landscape evolution usually known as the cycle of erosion was developed by W. M. Davis between 1884 and 1899 and owed much to the evolutionary thinking that had permeated both the natural and social sciences in Britain and North America during the latter half of the nineteenth century.

Davis believed that, just like life, landscapes evolved through progressive stages, each exhibiting characteristic landforms. Davis applied the popular analogy of age to landscapes. They initially started in their *youth*, with the tectonic uplift of a level surface; progressed to *maturity*, with strong dissection by rivers and streams; and finally reached *old age*, where the land is finally subdued to a low relief *peneplain* near sea level (Johnson, 1954) and ready for another cycle.

**Figure 36. Google Earth image showing the eastern Fairfield Bench. Note that the bench is mildly dissected with the deepest dissection caused by the Missouri River on right. Vertical exaggeration = 2; north toward top right hand corner.**

**Figure 37. The rolling eastern Fairfield bench, northeast of Great Falls, Montana. It was this erosion surface that inspired William Morris Davis to deduce his "cycle of erosion" or "geographic cycle."**

But this idea is fraught with difficulties. During the early 1900s, despite its popularity, geologists slowly became skeptical. By the 1950s, the hypothesis was widely rejected. Summerfield (1991, p. 460) considered the hypothesis vague, qualitative, and based on a number of unreasonable assumptions. Other than observations of erosion surfaces over large parts of the earth, it was simply a collection of intuitive deductions and not based on fieldwork:

> While stressing the Victorian character of much of Davis' work it is only fair to note that he departed from the characteristic standards of much nineteenth-century work in the natural sciences in three important particulars: his lack of detailed field measurements, his unconcern with details of processes prompting change and the entirely qualitative nature of his methods (Chorley et al., 1973, p. 194).

Davis's deductions were not necessarily wrong; it was his failure to test them in the field that was problematic. Davis could not demonstrate the transitions between stages by detailed observations and experimentation. When challenged on that point, he simply pointed out the many flat surfaces of Earth's landscape as evidence for his hypothesis (Johnson, 1954; Chorley et al., 1973, pp. 242, 243)—a logical fallacy called *begging the question*, a type of circular reasoning.

Peneplains are rolling erosion surfaces. To form a flat planation surface would take more time than was available, even on the geologic timescale. Some geologists pointed this out (Crickmay, 1933; 1974, p. 173; Hart, 1986, p. 21). Ollier (1991, p. 200) claimed that just one-half of Davis's cycle took the last half of the Phanerozoic, or 250 million years, in the highlands of southeast Australia! However, many of Davis's peneplains, including the ones in Montana, are actually quite flat (Crickmay, 1974, p. 174). They should more properly be called planation surfaces and not peneplains; and according to Davis's hypothesis, they should not have formed at all.

Another major problem is that streams and rivers dissect a surface; they do not plane it. They destroy already-existing planation and erosion surfaces. So, Davis's theory is defeated by uniformitarianism itself. Planation and erosion surfaces that are common worldwide formed in the past by some large-scale unique event (Oard, 2008).

Davis also failed to provide any examples of the ending stage: a peneplain at sea level (Flemal, 1971; Chorley et al., 1973, Phillips, 2002). Davis once suggested the low altitude plains of the Ob and Irtysh Rivers of western Siberia as a modern example of a peneplain, but these plains are not erosion surfaces but surfaces of deposition (Crickmay, 1972, p. 174). Thus, the final stage of the cycle of erosion is *not* observed in the landscape today.

> The scheme of the cycle is not meant to include any actual examples at all, because it is by intention a scheme of the imagination and not a matter of observation (Johnson, 1954, p. 281).

Many more problems with the cycle of erosion can be pointed out.

## The Weathering Hypothesis

A number of other hypotheses have been proposed in place of the cycle of erosion, but none seem to have fared well. These hypotheses include Walther Penck's erosion during slow tectonics, Lester King's parallel retreat of slopes, John Hack's dynamic equilibrium, C. H. Crickmay's lateral planation and unequal erosion, and the weathering hypothesis developed in the early to mid-1900s. The weathering hypothesis is the most popular idea today and seems to have survived among geomorphologists because it fills a theoretical void (Thomas, 1994).

