Origin of Appalachian Geomorphology

Part III: Channelized Erosion Late in the Flood

Michael J. Oard*

Abstract

Water and wind gaps are transverse erosional cuts through higher elevations. These features are abundant in the Appalachian Mountains, and several of them are briefly described. What they all have in common is the inability of actualists to offer a viable hypothesis for their formation. The common antecedent and superimposed stream hypotheses do not explain the observations. However, both water and wind gaps can be explained by the channelized flow phase during the runoff of the Floodwater from the Appalachians.

Introduction

Several independent lines of evidence suggest the erosion of up to 6.5 km of rock off of the Appalachian Mountains, depositing thick sediments on the eastern continental margin of the United States (see part I of this article, Oard, 2011b). The nature of the continental shelf-slope system indicates rapid, continuous sedimentation, suggesting a large erosional event, rather than extended, slow processes. During this event, as the Appalachians were eroded, large erosion surfaces were formed on both sides of the mountain range (see part II, Oard, 2011c). Other indications of the rapidity of the event are the erosional remnants (inselbergs or monadnocks) and surficial gravel lag deposits on the plateaus west of the Appalachians, similar to those found in the western United States (Klevberg and Oard, 1998; Oard 2008a, 2008b; Oard and Klevberg, 1998, 2005; Oard et al., 2005, 2006a, 2006b, 2007).

As far back as William Morris Davis in the early twentieth century, geologists have attempted to explain these erosion surfaces by various erosional cycles, but each hypothesis has been refuted by observation or evidence. The currently popular "weathering hypothesis" seems so only by default and has many problems of its own. Essentially, the actualistic scientists do not have a viable hypothesis that explains erosion surfaces—especially planation surfaces. However, the diluvial explanation of Flood runoff during the retreating stage of the Flood provides a straightforward mechanism (Oard, 2008a) that accords well with observations.

Late Flood Appalachian uplift, combined with decreasing Flood levels, caused sheet flow currents of the early retreating stage to flow off the Appalachians to the east and the west, rapidly eroding and planing the land on either side of the Appalachian Mountains. Erosional remnants were left behind on the Piedmont and in the Great Valley. Resistant rocks were carried long distances by large, energetic currents to the east, south, and west. As the Flood level continued to drop, the sheet flow currents were broken into channelized flows of steadily diminishing size and velocity, producing another unique set of landforms superimposed upon those already formed.

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

Linear Erosion Features

Superimposed on widespread sheet erosion features of the Appalachians and the offshore continental margin are linear erosion features. These include: (1) water and wind gaps through the Valley and Ridge and Blue Ridge Provinces, (2) valley erosion in the Valley and Ridge Province, (3) vertical dissection of the plateaus west of the Valley and Ridge Province, and (4) submarine canyons in the continental shelf-slope system. The offshore submarine canyons are beyond the scope of this paper but are discussed elsewhere (see Oard, 2008a).

Definitions

A water gap is "a deep pass in a mountain ridge, through which a stream flows; esp. a narrow gorge or ravine cut through resistant rocks by an antecedent stream or superposed stream" (Neuendorf et al., 2005, p. 715). Although a water gap is defined as cutting through a "mountain ridge," in practice this definition applies to any perpendicular cut through any topographical barrier, including a plateau (Douglas, 2005). In other words, a water gap can be considered a perpendicular cut through a mountain range, ridge, or other structural barrier. An antecedent stream is a stream that maintains its early course or direction despite subsequent uplift of the surrounding region (Neuendorf et al., 2005). Figure 1 shows a block diagram of an antecedent stream forming a water gap. The superimposition theory states that a stream established on a new surface maintains its course during downward erosion despite different rock types and structures encountered (Neuendorf et al., 2005). Figure 2 is a block diagram showing the formation of a water gap by superimposition.

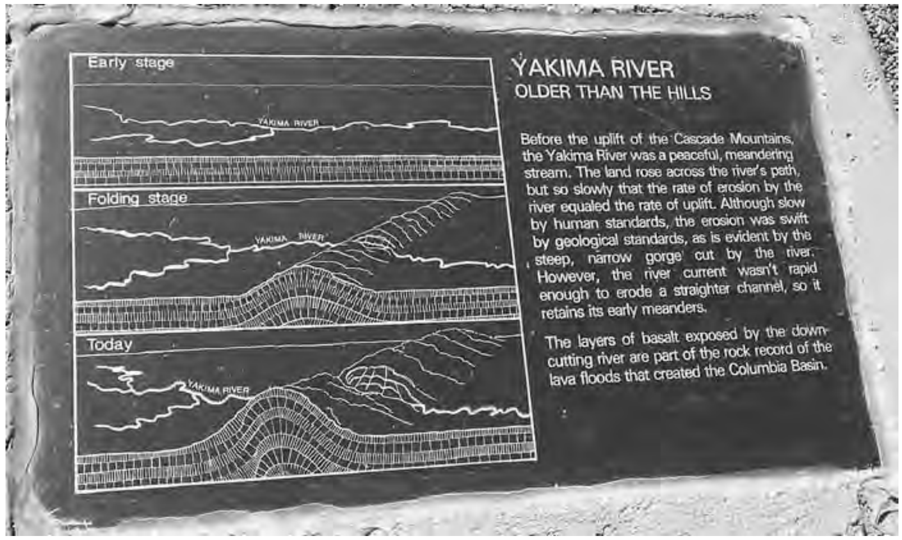


Figure 1. The antecedent stream hypothesis shown on a plaque near a Yakima River water gap, Washington. First, a stream is established; then, as a ridge slowly uplifts, the stream erodes through the barrier.

Figure 2. Block diagram of the superimposed stream hypothesis. The stream maintains its same course as most of the covermass (top layer) is eroded. Drawing by Bryan Miller.

The dictionary definition of a water gap is another case where assumptions override observations: it presupposes that water gaps are created by either antecedence or superimposition. Definitions of geological features should be purely descriptive without undue speculation concerning origin. Ironically, uniformitarian scientists claim five possible mechanisms for the formation of water gaps, and the inclusion of only two in the dictionary suggests further bias in the definition. The other three mechanisms for transverse drainage are: (1) perpendicular faults, (2) relief inversion followed by a reversal in drainage, and (3) stream piracy (Figure 3). The irony of the definition in Neuendorf et al. (2005) is that most geologists have rejected antecedence and superposition for most water gaps across the earth.

The stream piracy model seems to be the current favorite among geomorphologists. However, stream piracy also has trouble explaining water gaps. Bishop (1995, p. 449) stated:

> The key process in stream capture, namely, drainage head retreat, is difficult to envisage as a normal part of drainage net evolution, especially in the light of recent findings on drainage hollow evolution. Stream capture may therefore be a relatively rare event in drainage net evolution. This, and uncertainties with interpretations of supposed elbows

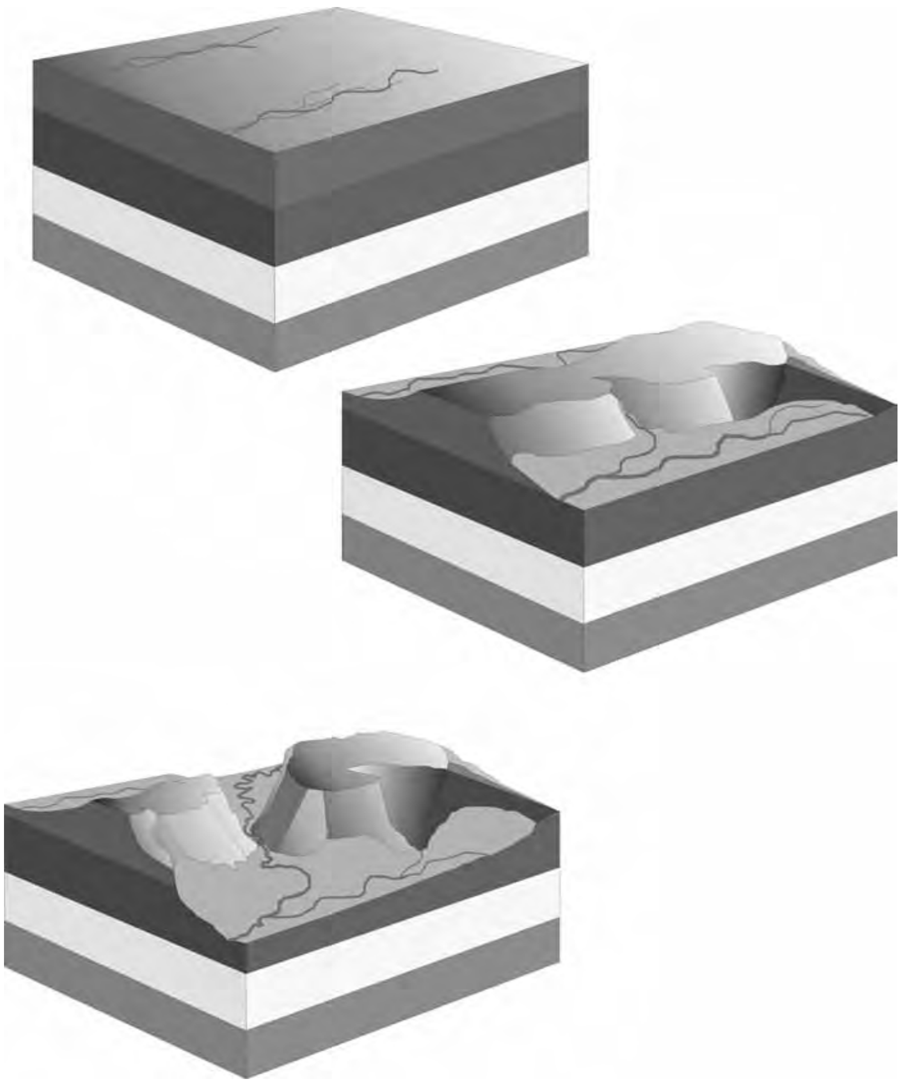


Figure 3. Schematic of stream piracy drawn by Peter Klevberg. As the stream valleys erode, a tributary stream supposedly erodes through the intervening ridge and eventually captures part of the stream on the other side of the divide.

> of capture, mean that stream capture should not be routinely invoked in interpretations of long-term drainage evolution. Further uncertainties associated with the maintenance of drainage lines during the erosion of significant crustal sections, especially in faulted and folded terrains, diminish the likelihood of many supposed examples of stream capture. It is more likely that examples of drainage rearrangement attributed to stream capture were generated by drainage diversion, but even this may involve special conditions.

In a flume experiment, Douglas and Schmeeckle (2007, p. 38) discovered that the mechanism of stream piracy is very difficult and needs extra "help":

> The final piracy experiment successfully produced a transverse drainage through headward erosion, but required the retreat of a strongly asymmetrical scarp ridge and required much more time than the other experiments. This supports Bishop's (1995) argument concerning piracies over utilization.

Stream piracy is not considered too probable for the Appalachian drainage.

A wind gap is "a shallow notch in the crest or upper part of a mountain ridge, usually at a higher level than a water gap" (Neuendorf et al., 2005, p. 723). The notch in a ridge has to be an *erosional* notch, not a notch caused by faulting or some other mechanism. In other words, the entire ridge was once near the same altitude, until a notch was eroded across its top. A wind gap is considered an ancient or incipient water gap, thought to have formed either when the sediments were thicker in the surrounding valleys or before the ridge had uplifted, if the ridge is a fault block. Thus, wind gaps are thought to have been originally cut by rivers before being uplifted above the present drainage or before the river changed its course. So the difference between water and wind gaps is that the former have present drainage, while the latter do not. Only wind passes through the gap at present, which is why it is called a *wind* gap.

Water and Wind Gaps

Water gaps are numerous in the Appalachian Mountains (Ver Steeg, 1930; Thompson, 1939; Strahler, 1945; Ahnert, 1998). Hundreds of them have been cut through resistant ridges, as have many wind gaps (Thornbury, 1965). Alvarez (1999, pp. 267–268) stated: "The Appalachian Valley and Ridge Province is the classic area for the problem of rivers cutting through the narrow ridges of fold-thrust belts." Speculation and controversy over the origin of water gaps have been going on for about 150 years. Although the major rivers flow through water gaps of the Valley and Ridge and Blue Ridge Provinces, many tributary streams also flow through water gaps, especially in the northern Appalachians (see Figures 23 and 24).

