

Using a New Glacial History Paradigm and Bald Eagle Through Valley Topographic Map Evidence to Determine Central Pennsylvania's Geomorphic History, USA

Eric Clausen

Jenkintown, PA, USA

Email: eric2clausen@gmail.com

How to cite this paper: Clausen, E. (2024) Using a New Glacial History Paradigm and Bald Eagle Through Valley Topographic Map Evidence to Determine Central Pennsylvania's Geomorphic History, USA. *Open Journal of Geology*, 14, 880-899.
<https://doi.org/10.4236/ojg.2024.149038>

Received: August 24, 2024

Accepted: September 26, 2024

Published: September 29, 2024

Copyright © 2024 by author(s) and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

A new glacial history paradigm that describes huge and prolonged southwest-oriented meltwater floods flowing along the rising rim of a deep “hole” (which a large continental icesheet created and occupied) is used to explain previously unexplained or poorly explained central Pennsylvania Bald Eagle through valley region topographic map evidence. Pennsylvania's Bald Eagle through valley as defined here extends in a northeast direction from near Altoona to near Williamsport along the Allegheny Front escarpment base and forms the boundary between the Appalachian Plateau to the northwest and the Ridge and Valley Province to the southeast. The Lycoming and Towanda Creek valleys follow a probable northeastern Bald Eagle through valley extension and a probable southern extension continues southward along the Allegheny Front base by crossing Juniata River tributary drainage basins to reach the Potomac River drainage basin. Landform features identified on topographic maps, which include through valleys (valleys crossing drainage divides), barbed tributaries, drainage route orientations, drainage route direction changes, water gaps, and gaps located along the Allegheny Front crest, are used to reconstruct how the Pennsylvania Susquehanna and Juniata River drainage systems developed. The resulting geomorphic history describes how massive southwest-oriented floods moving across what was probably a low relief and rising surface (now preserved if preserved at all by the region's highest elevations) flowed to an actively eroding Potomac River drainage system before being captured and sometimes reversed first by Juniata River valley headward erosion, second by West Branch Susquehanna River valley headward erosion (to create northeast-oriented Bald Eagle Creek and the northeast-oriented West Branch Susquehanna River segment) and third by North Branch

Susquehanna River valley headward erosion. This interpretation explains most if not all of the previously poorly explained and unexplained topographic map evidence.

Keywords

Allegheny Front, Appalachian Plateau, Barbed Tributaries, Juniata River, Susquehanna River, Ridge and Valley Province

1. Introduction

1.1. The Bald Eagle Through Valley and Accepted Paradigm Difficulties

Through valleys are valleys crossed by one or more drainage divides and usually originated as water-eroded valleys. Through valleys are abundant throughout North America and are useful when wanting to determine how a region's drainage systems evolved. However, in spite of excellent topographic map evidence, the geology literature rarely includes studies in which detailed topographic map through valley evidence has been used to reconstruct former drainage routes and drainage systems. The problem is, while not officially recognized as such, most through valleys are anomalous evidence that the accepted geology and glacial history paradigm (accepted paradigm) cannot satisfactorily explain.

The central Pennsylvania Bald Eagle through valley (see [Figure 1](#) and [Figure 2](#) for location) crosses the West Branch Susquehanna River (WBSR)-Juniata River drainage divide and represents the westernmost valley in Pennsylvania's Ridge and Valley Province. Northeast-oriented Little Juniata River headwaters drain the Bald Eagle through valley's southwestern end before turning in a southeast direction to flow through a water gap cut across a 200 - 300-meter-high linear ridge, known as Brush Mountain (to the southwest) and as Bald Eagle Mountain (to the northeast). Between the Little Juniata River's abrupt turn and the WBSR-Little Juniata River drainage divide, a short southwest-oriented Little Juniata River tributary, referred to here as Bald Eagle Creek South, drains the Bald Eagle through valley while to the northeast of the drainage divide, the Bald Eagle through valley is drained by the much longer northeast-oriented Bald Eagle Creek and a northeast-oriented WBSR segment. Near Williamsport, Pennsylvania, the WBSR leaves the through valley and turns in a south direction as it flows around the Bald Eagle Mountain northeast end.