The weathering hypothesis was first proposed by Falconer in 1911 (Small, 1978, p. 295). It was especially emphasized and developed by Wayland in the early 1930s and by Bailey Willis (1936) in his study of East African plateaus and rift valleys. It was advanced by Büdel during the third quarter of the twentieth century, primarily to account for tropical erosion and planation surfaces (Ahnert, 1998, p. 222).

In the hypothesis, erosion or planation surfaces form by two processes. First, a landscape is chemically weathered downward with time. The boundary between the weathered debris and unweathered rock is called the *weathering front*. Most weathering is accomplished by ubiquitous shallow groundwater (Baker and Twidale, 1991, p. 81). Second, the weathered debris is removed by sheet wash, stream erosion, or other mechanisms. Both stages can occur simultaneously. The mechanism is especially affective in the humid tropics, where weathering is sometimes observed deeper than 100 m. The resulting landform is called an etchplain if planar, and an etchsurface if not.

However, there are many problems with the weathering hypothesis. Most telling, weathering does not form a planation surface and would form an erosion surface only with great difficulty. Factors driving weathering rate vary spatially (Birkland, 1984; Hall, 1988), as does erosion. Lithology and drainage patterns are especially relevant to the weathering rate (Summerfield, 1991). Therefore, the weathering front should be *rough and not planar*. Twidale (2004, p. 160) stated: "Weaknesses in the country rock are exploited by moisture and the weathering front is frequently irregular in detail: a topography is developed." How could an exceptionally flat surface over a large area form by such irregular weathering?

Contrary to the hypothesis, weathering is more likely to *destroy* a planation surface than to create one. Hall (1988, p. 12, emphasis his) admitted:

> It is far from simple to determine what weathering process acted to cause the formation of any given landform. The type of weathering *currently* active may be in the process of destroying, rather than forming, that landform.

Although Hall was thinking about landforms in general, planation surfaces would fall under his generalization.

Even if the weathering occurred on a planar surface, there is the problem of stripping the debris away just as evenly (Bishop, 1966). Many planation surfaces are bare rock, especially in Africa. King (1975, p. 309) questioned how deep weathering products could be removed from a flat surface, leaving no weathered material behind. Taylor and Howard (1998) claim that tectonics causes the removal of the weathering products that collect during a stillstand. But, how would uplift of a planation surface erode the weathered material to bare rock? Even uplift would not stop the dissection of a surface.

Fourth, it has also been observed that planation surfaces sometimes cut across *both* weathered and unweathered surfaces, indicating that planation is independent of weathering (Bishop, 1966, p. 149). Pugh (1966, p. 125) stated: "The perfection of plains cut without distinction across weathered and unweathered material implies considerable efficiency of erosional processes." It also indicates that the denuding mechanism was independent of weathering—the heart of the hypothesis.

Fifth, how would the weathering hypothesis account for all the rounded rocks on top of some planation and erosion surfaces, especially those obviously transported long distances? The weathering hypothesis cannot account for any of these, whether on the high plains of Montana or the rolling plains and plateaus of Kentucky. Table I presents a summary of these difficulties.

### All Geomorphological Hypotheses Fail

Proponents of the weathering hypothesis can take comfort in one thing: no other secular geomorphological hypothesis explains the observations either. They all have numerous weaknesses, as noted by conventional old-age geologists (Crickmay 1974, p. 192, brackets mine):

> The difficulty that now confronts the student [all who study geomorphology] is that, though there are plenty of hypotheses of geomorphic evolution, there is not one that would not be rejected by any majority vote for all competent minds. This situation is in itself remarkable in a respectable department of science in the latter half of the 20th Century.

| **Table I. Some problems with the weathering hypothesis for the formation of planation surfaces** |
|---|
| Weathering causes a rough surface, not a planation surface. |
| Weathering will destroy an already existing planation surface. |
| Weathered debris must be stripped from the area. |
| Planation surfaces cut across both unweathered and weathered rock. |
| Cannot account for exotic rounded rocks with percussion marks. |

This situation is remarkable indeed! Crickmay went on to state how many inspiring ideas led into error with time.