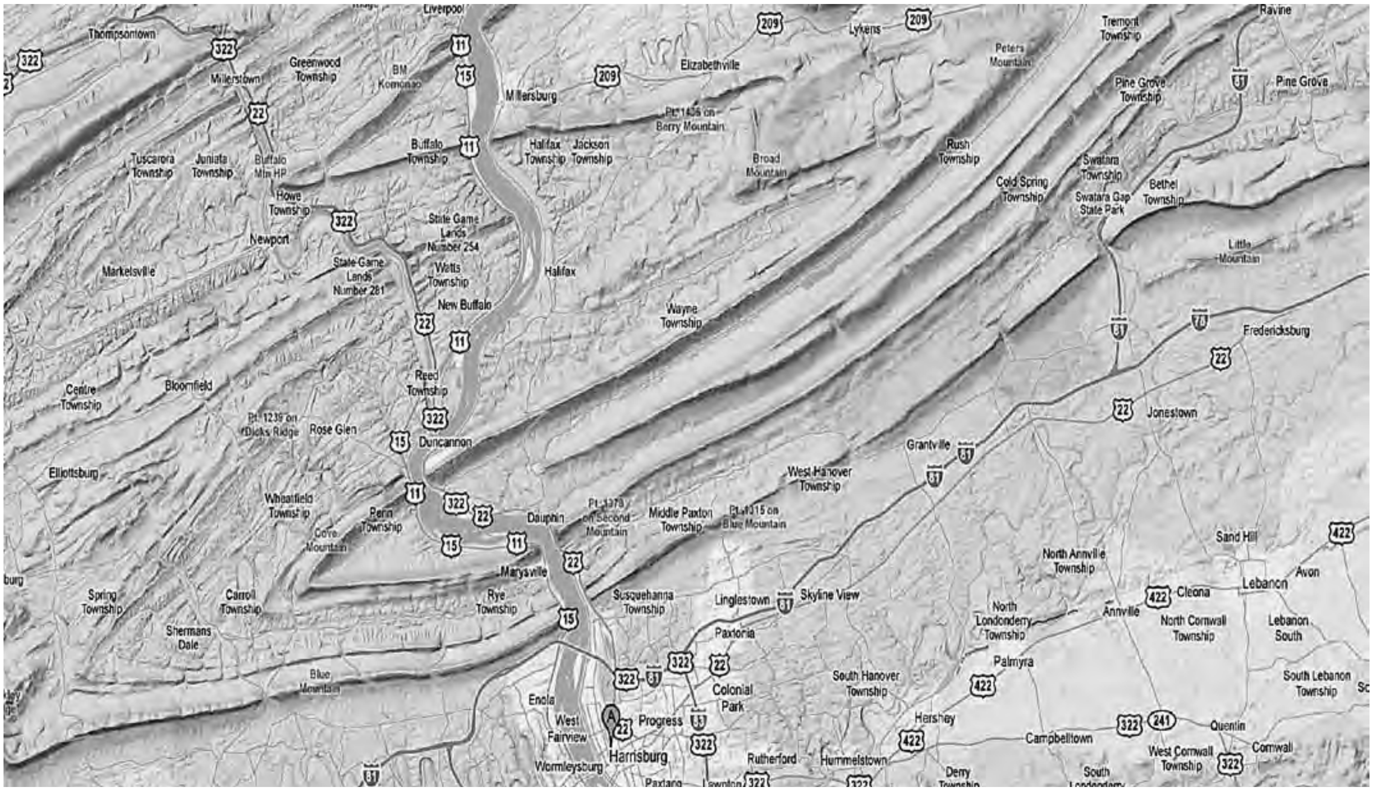


Figure 4. Google Maps Image of Susquehanna River water gaps north of Harrisburg, Pennsylvania. Note that the last two water gaps are aligned and the third to the north is almost aligned (© Google 2010).

The water gaps in the northern Appalachians start in the Valley and Ridge Province. One of the most famous is the series through which the Susquehanna River flows. The river cuts through the folded and eroded ridges of Blue Mountain north of Harrisburg, Pennsylvania (Figure 4). Blue Mountain is a linear mountain that stretches hundreds of kilometers northeast and is also called the Eastern Structural Front (Karle, 2009). Figure 5 shows the last water gap through Blue Mountain before the river flows out into the Great Valley at Harrisburg. Figure 6 shows the fifth water gap north of Harrisburg, seen at the top center of Figure 4. The Susquehanna River course is not influenced by the hardness or softness of the rocks (Short and Blair, 1986). The river, on the 37-km stretch upstream from Harrisburg (Figure 4), could have flowed around four out of five of the resistant ridges, had it followed the expected course at lower elevations over softer rocks (Strahler, 1945).

Figure 5. View north of the last water gaps on the Susquehanna River before entering the Great Valley at Harrisburg, Pennsylvania.

Ver Steeg (1930) listed 34 major water gaps in the northern Appalachian Mountains. Besides the Susquehanna

Figure 6. The fifth water gap north of Harrisburg, Pennsylvania, looking south.

River, the Schuylkill, Lehigh, and Juniata Rivers flow through major water gaps in various mountains or ridges. Another famous gap is the Delaware water gap (Figures 7 and 8) on the Delaware River through the Eastern Structural Front at the border of New Jersey and Pennsylvania (Karle, 2009). Interstate 80 follows this narrow, 365-m deep gap (Ver Steeg, 1930). Early geologists thought that it followed a transverse fault through the ridge (Strahler, 1945), but later research has discounted that hypothesis (Epstein, 1966). Karle (2009) showed that with vertical cliffs and talus slopes devoid of vegetation, the cliffs

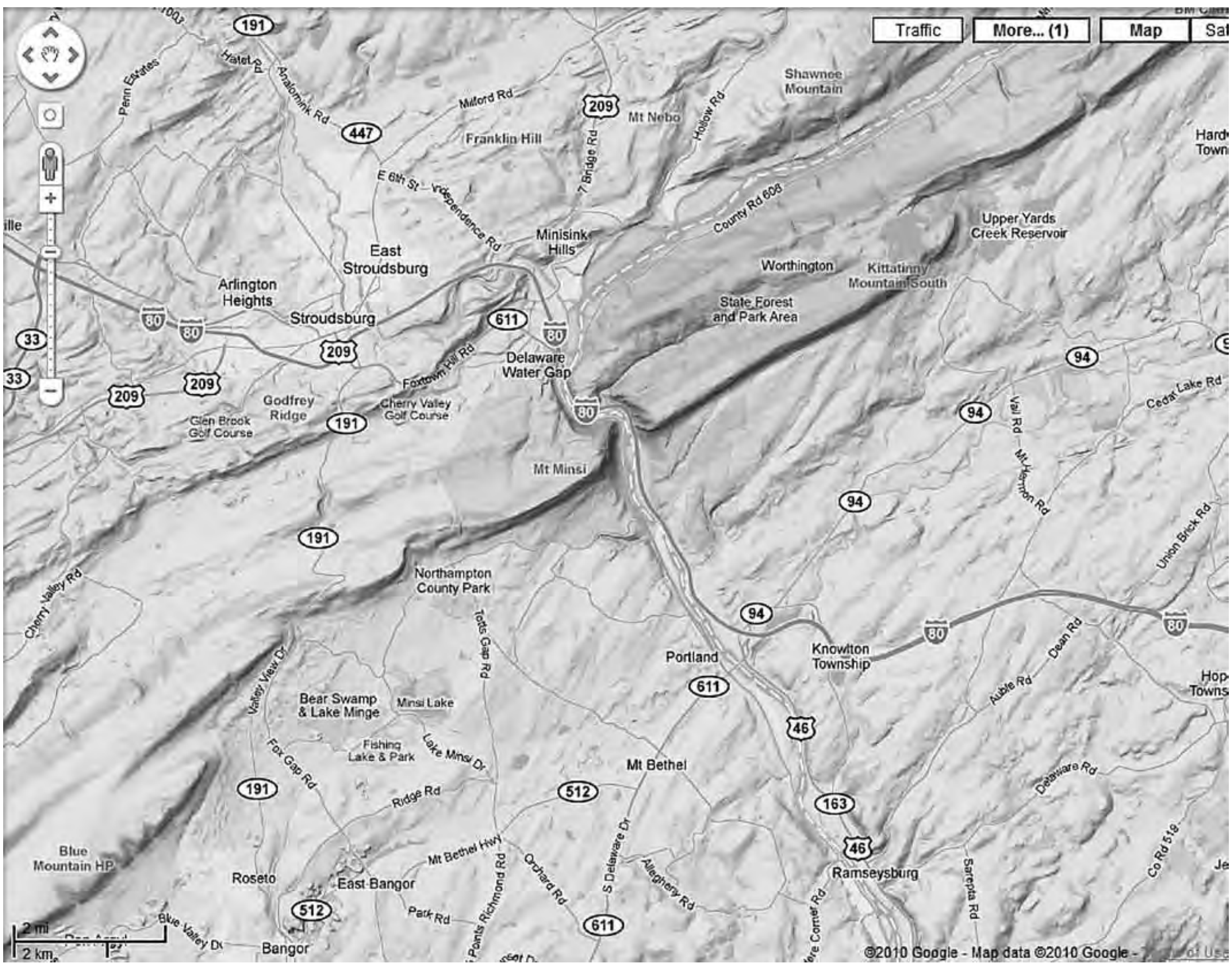


Figure 7. Google Maps terrain view of Delaware Water Gap.

Figure 8. The Delaware water gap through Kittatinny Mountain (Eastern Structural Front) along the border of Pennsylvania and New Jersey, looking west from I-80.

around the Delaware water gap, as well as the Eastern Structural Front must be young features. Most water gaps in the Appalachians are erosional and cannot be attributed to faulting. In fact, many well-known faults have not resulted in water gaps (e.g., Strahler, 1945, pp. 46, 63–65).

In the central Appalachians, water gaps occur on the Potomac, James, Shenandoah, and New Rivers (Thompson, 1939; Fridley, 1939; Short and Blair, 1986). Harpers Ferry on the Potomac River is one of historical significance. The New River starts near the Blue Ridge Escarpment in North Carolina and cuts northwest through at least four ridges of the Valley and Ridge Province via major water gaps (Figure 9) (Bartholomew and Mills, 1991; Ward et al,