Bald Eagle and Brush Mountains form the Bald Eagle through valley southeast wall while the Allegheny Front forms the through valley northwest wall. To the northwest of the Allegheny Front is the Appalachian Plateau. According to Thornbury [1], "Bald Eagle Mountain flanks the Nittany [Valley] on the northwest, and this homoclinal ridge of Tuscarora sandstone is continuous from near Altoona to Williamsport, Pennsylvania, a distance of 140 miles [225 kilometers]. Between Bald

Eagle Mountain and the Allegheny Front is a narrow valley on the Devonian Helderberg limestone, which is followed by northeastward-flowing Bald Eagle Creek for some 60 miles [97 kilometers]”. Previously in his Allegheny Front description Thornbury said “Throughout its length, the Middle section [of the Ridge and Valley Province] is bounded on the west by the prominent escarpment that forms the eastern edge of the Appalachian Plateau. This escarpment, here known as the Allegheny Front, attains a height of 1800 feet [550 meters] near Altoona, Pennsylvania.... The Allegheny Front in this area is capped with the Mississippian Pocono sandstone”.

The WBSR (see **Figure 2**) begins in the Appalachian Plateau and flows in a northeast direction before turning in a southeast direction to cross the Allegheny Front and enter the northeast-oriented Bald Eagle through valley much like a barbed tributary (at Loch Haven). After being joined by northeast-oriented Bald Eagle Creek the WBSR turns in a northeast direction to reach the Bald Eagle Mountain northeast end where the WBSR turns to flow in a south direction. The Little Juniata River is the northwesternmost Juniata River branch and begins to the south of Altoona and flows in a northeast direction along the Bald Eagle through valley floor to Tyrone where it turns abruptly to flow through the water gap that now separates Bald Eagle Mountain from Brush Mountain. The Little Juniata River then flows in a southeast direction to join other Juniata River branches, so as to become the Juniata River before turning in a northeast direction and after still additional direction changes eventually reaching the Susquehanna River.

Geologic maps [2] show the Bald Eagle through valley like most Ridge and Valley

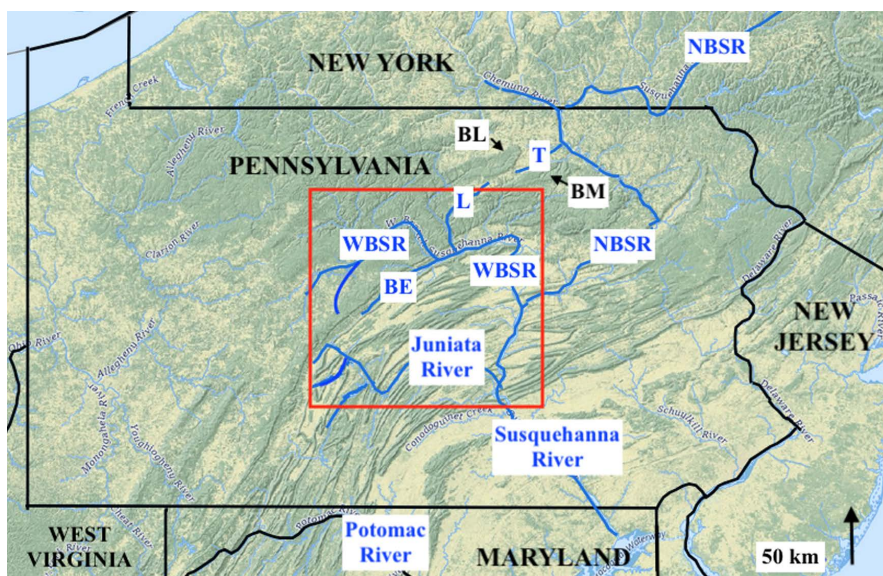


Figure 1. Modified map from the United States Geological Survey (USGS) National Map website showing the detailed map location (red rectangle) in **Figure 2**. Letters identify drainage routes as follows: BE-Bald Eagle Creek, L-Lycoming Creek, NBSR-North Branch Susquehanna River, T-Towanda Creek and WBSR-West Branch Susquehanna River. BL and BM identify the Blossburg and Barclay Mountain synclinal upland locations.

Province through valleys extends along more easily eroded bedrock units, which partially explains the through valley location. What the accepted geology and glacial history paradigm (accepted paradigm) prevents geologists from explaining is why a drainage divide now separates northeast-oriented Little Juniata River headwaters from northeast-oriented Bald Eagle Creek headwaters or why other drainage divides now cross the Bald Eagle through valley northeastern and southern extensions. Further, the accepted paradigm does not explain how the Little Juniata River eroded its water gap across the now high Brush Mountain-Bald Eagle Mountain linear ridge. Also, difficult to explain are higher elevation, less deep and less obvious through valleys crossing the same WBSR-Juniata River drainage divide (red dashed line in **Figure 2**). Adding to the accepted paradigm's difficulties are gaps notched into the Allegheny Front crestline, which link Bald Eagle Creek and Little Juniata River tributaries with north-oriented WBSR tributary drainage routes.