> A century and a half of literature bearing on scenery and its meaning shows primarily the inspired innovations that carried understanding forward; followed in every case by diversion from sound thinking into inaccuracy and error (Crickmay, 1974, p. 201).

Thomas and Summerfield (1987, pp. 936–937, emphasis added) expressed the same sentiment over the failure to explain planation surfaces:

> Understanding the long-term denudation of landscapes remains speculative, despite attempts to find bridges between theories and the evidence which supports them. The existence of planation surfaces is asserted by a host of writers, yet few attempt any serious explanation of their development ... It is perplexing that after a century of argument and observation of the continents, *no generally accepted mechanism for planation has been forthcoming.*

Small (1978, p. 13) corroborated, despairing of geomorphology's insoluble puzzles:

> Any serious student of geomorphology will quickly realize what is actually known with certainty about landforms and their origin is surprisingly small, despite the vast amount of research, testified to by innumerable books, articles and reports, which has been done during the last fifty or so years.

Davis confidently predicted that uniformitarianism would lead to robust explanations of landforms during the twentieth century, but it seems he was as wrong about that as he was about the cycle of erosion. Why have scientists failed to explain such common, obvious features? Once confident in their explanations, geomorphologists now wander in the wilderness (Baker, and Twidale, 1991, p. 81). Could it be that their basic starting premise of uniformitarianism, or actualism, is wrong and needs to be discarded?

Modern hypotheses of landform formation incorporate rapid uplift, plate tectonics, and radiometric dating into landform evolution (Summerfield, 1991, 2000). But they still do not propose specific mechanisms to form flat, eroded land. Geomorphologists have generally quit trying to deduce the origin of landforms and have retreated into *process geomorphology*, which studies the small time and space variables operating on the earth's surface today. They hope that these detailed studies will somehow generate a general theory that will one day be able to explain the origin of landforms.

Ahnert (1998, p. 229) noted that new approaches with new methods are required to understand erosion surfaces (his peneplains): "There are still many aspects of peneplains to be explained. Perhaps some entirely new approaches with new methods are needed."

I agree that a *new* approach is needed—a catastrophic approach.

## Erosion Surfaces Carved During Flood Runoff

Davis believed that a key transformation in thinking was required to understand landforms. The doctrine of the Genesis Flood, which lingered into the late 1800s in a greatly weakened state (Mortenson, 2004), had to first be overthrown.

> The emancipation of geology from the doctrine of catastrophism was a necessary step before progress could be made towards an understanding of the lands (Johnson, 1954, p. 77).

Instead, history shows that Davis's antipathy to the Flood led geomorphology into a dead end. That is because the key to geomorphology is the Genesis Flood (Oard, 2008), precisely contrary to conventional thinking over the past century.

It is looking like planation and erosion surfaces can be explained by—and only by—the retreat of Floodwaters off emerging continents. Since many planation surfaces are quite large, covering areas > 2,500 km$^2$, planation requires a large-scale process, best explained by the sheet-flow phase of Walker's (1994) model (Figure 38). Some additional planation undoubtedly occurred during the channelized-flow phase but at smaller scales.

Early in the retreating stage, water currents would have been changing from continental-scale flow to the megaregional scale, flowing off and away from emerging mountains, such as the Appalachians. Figure 39 presents a schematic of these processes during the planing of the Piedmont and Appalachian Plateaus Provinces. These currents would have been generally characterized by high velocities. Entrained rocks and debris would have planed the land surface, like sandpaper smoothing rough wood. Faster currents would have eroded wide areas to flat surfaces, shaving both hard and soft rocks evenly with extremely high current energy (Figure 39b,c). Where sheet currents were relatively slow, a more rolling erosional surface would have been created.