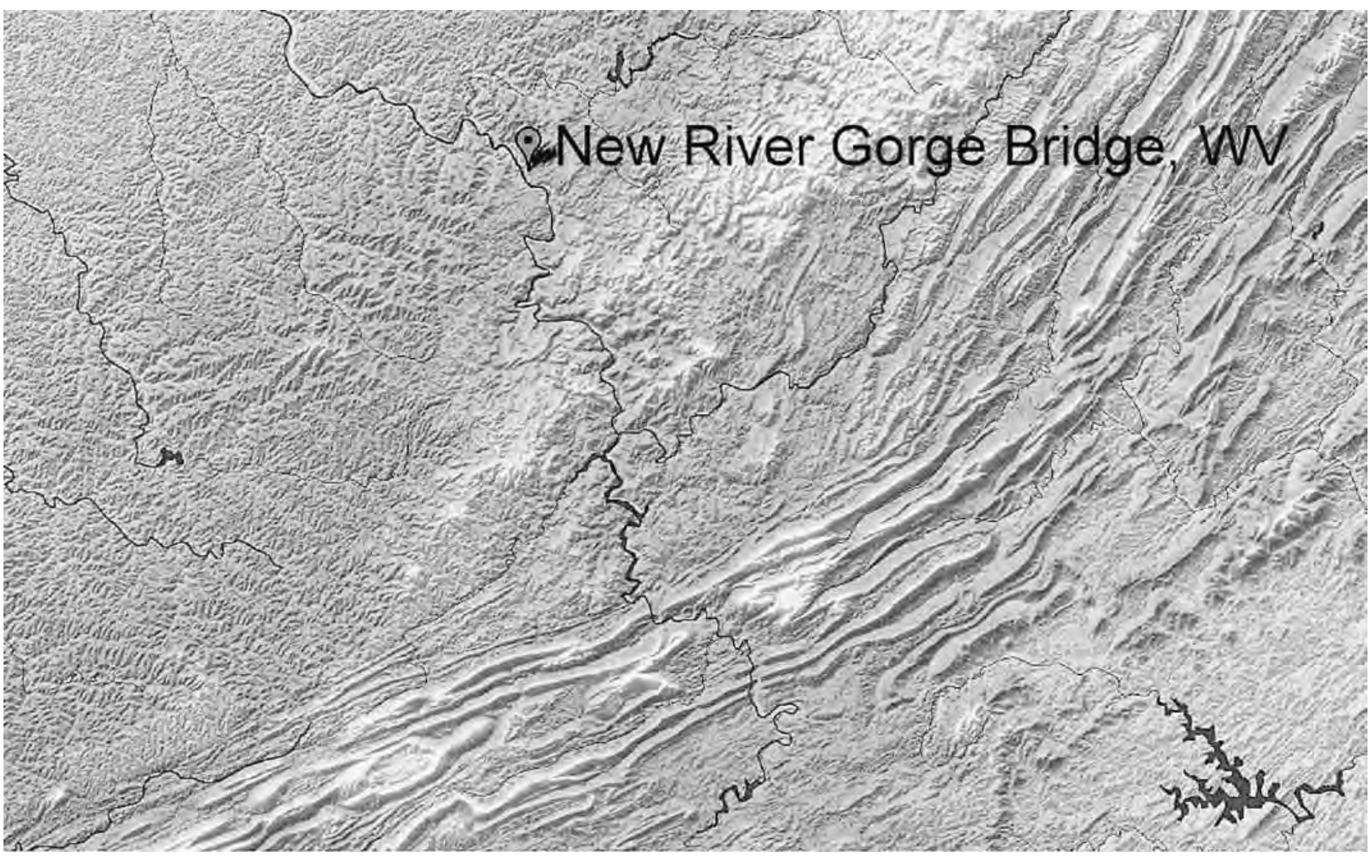


Figure 9. Shaded relief map of New River. Downstream toward top. Note that the river cuts almost straight through the Valley and Ridge Province (© Google 2010).

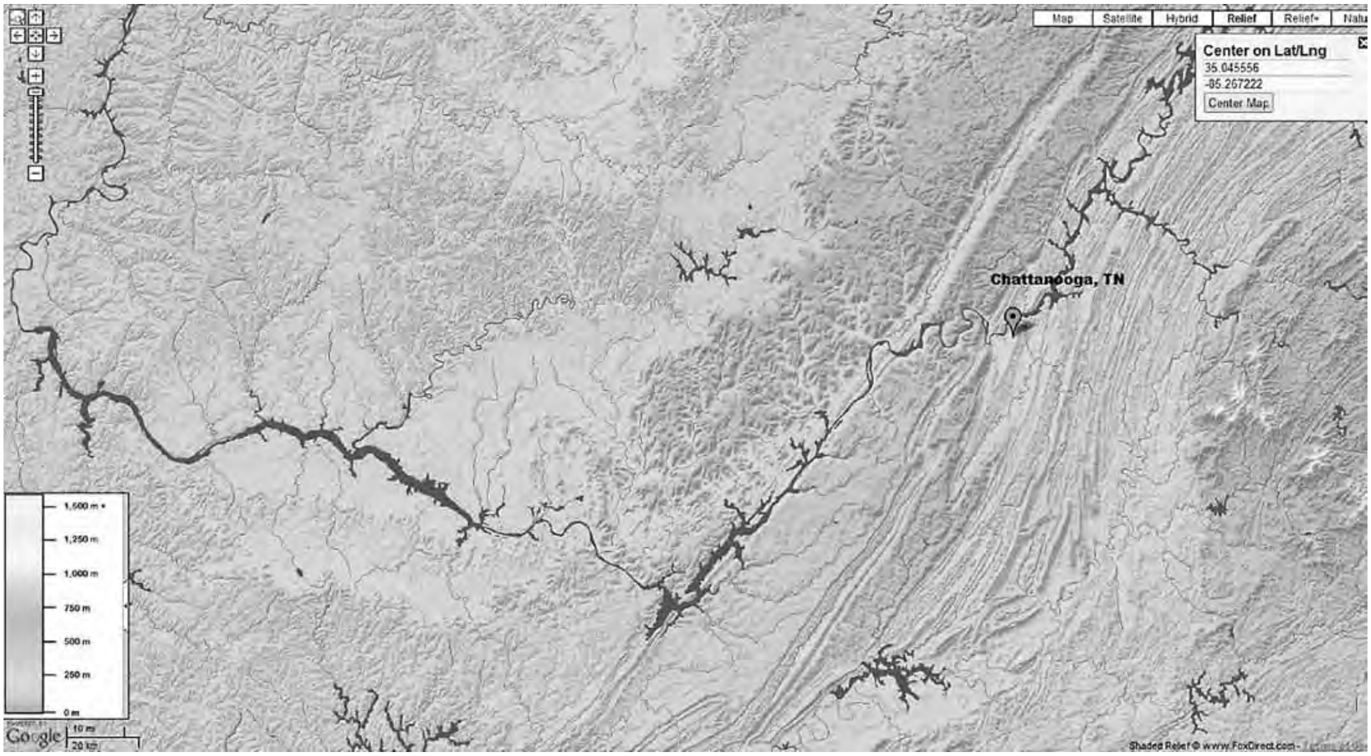


Figure 10. Shaded relief map of Tennessee River crossing Walden Ridge southwest of Chattanooga, continuing down Sequatchie Valley and cutting WNW at Guntersville (© Google 2010).

2005). Figure 18 of Part II of this series (Oard, 2011c) showed the 275-m deep New River Gorge at the New River Bridge, West Virginia.

Other enigmatic water gaps occur in the southern Appalachians. The course of the Tennessee River has always perplexed geologists. The river flows south down a valley of the Valley and Ridge Province for 400 km and instead of transecting a relatively low divide, 76 m higher, to the south, it turns southwest across the southeast Cumberland Plateau southwest of Chattanooga, Tennessee, through a 300-m deep "youthful" water gap (Figure 10) in Walden Ridge (Fenneman, 1938; Milici, 1968; Ollier, 1981; Williams and Akridge, 2005). A close-up view shows that the water gap is even meandering (Figure 11), an observation I have noted for other water gaps. The nearly flat-topped, relatively wide Walden Ridge lies between Chattanooga, Tennessee (Figure 12) and Sequatchie Valley (Figure 13). Figure 14 shows the Tennessee River within Walden Ridge. Had the Tennessee River followed the easiest course, it would have flowed south from Chattanooga, out onto the Piedmont of northern Georgia. Thornbury (1965, pp. 124, 126, brackets mine) stated:

> The abrupt change in direction of the Tennessee River southwest of Chattanooga, Tennessee, from a southwest to a northwest [actually south to a southwest] course, along with its gorge through Walden Ridge, has long puzzled geologists.

If that is not enough of a puzzle, the Tennessee River continues south down Sequatchie Valley for 120 km into northeastern Alabama, then turns west northwestward into northwest Alabama, and finally turns almost due north into higher terrain (Thornbury, 1965). It could easily be presumed that the Tennessee River would have continued south through Alabama to the Gulf of Mexico. Instead, it actually flows into the Ohio River at Paducah, Kentucky.

One of the most interesting aspects of the Appalachian water gaps is that multiple gaps are often aligned, as if the eroding current continued its course regardless of obstructions (Von Engeln, 1942). Even ridges and mountains could not divert the flow. This phenomenon occurs in both the northern (Strahler, 1945) and southern (Thompson, 1939) Appalachians. Figures 15 and 16 show two and three aligned water gaps through ridges in Pennslyvania. Figure 17 shows the two aligned water gaps at Harpers Ferry just after the Shenandoah River, coming from the south, joins the Potomac River, coming from the north.

Ver Steeg (1930) listed many wind gaps through the northern Appalachian

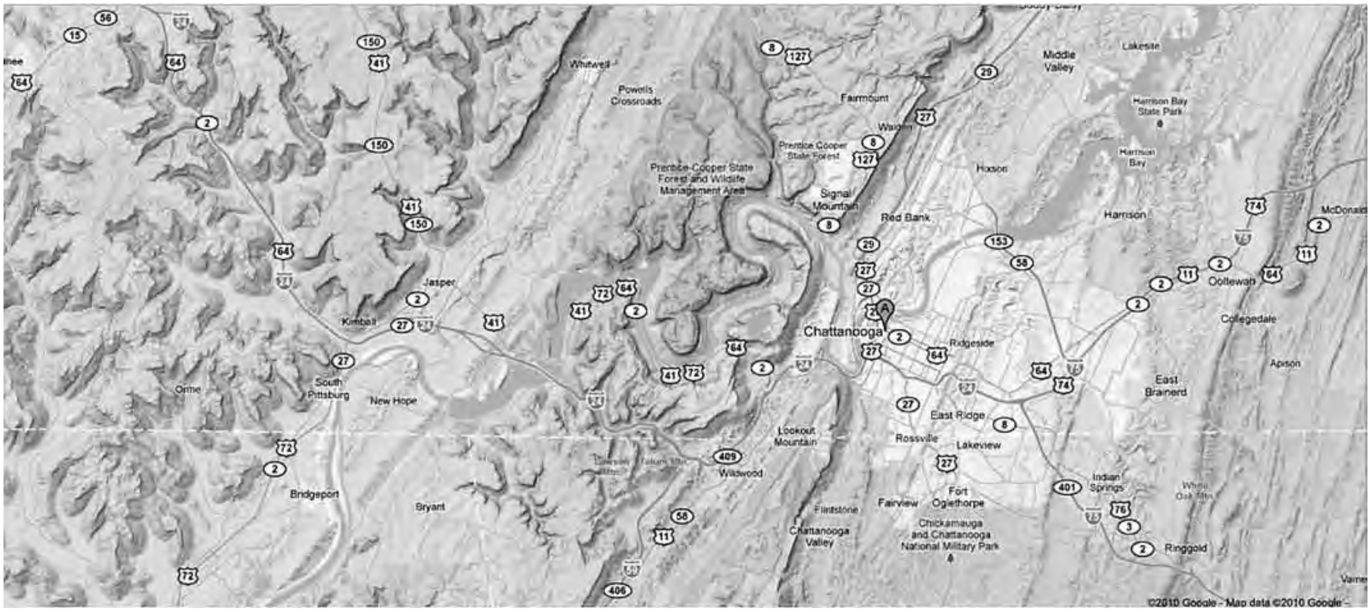


Figure 11. Google Maps close-up view of the meandering Tennessee River cutting through Walden Ridge southwest of Chattanooga. Note the flat tops of the Cumberland Plateau west of Chattanooga with the plateau much dissected, especially by the Sequatchie Valley running northeast-southwest just to the left of the center of the image.

Figure 12. Walden Ridge, southeast Cumberland Plateau, view west across Chattanooga, Tennessee.

Figure 13. Walden Ridge, southeast Cumberland Plateau, view east from Sequatchie Valley.

ridges. Figure 18 shows a wind gap along Interstate 80. Figure 19 shows two wind gaps through the Valley and Ridge Province. The wind gaps occur at various altitudes, ranging from 220 to 520 m asl. Thompson (1939) described 161 wind gaps through the Virginia Blue Ridge alone. One of the more famous is the Cumberland wind gap on the border of southwest Virginia and southeast Kentucky (Figures 20 and 21). Early settlers passed through it on their way to Kentucky. It is nearly 185 m deep, as measured on the northeast side (Rich, 1933). Like the other Appalachian gaps, its origin is a mystery (see Thornbury, 1965, p. 145).

The anomalous drainage throughout the Valley and Ridge and Blue Ridge Provinces is a major geomorphological problem: "One of the major geomorphic problems of the folded Appalachians is the anomalous drainage, with transverse streams flowing across the structure, creating wind and water gaps" (Short and Blair, 1986, p. 56). Mills et al. (1987, p. 12) wrote that

> many master streams flow in deep gorges through ridges of resistant rock, with the Valley and Ridge

Figure 14. Tennessee River passing through Walden Ridge in a 300-m deep water gap.

of Pennsylvania having the most dramatic examples. The problem of how streams were able to cut through such obstacles has fascinated many geomorphologists.