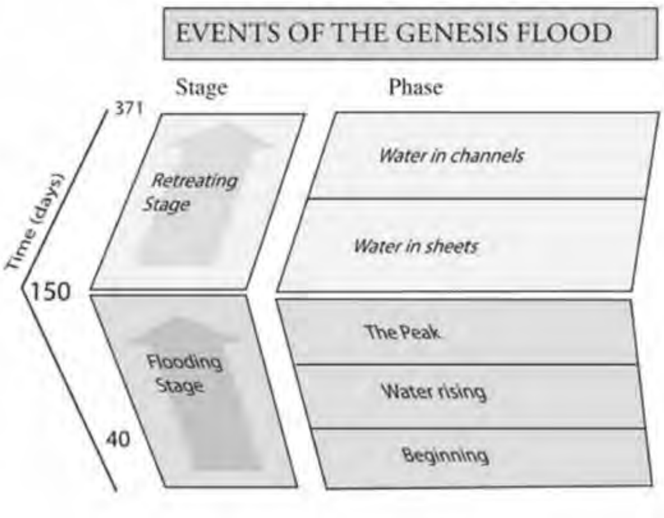

**Figure 38. Walker's classification of the Flood into the 150-day flooding stage and the 221-day retreating stage with five phases.**

Cobbles and boulders would have been transported in the fast turbulent flow (Figure 39c). Clasts would repeatedly crash into others, forming percussion marks. Based on the rock sizes found on top of the Cypress Hills planation surface, Klevberg and Oard (1998) estimated current velocities in excess of 30 m/sec.

Sheet-flow erosion from modern to strong currents is evident in the Piedmont and the dissected plateaus west of the Appalachian Plateau Province. But in the Valley and Ridge Province, it is likely that the currents were too weak to form an erosion or planation surface, probably because the area represented the "divide" between west-flowing and east-flowing water. The geomorphology of the Valley and Ridge Province attests to slower currents that left ridges upstanding. Ridge-perpendicular currents would have eventually cut water and wind gaps as the sheet flow was transforming into channelized flow (Oard, in press). Because of the weaker currents just west of the Blue Ridge Province, the Flood currents would have more and more been channeled down the valleys to flow parallel to the ridges. It is likely that strong channelized currents formed the Great Valley as the water was rushing toward the Atlantic Ocean in the north and the Mississippi River Valley in the south.

While the Floodwaters were planing the continental surfaces, local variations in the currents, landscape, rock hardness, and structure would result in the rapid formation of tall erosional remnants. These would include the abundant monadnocks seen on the Piedmont, especially as the Blue Ridge Escarpment was eroded toward the northwest. These monadnocks are similar to erosional remnants, like Devils Tower, in northeast Wyoming, seen in the west and explained by retreating Floodwater (Oard, 2008, 2009).

## Summary

Conventional geomorphology cannot explain the landforms of the Appalachian Mountain region. However, late Flood sheet flow, operating at high velocities over large areas, can explain the landforms. During the erosion of up to 6.5 km of rock from the Appalachians, erosion surfaces were cut on both sides of the Blue Ridge Mountains. To the east is the Piedmont, a rolling erosion surface interspersed with erosional remnants