Vertical Dissection of Plateaus

The Appalachian Plateau is severely dissected (Thornbury, 1965), with everything from minor valleys (Figure 22) to major 300–600-m deep river valleys (see Figure 11), such as on the New River in West Virginia. The eastern margin of the Appalachian Plateau has been especially eroded, creating the Cumberland Mountains on the southeast edge and the Allegheny Mountains on the northeast edge (see Part II, Oard, 2011c).

Figure 15. Google Maps close-up view of aligned water gaps of the Susquehanna River north of Harrisburg, Pennsylvania.

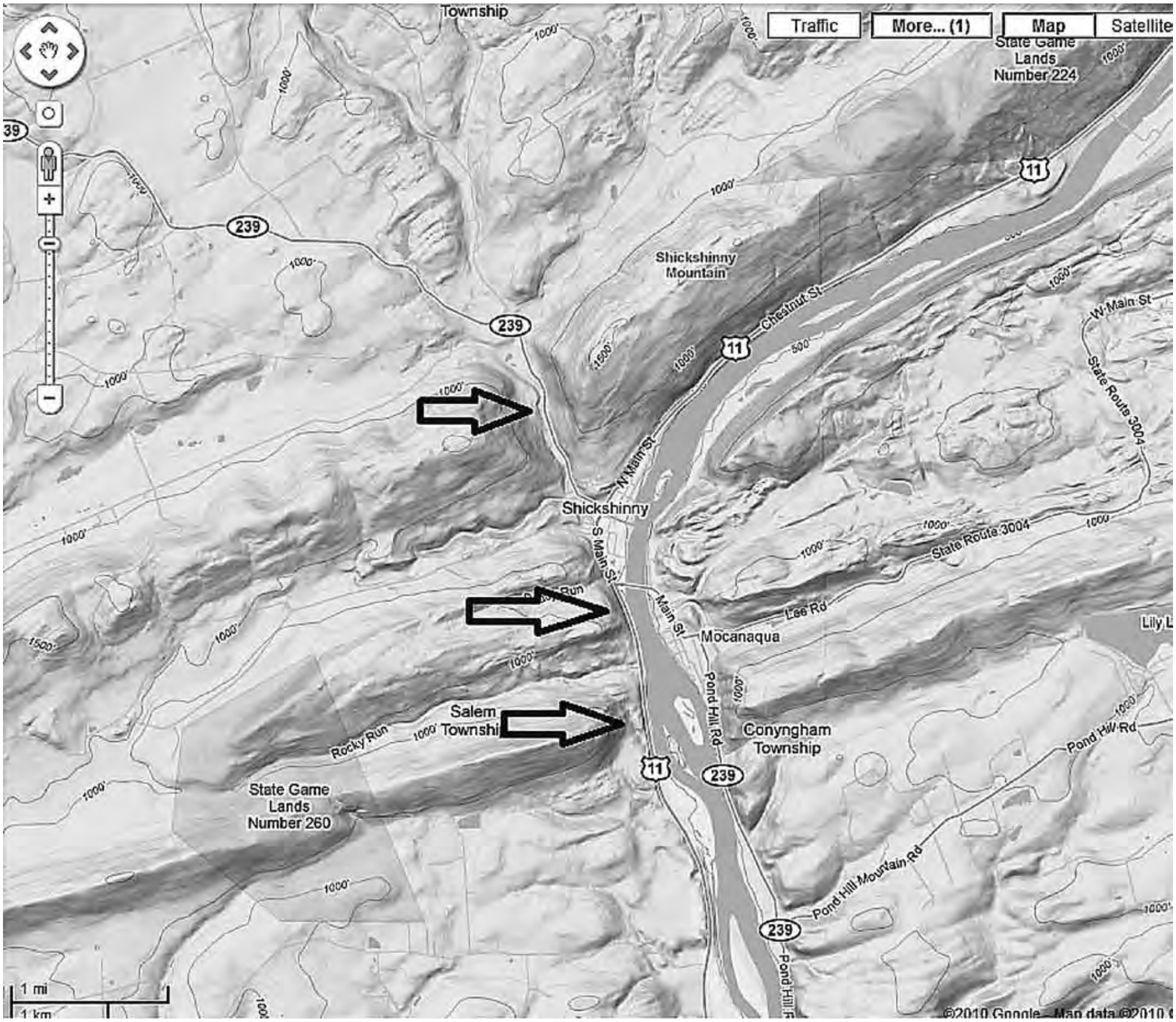


Figure 16. Google Maps view of three aligned water gaps (arrows) near Shickshinny, Pennsylvania. Note that the river passes through only two of them.

The rivers cutting the western plateau commonly have a second erosion surface along the sides called a *strath terrace* (see Figure 25 in Oard, 2011c). The Interior Low Plateaus Province to the west is also dissected but about half as much as the Appalachian Plateau Province to the east.

Uniformitarian Hypotheses and Problems

There are five uniformitarian hypotheses for the origin of water gaps, also called *transverse drainage* (Oberlander, 1965). Two of these, gaps as the surface expression of faults cutting through the mountains and William Morris Davis's relief inversion plus reversal in drainage, are not held today. That leaves three current uniformitarian hypotheses: (1) the antecedent stream, (2) the superimposed stream, and (3) stream piracy (Stokes and Mather, 2003, p. 76). The stream piracy hypothesis (Figure 3) has been locally suggested by a few early geologists (Adams, 1928; Fridley, 1939; Milici, 1968), but it is not considered

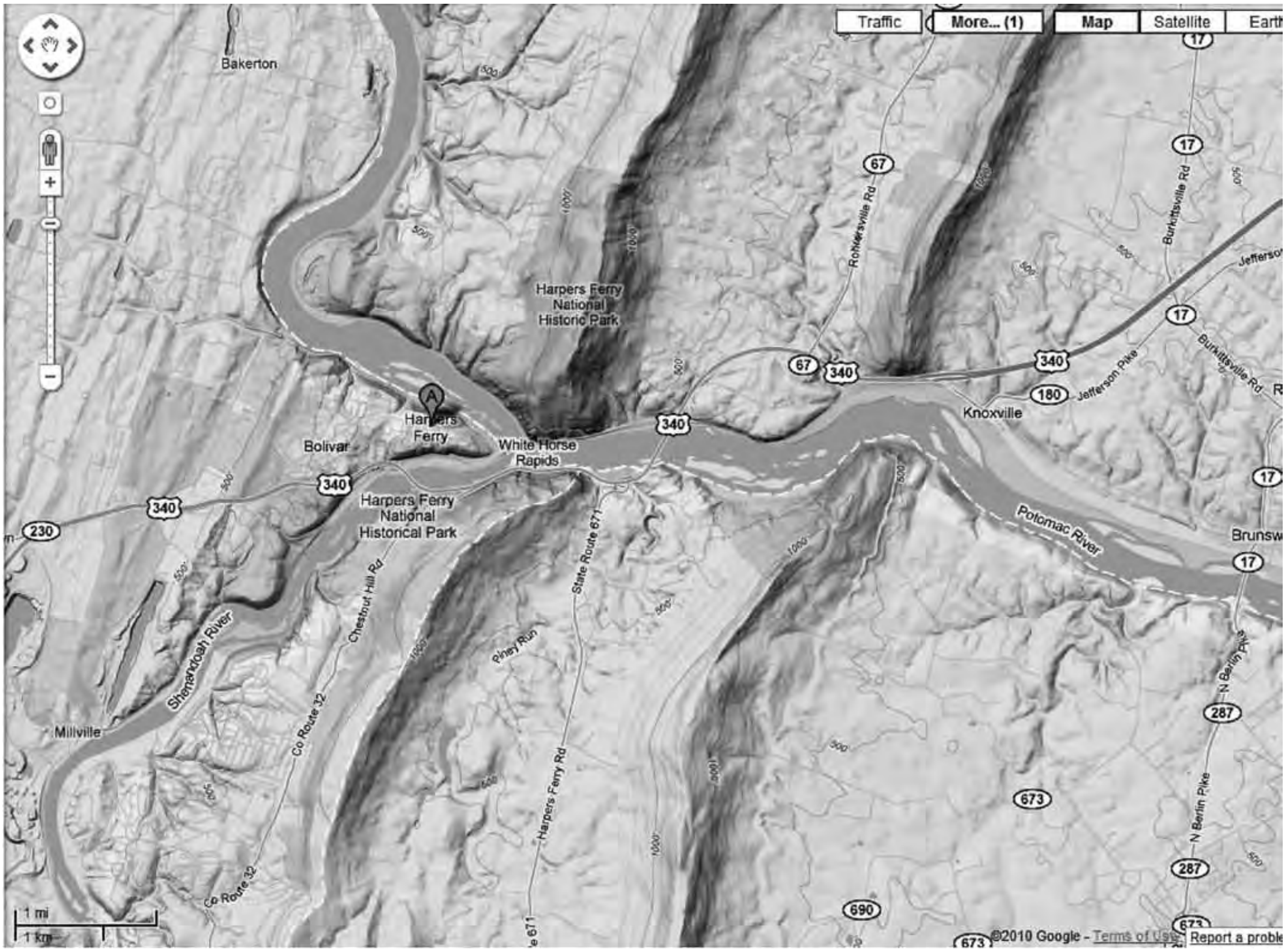


Figure 17. Google Maps view of aligned water gaps at Harpers Ferry, West Virginia. The Shenandoah River is coming from the south and joining the Potomac right at the gap—confluence of streams just upstream of gaps is not unusual.

Figure 18. A wind gap through a ridge near milepost 251 on I-80 in Pennsylvania.

likely by geologists today (Clark, 1989; Morisawa, 1989; Strahler, 1945) and thus will not be discussed.

Antecedent Stream Hypothesis

The antecedent stream hypothesis, defined above and illustrated in Figure 1, seems to have been the first invoked to explain transverse drainage. John Wesley Powell simply *assumed* the Green River through the Uinta Mountains and the Colorado River through Grand Canyon had been eroded by antecedent rivers. Most other geologists accepted this hypothesis until the mid 1900s, when it ran into severe problems. Supposedly,

Figure 19. Two wind gaps through one of the ridges of the Valley and Ridge Province, looking southwest from Pennsylvania Turnpike, Milepost 204.

antecedence can be true only of large rivers since only they have enough erosive power to keep up with uplift (Ahnert, 1998). As noted above, some small tributaries in the Appalachian Mountains pass through water gaps.

Some investigators believe that river erosion would be slower than mountain building, thus eliminating this hypothesis from contention. Although Twidale (1976) disagreed, he admitted that antecedent rivers or streams are actually *rare*. Many water gaps once assumed to have formed by the antecedent stream hypothesis have been "reinterpreted" and attributed to other mechanisms, showing that there never was much evidence for the hypothesis to begin with. Its only strength is its contiguity with the uniformitarian or actualistic assumption.

In order to demonstrate antecedence, one must prove that the river in question predates uplift, but that is difficult (Twidale, 1976). Furthermore, uplift must be slow enough and steady enough so that the river's course is not deflected (Ranney, 2005). This represents a special conjunction of time and erosion—a major special condition that is not likely.

Figure 20. Google Earth view of Cumberland Gap, no vertical exaggeration, looking northwest.

Figure 21. Cumberland wind gap on the border of Kentucky and Virginia, looking northwest.

Figure 22. Dissected Allegheny Plateau at Glade Creek on Interstate 64 at Philip G. McDonald Memorial Bridge, West Virginia. The erosion surface is easy to see in the accordant summits of the hills.

Table I. Problems with the antecedent stream hypothesis
1. Now considered rare
2. Streams must predate mountain uplift
3. Must prove the mountains uplifted
4. Mountain uplift must be slow enough to not deflect the stream
5. Little if any lake deposits upstream caused by fast mountain uplift
6. Hypothesis rejected for many previously assumed antecedent streams
7. Aligned water gaps

If uplift was too rapid, a river in an enclosed basin would become a lake, and these deposits are rarely found upstream of barriers.

If a water gap through one barrier is difficult to achieve, aligned water gaps through multiple uplifts, such as on the Susquehanna north of Harrisburg (Figure 15), would be much less likely. The antecedent stream hypothesis appears to be a very simplistic explanation with little or no evidence, but it has been advanced when alternatives seem even more improbable (Small, 1978).

This hypothesis is rarely invoked. It is hard to even imagine how positive evidence could be adduced. Chorley et al. (1984, p. 21) confessed:

> In practice it is often difficult to assign a cause to such discordance; indeed, the type example of supposed antecedence, that of the Green River cutting across the Uinta Mountains in northern Utah, is now considered to be due, in part at least, to superimposition.

Actually, superimposition for the Green River is out also, so uniformitarian scientists are left with stream piracy, which cannot be demonstrated for this river either, or for any other river (Bishop, 1995; Douglas & Schmeeckle, 2007). Table I summarizes the difficulties with the antecedent stream hypothesis.

Superimposed Stream Hypothesis

In the superimposed stream hypothesis, a landscape is buried by renewed sedimentation, usually by a marine transgression. Then, a stream or river is established on the generally flat cover of sediments or sedimentary rock, called the "covermass." As erosion takes place over millions of years, the stream erodes downward in the same location (Figure 2). In that way, after millions of years, the stream ends up flowing through structural barriers. At the same time, the rest of the covermass not in the path of the river is somehow eroded or mostly eroded, leaving behind the stream or river flowing through ridges or mountains. Geomorphologists default to this hypothesis if they find any remnant of the so-called covermass or indirect evidence of its existence (Twidale, 2004). This is quite a stretch of imagination based on little evidence of a covermass.

Discordant drainage in the Appalachian Mountains was initially attributed to antecedent streams (Von Engeln, 1942), probably because it was the reigning idea at the time. However, superimposition later became favored (Strahler, 1945; Thompson, 1939), partly because the tops of the ridges are thought to define an ancient erosion surface (Short and Blair, 1986). If so, that surface would have been generally level, and rivers flowing across it were assumed to have cut down into older deformed sedimentary rocks. This is thought true only of large rivers; smaller flows are generally congruent with the structure (Kaktins and Delano, 1999). Ollier (1991, p. 33) noted that the major rivers were caused by superimposition while their tributaries were not:

> Classic examples of superimposed drainage are found in the Appalachian Mountains. Accordant levels of ridge tops show that the folded Palaeozoic strata were planated, and major rivers such as the Susquehana [sic] originally flowed across this plain regardless of structure. They have later been incised and now flow through superimposed gorges, but tributaries are strongly structurally controlled.

As previously mentioned, many tributaries do flow parallel to the ridges, but then they mysteriously jump across ridges through water gaps (Figures 23 and 24).

Von Engeln (1942) also pointed to the aligned water gaps as evidence of superimposition, since these features would not be likely caused by antecedence or stream piracy. Strahler (1945) saw two possibilities: superimposition and fault control. He left no room for stream piracy, and claimed that wind gaps were evidence of superimposition. William Morris Davis also believed that the Appalachian water and wind gaps were created by superimposition (Morisawa, 1989). His second cause of fault control has since been shown not to be the case for most Appalachian water and wind gaps, although some gaps could be caused by structural weakness (Clark, 1989; Epstein, 1966; Morisawa, 1989). Thus, the superimposed stream hypothesis seems to have been accepted by default, because of the insurmountable problems with alternatives.

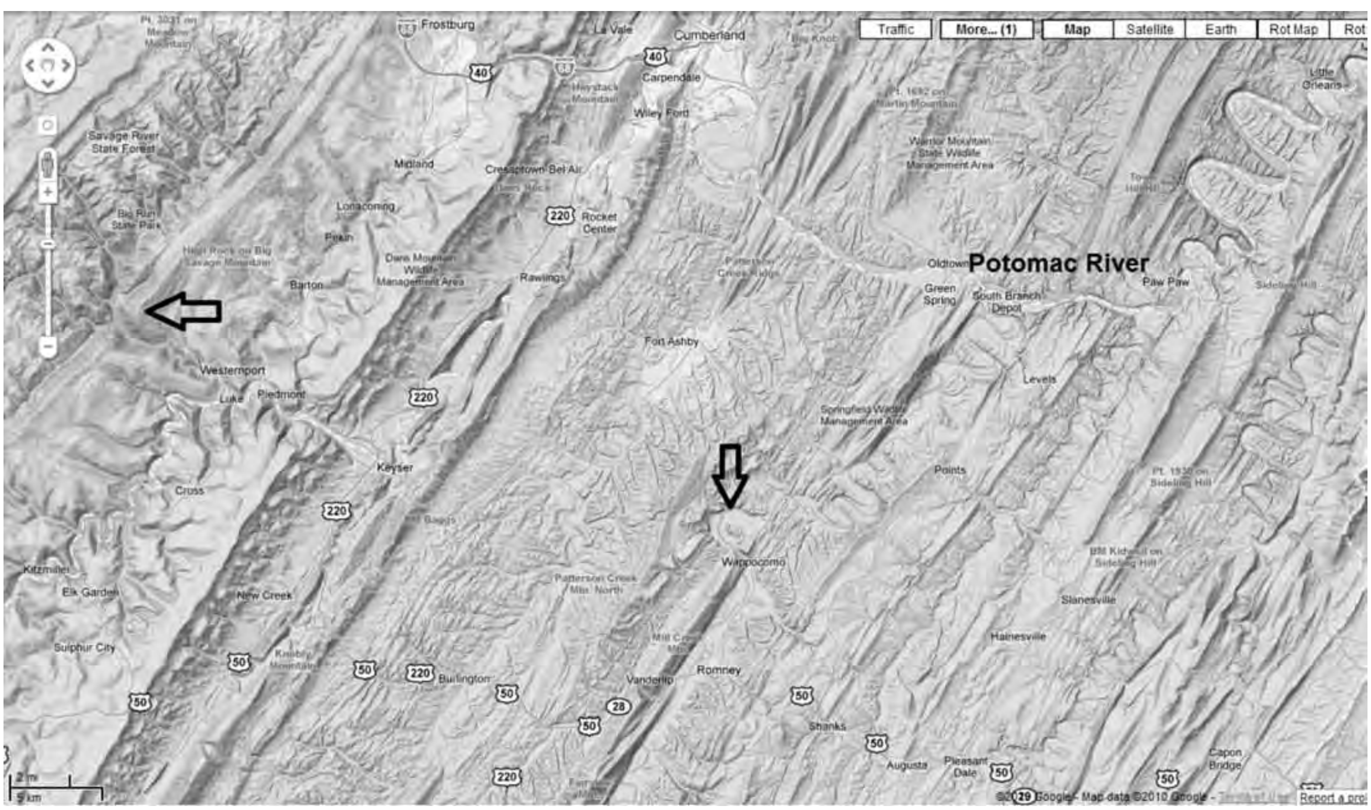


Figure 23. Google Maps image of two tributaries (arrows) of the Potomac River that generally flow parallel to ridges but then cross the ridges.

But this hypothesis has its own problems. Perhaps the most significant is the absence of evidence for the proposed transgression, the great volume of "covermass," and the "peneplain" prior to downward erosion by rivers (Mills et al., 1987). Kaktins and Delano (1999, p. 382) stated:

> Because Cretaceous marine deposits do not occur within the Appalachian fold belt, a subsequent episode of peneplanation was also required…. This proposal is seriously impaired by its reliance on both the questionable concept of peneplanation and the purely hypothetical Cretaceous marine cover.

Another difficulty is the tendency of modern rivers to take the path of least resistance. We would expect a downward-cutting river to change course as it encountered a more resistant anticline, and flow through the more easily eroded covermass. Finally, it is hard to adduce positive evidence for this idea, like the antecedent stream hypothesis. Mills et al. (1987, p. 14) summarized:

> As for superposition from an unconformable cover mass, there is no evidence of such a cover, and unlike in the ancient Appalachians, it is much more difficult to claim that the cover mass has been removed by erosion.

Ollier (1991, p. 33) also admitted there is no evidence for the Appalachian covermass:

> The age of the old planation is controversial, as is the former existence of a Cretaceous cover. The lack of any remnants of a Cretaceous cover makes the idea questionable.

Because of the lack of a covermass, Epstein (1966) rejected regional superimposition while accepting "local" superimposition.

On a larger scale, superimposition has a problem with removing the covermass in between the rivers. If the rivers are cutting vertically, then why would we expect laterally extensive erosion of these sediments on the ridges between the rivers? The hypothesis requires the river to maintain the *same* course and downcut into both resistant and nonresistant formations, while at the same time having the drainage basin erode the covermass all across the remainder of the region. Thus, the soft rocks are cut into valleys and leave the more resistant rocks as ridges, while the main rivers do not change course through the ridges (Crickmay, 1974). However, as seen in the highly dissected plateaus on the west side of the Appalachians (and elsewhere) fluvial erosion does not create level surfaces. And again, what evidence would we find to indicate that this had happened. The complete erosion of the

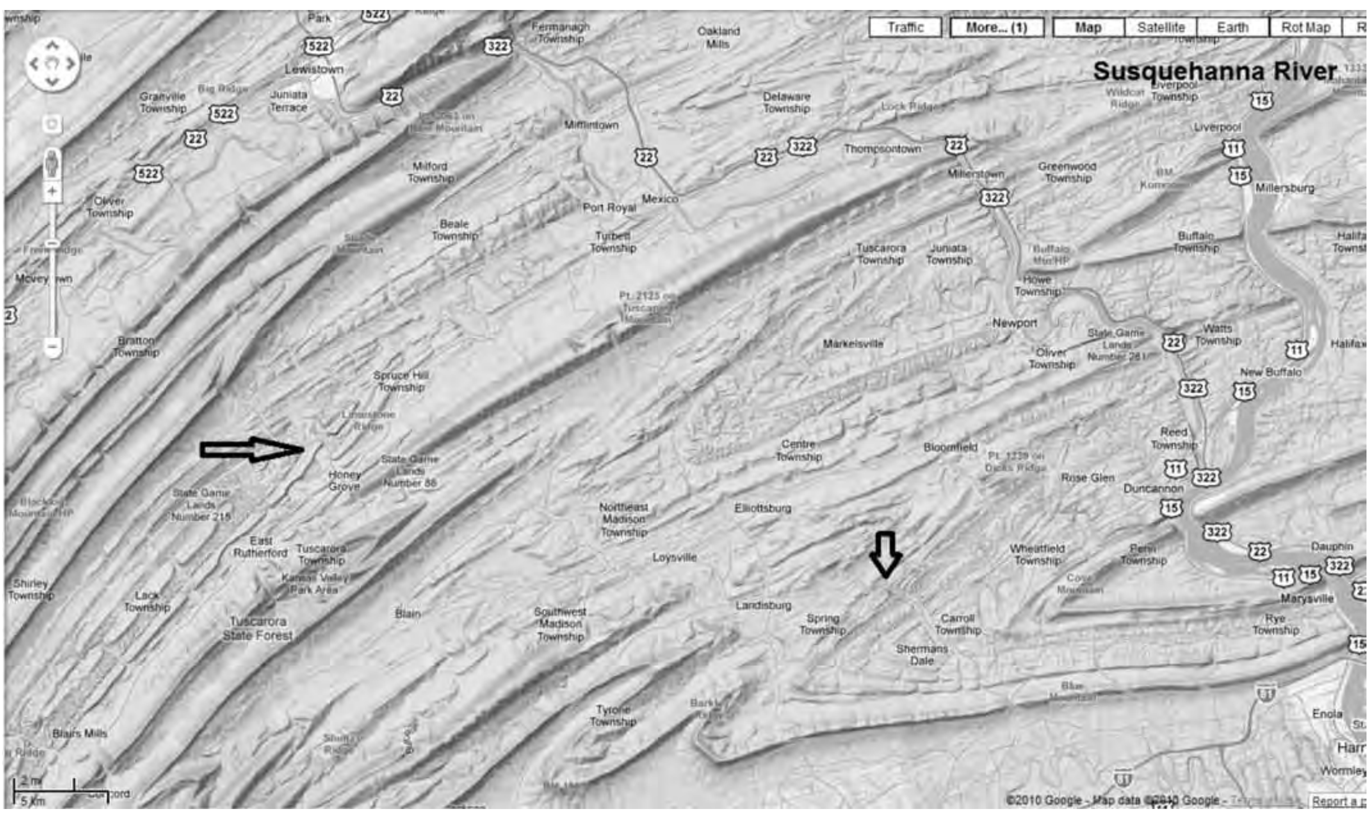


Figure 24. Google maps image of two tributaries to the Susquehanna River passing through water gaps.

covermass means that this is ultimately an argument from a lack of evidence:

> Although a plausible mechanism, superimposition is extremely difficult to verify except in the case of very young orogens [uplifted linear, folded, and deformed mountain belts] where vestiges of the original sedimentary cover remain. In ancient mountain belts, denudation will have removed all the evidence of any pre-existing sedimentary cover (Summerfield, 1991, p. 411, brackets added).