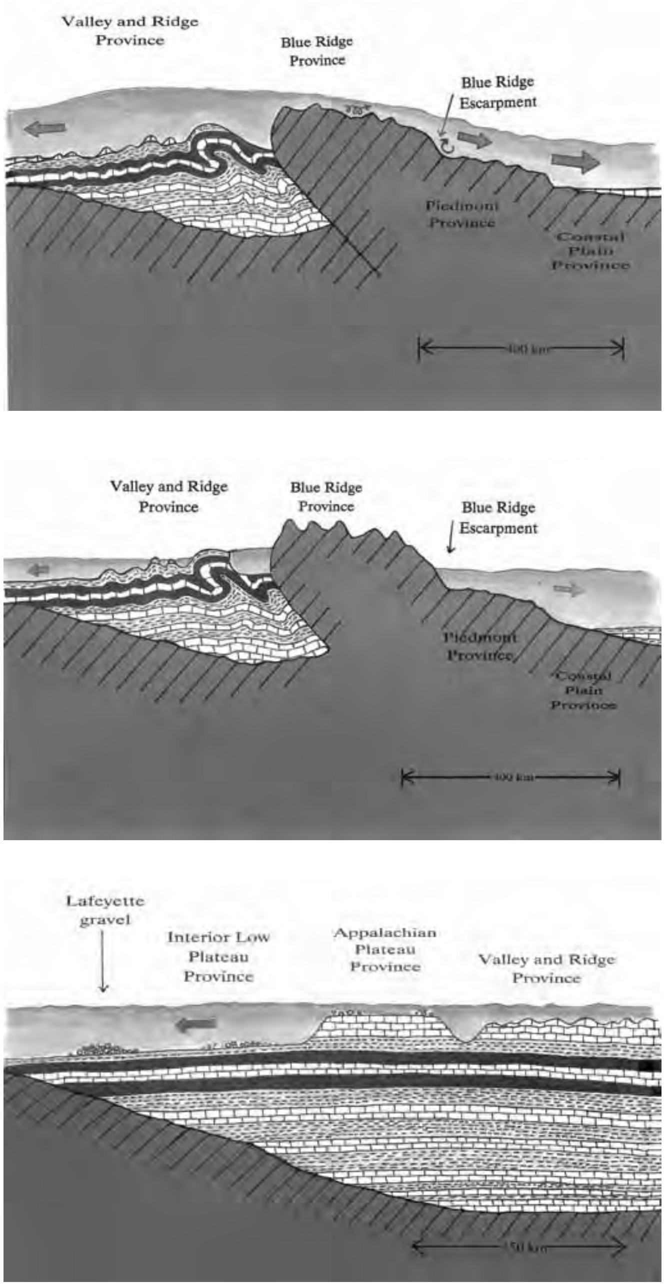

**Figure 39. Summary of erosional features created during the sheet-flow phase (drawn by Melanie Richard).**

**(a) *(top)* Water moving off the rising Appalachians with the "divide" the Valley and Ridge Province.**

**(b) *(middle)* The water erodes the Blue Ridge into a mountainous terrain, but planes the Piedmont Province, leaving behind erosional remnants called monadnocks.**

**(c) *(bottom)* The focus shifts to the western Appalachian Basin, where the Appalachian Plateau and Interior Low Plateau Provinces planed with resistant rocks carried far to the west.**

called monadnocks. Erosion planed the various igneous and metamorphic rocks down to a generally gently rolling surface. To the west, the landforms of the Valley and Ridge were formed as much by lithologic variation as by erosion, probably because current velocity was weaker than on the Piedmont. Further west, the Appalachian Plateaus Province and the Interior Low Plateaus Province are both extensive erosion surfaces caused by currents moving toward the west, away from the mountains. Resistant gravels from the Appalachian Mountains have been transported long distances east, south, and west.

William Morris Davis's "cycle of erosion" was the best uniformitarian explanation for erosion surfaces in the early 1900s. However, it suffered from a number of problems and has mostly been rejected. Several other hypotheses have been invoked, all with major problems. None of these is widely believed by actualistic scientists, and the current popular theory, the weathering hypothesis, has almost as many problems.

Large erosion surfaces would have easily formed during the sheet-flow phase of the retreating stage of the Flood. Like many similar locations worldwide, water flowing away from the rising Appalachian Mountains planed the land, creating erosion surfaces on both sides of the mountains. The speed of the erosional event, the extent of the sheet-flow currents, and the water velocity are all recorded in the presence of large erosion surfaces with erosional remnants and resistant gravels transported over great distances.

In Part III, I will describe the succeeding phase of the Flood—the channelized phase—and its geomorphological effects on the Appalachians. Its narrow currents rapidly eroded valleys, water and wind gaps, and submarine canyons offshore on the continental margin.

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

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