Even if a remnant of a sedimentary formation that once stood above the terrain can be found, one still has to demonstrate that the strata were once continuous and horizontal over a wide area, as well as having a covermass that is able to cause rivers to cut down through more resistant rocks. Table II summarizes the evidence against the hypothesis.

Table II. Problems with the superimposed stream hypothesis
1. Lack of evidence for a transgression of the sea and/or a covermass
2. Most, if not all, covermass eroded while rivers concentrate erosion linearly
3. Usually no evidence
4. Erosional remnants do not prove a covermass
5. In some cases, the covermass volume is huge and erosion must be great
6. Change in geological structure or lithology does not deflect the stream
7. Stream must maintain same course even after softer valley rocks eroded

All Uniformitarian Hypotheses Fail

In summary, none of the three major uniformitarian hypotheses are convincing for the Appalachian Mountains. This is also true for the thousands of water gaps across the earth found to date. Hack (1989) acknowledged that the origin of water gaps has not been explained, despite all the attempts. Uniformitarian geomorphologists seem to bounce from one hypothesis to another, stuck in the rut of their failed paradigm. However, they rarely present any evidence, much less compelling evidence. The only geomorphological cycle we see is the cycle through the failed hypotheses in desperate search of explanation.

Thomas Oberlander is a renowned expert on water gaps. He has many sobering thoughts on past and present research. For instance, Oberlander (1965, p. 1, emphasis and brackets added) noted the *conjectural* emphasis in explanations:

> The question of the origin of geological discordant drainage has almost always been attacked *deductively*, leading toward conclusions that remain largely within the realm of *conjecture*. Accordingly, the anomalous stream courses are attributed to previous tectonic environment [antecedence], to superposition from *hypothetical* erosion surfaces or covermasses, or to headward extension under largely *unspecified* controls [stream piracy].

Twenty years later, Oberlander (1985, p. 155, brackets and emphasis added) expressed the same opinion:

> Large streams transverse to deformational structures are conspicuous geomorphic elements in orogens [mountains] of *all ages*. Each such stream and each breached structure presents a geomorphic problem. However, the *apparent absence of empirical evidence* for the origin of such drainage generally limits comment upon it.

Then he stated (Oberlander, 1985, pp. 155–156, emphasis and brackets added):

> Transverse streams in areas of Cenozoic deformation are routinely attributed to stream antecedence to structure; where older structures are involved the choice includes antecedence, stream superposition from an unidentified covermass, or headward stream extension in some unspecified manner [piracy]. Whatever the choice, we are *rarely* provided with conclusive supporting arguments.

In regard to the Appalachian water and wind gaps, Clark, (1989, p. 225, 229) summarized:

> At this stage there are many facts, several hypotheses, but no single overall transverse drainage scheme that can be advanced as absolute … Still, lack of information on critical geochemical, geological, and geophysical datasets hampers further hypothesis erection and testing. Many of the same problems that dog the peneplain question (Seven et al., 1983, p. 161) also plague the unraveling of Appalachian drainage history. Is it any wonder that Craig (1979) could find no commonality of origin? What was written in 1932–33 [sic] can still be quoted today: "The Appalachian problem, like the poor, we shall have with us always." (Bryan et al., 1932/33, p. 318).

There has been little written on the origin of Appalachian transverse drainage problems during the past 20 years, so the problem is still a major mystery of Appalachian geomorphology.

If all of the classical uniformitarian hypotheses are insufficient, then we must conclude the necessity of searching for an explanation within a completely different paradigm. Ironically, the features of these landforms readily can be explained by the great nemesis of modern geology—the Genesis Flood.

Sheet Flow Transforms into Channelized Flow

Just as the sheet-flow phase explains the regional erosion surfaces and the deposition of widespread gravel lag deposits across these surfaces, the subsequent channelized-flow phase (Walker, 1994) is a logical answer to the problem of water and wind gaps. Water and wind gaps appear to be the last large-scale features formed by the Flood's recession off the Appalachians. As the sheet currents began to diminish into large embayments and channels, they would have still been flowing perpendicular to ridges (Figure 25a), initiating the water and wind gaps. The water and wind gaps indicate that the water was at first flowing perpendicular to the mountains when the Appalachian erosion surfaces were formed, since it takes perpendicular flow to create water and wind gaps. When the water and wind gaps were first started, the flow velocities would have been incredibly high, and locally variable (Schumm and Ethridge, 1994, p. 11). The water flow may have taken advantage of possible structural weakness or a low spot on the ridge. Epstein (1966) and Mills et al. (1987) believe some Appalachian water gaps started in zones of structural weakness. Regardless, initiated notches would have been carved along the ridge.

Once a notch was cut, water would have sought that channel, increasing flow velocity relative to the surrounding area (Figure 25b). The notch would quickly grow as more water was forced through the narrow opening. In addition, the faster water would have carried abrasive particles, cutting the gap even faster (Figure 25c). Fenneman (1938, pp. 198–199) noticed that the ridge tops are slightly lower around Appalachian water gaps, indicating decreasing current width during the erosion of the gaps.

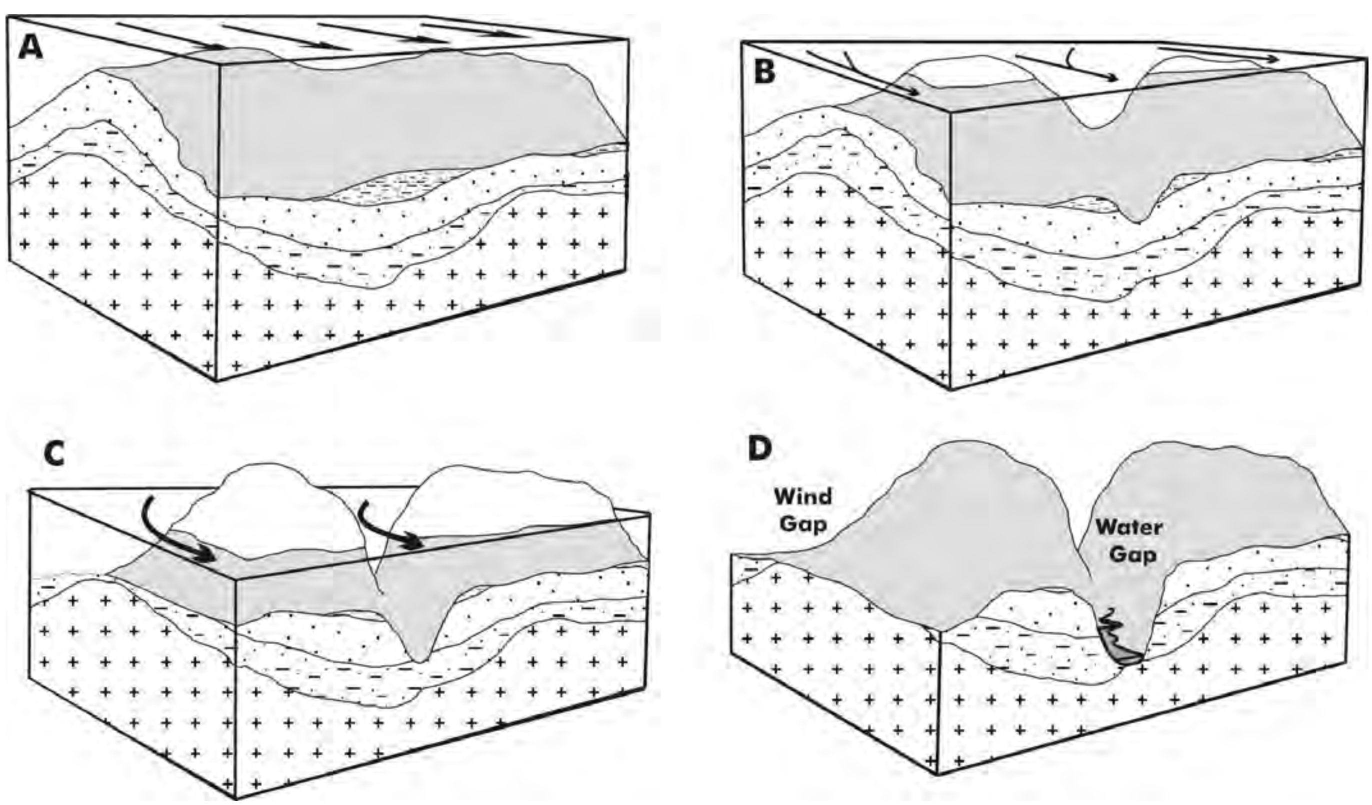


Figure 25. Series of schematics on the formation of water and wind gaps. Drawings by Peter Klevberg. (A) Water flowing perpendicular to a transverse ridge forms shallow notches on the ridge. (B) Notches eroded further as the water level drops below the top of the ridge. (C) Floodwater continues to drain as notches deepen. (D) Floodwater completely drained with a river running through the lowest notch, the water gap. Erosion ceased too early through the other notch, leaving a wind gap.

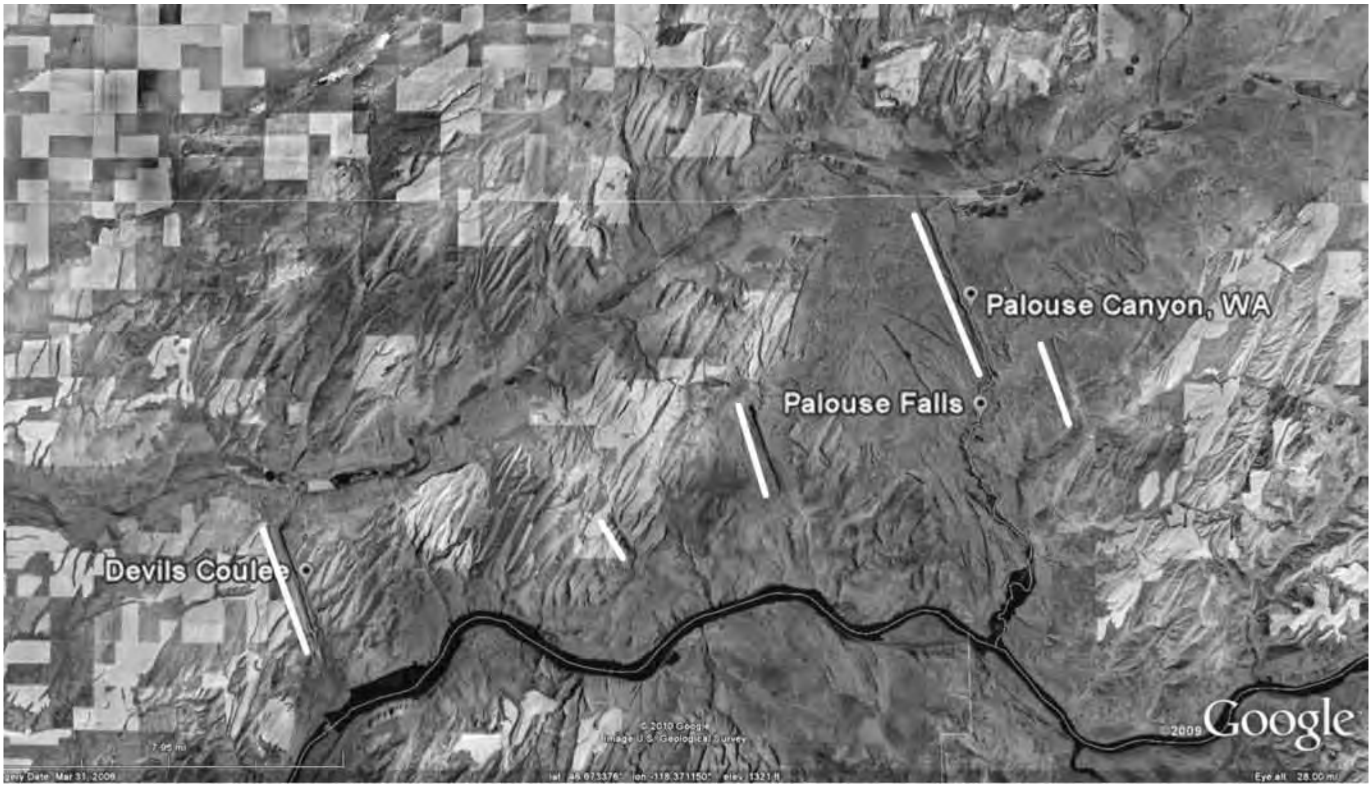


Figure 26. Goggle image of the ridge between Washtucna Coulee and the Snake River (lower center) showing where the Lake Missoula flood breached the ridge at generally four locations, but only two deep channels were cut through the ridge at Devils Coulee and Palouse Canyon.

While water and wind gaps were being formed, and the ridges become more and more exposed, the channelized flow would tend to also channel between the ridges, eroding the soft rocks. So, there would eventually be flow through ridges in the water and wind gaps previously formed and flow between ridges, as the water continued to drain toward the ocean.

The Flood explanation also differentiates between wind and water gaps. Wind gaps represent early water gaps that were left high and dry as the water level rapidly dropped or the current velocity diminished quickly, leading to the cessation of erosion (Figure 25c, d). These would have remained as remnants at high elevations while the lowering water carved new gaps at lower elevations, establishing the basic post-Flood drainage patterns. Today, only wind traverses the higher gaps, while the rivers naturally take advantage of the low water course through the water gap established at the very end of the Flood (Figure 25d). Changes in water level and velocity to stop the water flow through what are now wind gaps would have been caused by a variety of mechanisms, such as tectonic shifts caused by ongoing folding, current shifts, or diversion by rapid adjacent erosion.

This type of process is seen on a small scale in the breaching of an earth dam by water flowing over its top. Finding a zone of weakness, the sheet flow over the top rapidly cuts a narrow deep notch that channels the water through. Most of the remainder of the dam wall usually remains intact. Also, the anomalously high velocities and the scale of the channelized currents is the only feasible explanation for the phenomenon of *aligned* water gaps in a series of perpendicular ridges.

Crickmay (1933) stated that wind gaps have been modified little by weathering since they first formed. This is entirely consistent with the Flood explanation—the channelized-flow phase was the last event of the Flood and not that long ago. This "youthfulness" is also an argument against the actualistic model; we would have to accept that wind gaps have remained untouched by erosion for millions of years.

Water and wind gaps in the Appalachians show similarities to those in the western United States, such as those

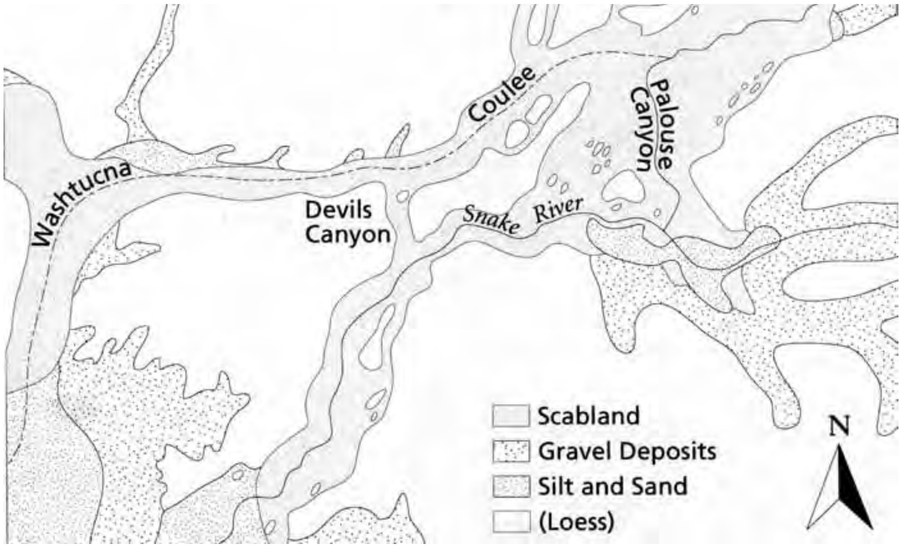


Figure 27. Map of ridge between Washtucna Coulee and the Snake River, showing Palouse Canyon, a water gap, and Devils Canyon, a deep wind gap, cut during the Lake Missoula flood. Modified from Bretz (1928, p. 205) by Mark Wolfe.

Figure 28. Palouse Canyon downstream from Palouse Falls

formed by the Lake Missoula flood at the peak of the Ice Age (Oard, 2003, 2004a, 2004b). The Lake Missoula floodwater rushed south into the head of Washtucna Coulee. It overtopped the ridge between Washtucna Coulee and the Snake River at generally four locations (Figure 26), forming a water gap and one deep wind gap (Figure 27). At the head of one—Palouse Canyon—its width was initially around 13 km, but the flow narrowed, cutting a vertically walled canyon 150 m deep—down to the level of the Snake River (Figure 28). Subsequently, the Palouse River, instead of continuing west down Washtucna Coulee as before, took a 90° left turn, flowing into the Snake River. Palouse Falls (Figure 29) is a remnant left from the canyon cutting and would represent a *knickpoint*.

Devils Coulee, 24 km west of Palouse Canyon, is a narrow notch 150 m deep that was eroded through the ridge (Figures 26 and 27). However, the current did not erode this coulee deep enough at its entrance from Washtucna Coulee. The entrance to Devils Coulee is approximately 30 m above Washtucna Coulee, and so no stream was diverted down it. Therefore, Devils Coulee remains a wind gap.

Palouse Canyon and Devils Coulee are examples of how large volumes of energetic floodwater perpendicular to a ridge can rapidly excavate water and wind gaps in hard rock (Oard, 2003).

Figure 30 shows two schematics of sheet flow transforming into channelized flow, forming water and wind gaps with the water being channelized more and more down the valleys and through developing water and wind gaps of the Valley and Ridge and Blue Ridge Provinces. The velocity of the water was likely enough to erode the bottom of the Great Valley into a linear erosion surface.

Summary

The Appalachian Mountains are a complex fold and thrust belt in the eastern United States. Several overlapping lines of evidence suggest that as much as 6.5 km of rock was eroded from the Appalachians during mainly Cenozoic uplift. At the same time, regional geomorphological features were formed. No actualistic hypothesis has been able to explain the geology and landforms observed. However, the retreating stage of the Flood, with its two phases, readily accounts for all of these features, including erosion surfaces, monadnocks, plateaus, and the many wind and water gaps cutting through the mountains along its entire length.

Figure 29. Palouse Falls on the Palouse River between Washtucna Coulee and the Snake River.

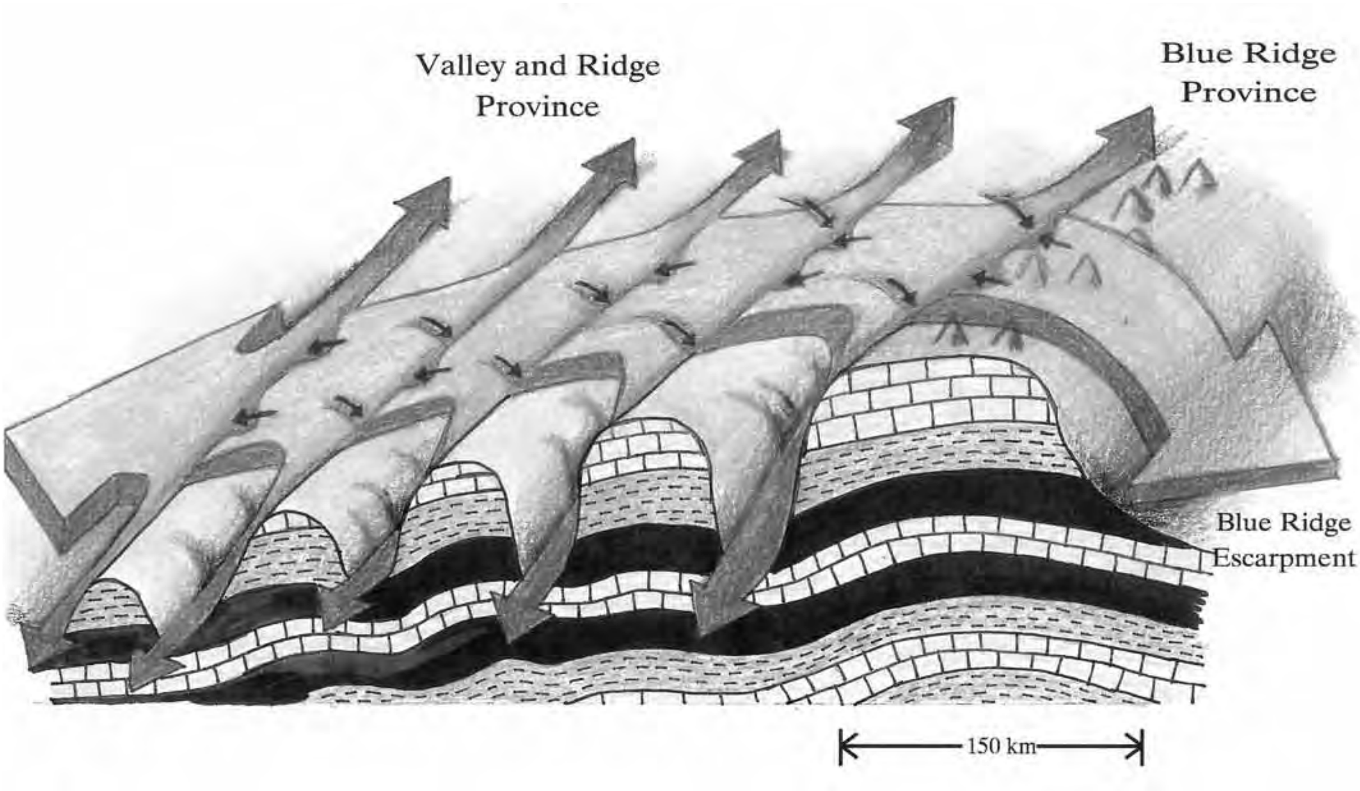
Sheet flow produced extensive erosion surfaces, mainly on the Piedmont and on the plateaus west of the Valley and Ridge Province. The extent and speed of these currents is evidenced by the extent and nature of the erosion, as well as by the gravel veneer deposited on top of the erosional surfaces. But the best way to visualize the energy involved is to understand that the shelf-slope system on the present continental margin was rapidly deposited from eroded Appalachian sediments.

As the combination of uplift and base-level decline caused the Appalachian Mountains to emerge from the Flood, the flow diverged from either side of the rising peaks. Sediments eroded west of the Appalachian divide were transported west, where they merged with water flowing east from the rising Rockies, carrying vast amounts of sediment that would form the massive Gulf of Mexico coastal plain and continental margin sediments. Erosion surfaces were later formed on either side of the Appalachian Mountains. As the Floodwater transformed from sheet flow into channelized flow, the erosion became narrow and linear. Valleys, canyons, and water and wind gaps would then be cut until the Flood ended. This is similar to the two-step erosion on the Colorado Plateau: (1) the Great Denudation from sheet flow, and (2) the Grand Canyon, Zion Canyon, and other canyons from channelized flow (Oard, 2010, 2011a).

Much of the erosion, the formation of erosion surfaces, and the cutting of water and wind gaps in the Appalachians are dated by secular scientists as late Mesozoic and Cenozoic. The deposition of the sediments along the coastal plain and offshore also occurred during this time. The pattern is typical of the retreating stage of the Flood seen elsewhere. It also indicates that the Flood/post-Flood boundary in this region corresponds approximately to the very late Cenozoic, assuming the secular geologic timescale.

Acknowledgments

I thank Melanie Richard for drawing Figure 30 and my son-in-law Mark Wolfe for drawing Figure 27. I also thank two anonymous reviewers who significantly improved the manuscript and supplied me with the Google images and aerial photos. This work was supported by a grant from the Creation Research Society.



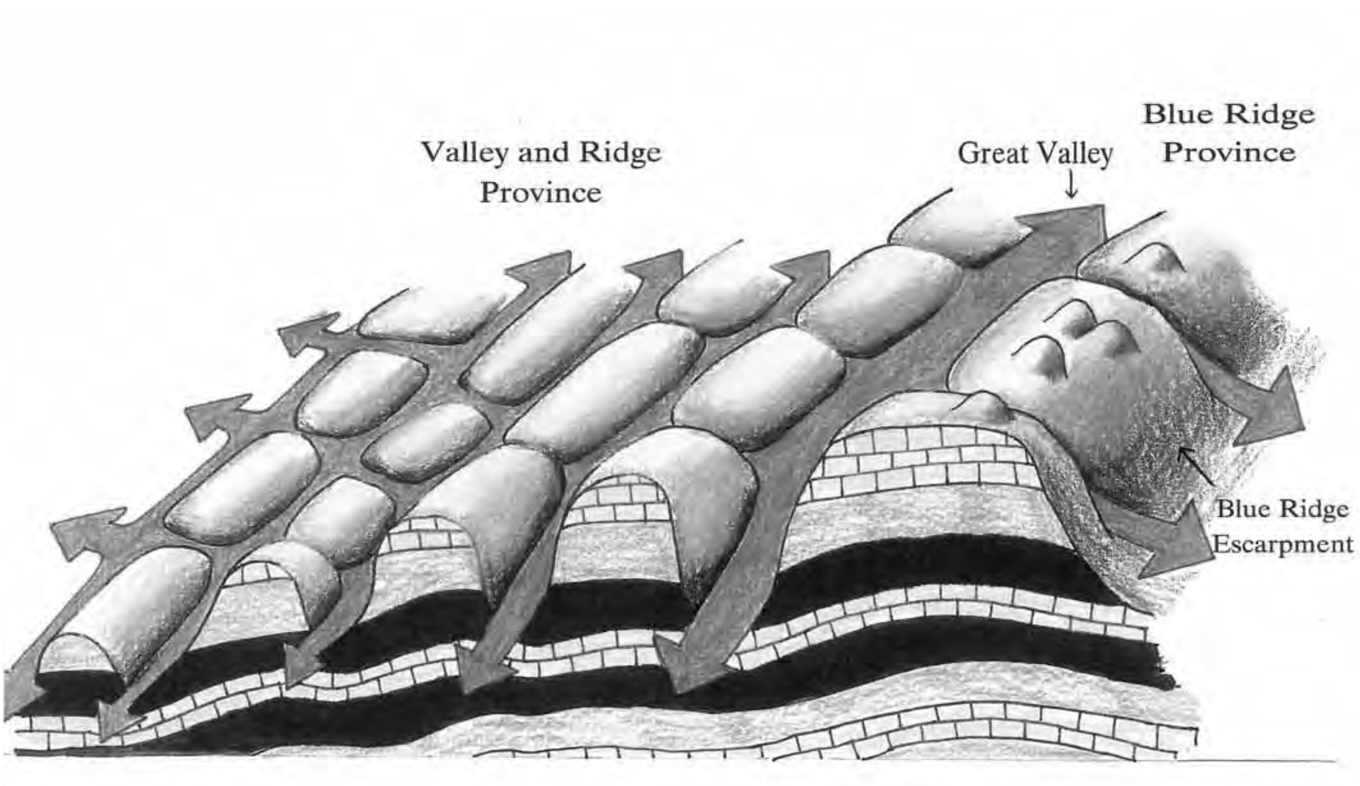


Figure 30. Big picture of the formation of water and wind gaps in the Appalachians. Drawing by Mrs. Melanie Richard. (A) Sheet flow transforms into channelized flow and starts to erode water and wind gaps. (B) Channelized flow drains down the valleys and across water and wind gaps of the Valley and Ridge and the Blue Ridge Provinces

References

CRSQ: Creation Research Society Quarterly

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

Adams, G.I. 1928. The course of the Tennessee River and the physiography of the southern Appalachian region. *The Journal of Geology* 36:481–493.

Ahnert, F. 1998. *Introduction to Geomorphology*. Arnold, London, UK.

Alvarez, W. 1999. Drainage on evolving fold-thrust belts: a study of transverse canyons in the Apennines. *Basin Research* 11:267–284.

Bartholomew, M.J., and H.H. Mills. 1991. Old courses of the New River: its late Cenozoic migration and bedrock control inferred from high-level stream gravels, southwestern Virginia. *GSA Bulletin* 103:73–81.

Bishop, P. 1995. Drainage rearrangement by river capture, beheading and diversion. *Progress in Physical Geography* 19(4):449–473.

Bretz, J.H. 1928. Alternative hypotheses for Channeled Scabland. I. *Journal of Geology* 36:193–223.

Chorley, R.J., S.A. Schumm, and D.E. Sugden. 1984. *Geomorphology*. Methuen, London, UK.

Clark, G.M. 1989. Central and southern Appalachian water and wind gap origins: review and new data. *Geomorphology* 2:209–232.

Crickmay, C.H. 1933. The later stages of the cycle of erosion: some weaknesses in the theory of the cycle of erosion. *Geological Magazine* 70:337–347.

Crickmay, C.H. 1974. *The Work of the River: A Critical Study of the Central Aspects of Geomorphology*. American Elsevier Publishing Co., New York, NY.

Douglass, J.C. 2005. Criterion approach to transverse drainages. PhD thesis, Arizona State University, Tucson, Arizona.

Douglass, J., and M. Schmeeckle. 2007. Analogue modeling of transverse drainage mechanisms. *Geomorphology* 84:22–43.

Epstein, J.B. 1966. Structural control of wind gaps and water gaps and of stream capture in the Stroudsburg area, Pennsylvania and New Jersey. *U. S. Geological Survey Professional Paper 550-B*, Washington, DC.

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

Fridley, H.M. 1939. Solution and stream piracy. *Journal of Geology* 47:178–188.

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.

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. *JofC* 23(3):76–83.

Klevberg, P., and M.J. Oard, 1998. Paleohydrology of the Cypress Hills Formation and Flaxville gravel. In Walsh, R.E. (editor), *Proceedings of the Fourth International Conference on Creationism*, technical symposium sessions, pp. 361–378. Creation Science Fellowship, Pittsburgh, PA.

Milici, R.C. 1968. Mesozoic and Cenozoic physiographic development of the lower Tennessee River: in terms of the dynamic equilibrium concept. *Journal of Geology* 76:472–479.

Mills, H.H., G.R. Brakenridge, R.B. Jacobson, W.L. Newell, M.J. Pavich, and J.S. Pomeroy. 1987. Appalachian mountains and plateaus. In Graf, W.L. (editor), *Geomorphic Systems of North America*, pp. 5–50. Geological Society of America Centennial Special, Volume 2, Boulder, CO.

Morisawa, M. 1989. Rivers and valleys of Pennsylvania, revisited. *Geomorphology* 2:1–22.

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

Oard, M. J. 2003. Evidence for only one gigantic Lake Missoula flood. In Ivey, Jr., R.L. (editor), *The Fifth International Conference on Creationism*, technical symposium sessions, pp. 219–231. Creation Science Fellowship, Pittsburgh, PA.

Oard, M. J. 2004a. *Frozen in Time: The Woolly Mammoth, the Ice Age, and the Biblical Key to Their Secrets*. Master Books, Green Forest, AR.

Oard, M. J. 2004b. *The Missoula Flood Controversy and the Genesis Flood*. Creation Research Society Monograph No. 13, Chino Valley, AZ.

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

Oard, M.J. 2008b. Long-distance Flood transport of the Nenana Gravel of Alaska—similar to other gravels in the United States. *CRSQ* 44:264–278.

Oard, M.J. 2010. The origin of Grand Canyon part IV: the great denudation. *CRSQ* 47:146–157.

Oard, M.J. 2011a. The origin of Grand Canyon part V: carved by late Flood channelized erosion. *CRSQ* 47:271–282.

Oard, M.J. 2011b. Origin of Appalachian geomorphology, part I: erosion by retreating floodwater and the formation of the continental margin. *CRSQ* 48:33–48.

Oard, M.J. 2011c. Origin of Appalachian geomorphology, part II: formation of surficial erosion surfaces. *CRSQ* 48:105–122.

Oard, M.J., J. Hergenrather, and P. Klevberg. 2005. Flood transported quartzites—east of the Rocky Mountains. *JofC* 19 (3):76–90.

Oard, M.J., J. Hergenrather, and P. Klevberg. 2006a. Flood transported quartzites: part 2—west of the Rocky Mountains. *JofC* 20 (2):71–81.

Oard, M.J., J. Hergenrather, and P. Klevberg. 2006b. Flood transported quartzites: part 3—failure of uniformitarian interpretations. *JofC* 20 (3): 78–86.

Oard, M.J., J. Hergenrather, and P. Klevberg. 2007. Flood transported quartzites: part 4—diluvial interpretations. *JofC* 21(1):86–91

Oard, M.J. and P. Klevberg, 1998. A diluvial interpretation of the Cypress Hills Formation, Flaxville gravels, and related deposits. In Walsh, R.E. (editor). *Proceedings of the Fourth International Conference on Creationism*, technical symposium sessions, pp. 421–436. Creation Science Fellowship, Pittsburgh, PA.

Oard, M.J., and P. Klevberg. 2005. Deposits remaining from the Genesis Flood: rim gravels in Arizona. *CRSQ* 42:1–17.

Oberlander, T. 1965. *The Zagros Streams: A New Interpretation of Transverse Drainage in an Orogenic Zone*. Syracuse Geographical Series No. 1, Syracuse, NY.

Oberlander, T.M. 1985. Origin of drainage transverse to structures in orogens. In Morisawa, M., and J.T. Hack (editors), *Tectonic Geomorphology*, pp. 155–182. Allen and Unwin, Boston, MA.

Ollier, C. 1981. *Tectonics and Landforms*. Longman, New York, NY.

Ollier, C. 1991. *Ancient Landforms*. Belhaven Press, New York, NY.

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

Rich, J.L. 1933. Physiography and structure at Cumberland Gap. *GSA Bulletin* 44:1,219–1,236.

Schumm, S., and F.G. Ethridge. 1994. Origin, evolution and morphology of fluvial valleys. In Dalrymple, R.W., R. Boyd, and B.A. Zaitlin (editors), *Incised-Valley Systems: Origins and Sedimentary Sequences*, pp. 11–27. SEPM Special Publication No. 51, Tulsa, OK.

Short, N.M., and R.W. Blair, Jr. (editors). 1986. *Geomorphology from Space: A Global Overview of Regional Landforms*. NASA, Washington, DC.

Small, R.J. 1978. *The Study of Landforms: A Textbook of Geomorphology*, 2nd Edition. Cambridge University Press, London, UK.

Stokes, M., and A.E. Mather 2003. Tectonic origin and evolution of a transverse drainage: the Río Almanzora, Betic Cordillera, Southeast Spain. *Geomorphology* 50:59–81.

Strahler, A.N. 1945. Hypotheses of stream development in the folded Appalachians of Pennsylvania. *GSA Bulletin* 56:45–88.

Summerfield, M.A. 1991. *Global Geomorphology*. Longman Scientific & Technical, New York, NY.

Thompson, H.D. 1939. Drainage evolution in the southern Appalachians. *GSA Bulletin* 50:1,323–1,356.

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

Twidale, C.R. 1976. *Analysis of Landforms*. John Wiley & Sons Australasia Pty Ltd, New York, NY.

Twidale, C.R. 2004. River patterns and their meaning. *Earth-Science Reviews* 67:159–218.

Ver Steeg, K. 1930. Wind gaps and water gaps of the Northern Appalachians, their characteristics and significance. *Annals of the New York Academy of Sciences* 32:87–220.

Von Engeln, O.D. 1942. *Geomorphology: Systematic and Regional*. Macmillan, New York, NY.

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.

Ward, D.J., J.A. Spotila, G.S. Hancock, and J.M. Galbraith 2005. New constraints on the late Cenozoic incision history of the New River, Virginia. *Geomorphology* 72:54–72.

Williams, E.L., and A.J. Akridge. 2005. Sequatchie Valley Tennessee and Alabama: a different approach. *CRSQ* 41:276–288.