1.2. The Bald Eagle Through Valley Northeast and Southwest Extensions

The Bald Eagle through valley is a segment of what can be considered to be a much longer through valley. One possible northeast extension is a 4-kilometer

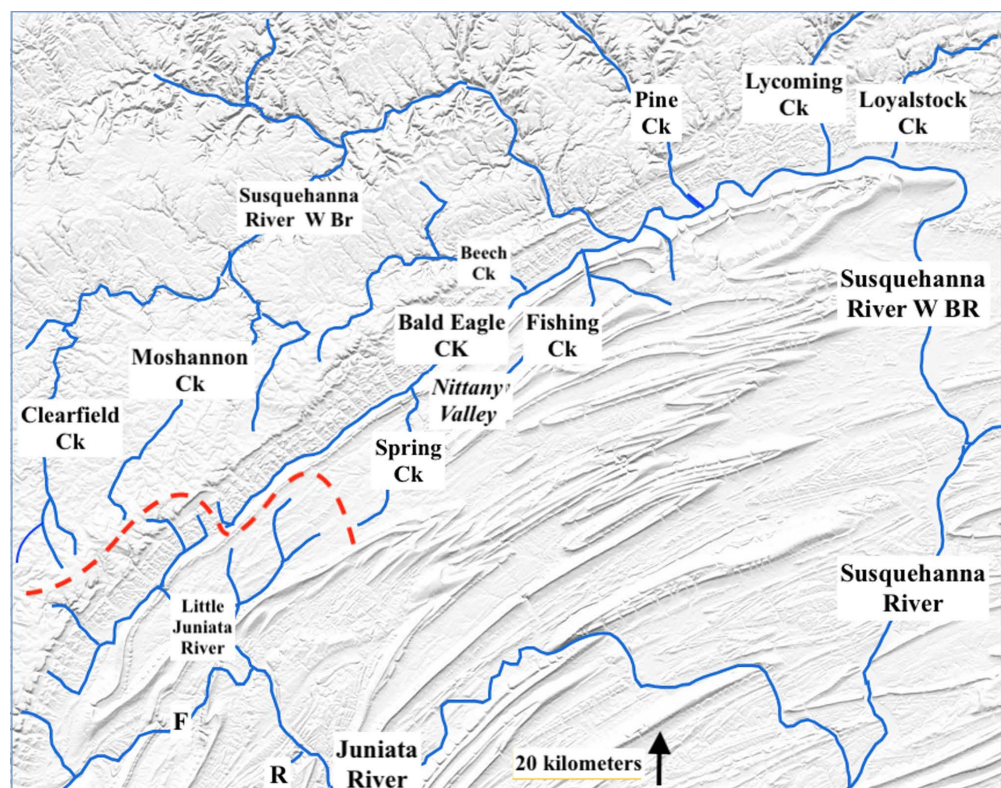


Figure 2. Modified map from the USGS National Map website showing drainage routes related to this paper's Bald Eagle through valley study area. The letters F and R identify the Juniata River Franks-town and Raystown Branches. The red dashed line shows where the WBSR-Little Juniata River drainage divide crosses the Bald Eagle through valley.

wide and approximately 300-meter deep through valley now located between the Barclay Mountain synclinal upland (rising to more than 700 meters to the southeast) and the Blossburg synclinal upland (rising to more than 700 meters to the northwest) which links southwest-oriented Lycoming Creek headwaters with northeast-oriented Towanda Creek headwaters (see **Figure 1** for location). Towanda Creek today flows in a northeast direction from its 375-meter-high drainage divide with Lycoming Creek to join the southeast-oriented North Branch Susquehanna River (NBSR) segment as a barbed tributary. The new glacial history paradigm described by Clausen [3] caused the author of this paper to notice that massive and prolonged southwest-oriented continental icesheet meltwater floods which initially flowed on a surface as high as or higher than today's Barclay Mountain and Blossburg synclinal uplands highest elevations could have eroded the valley between those two uplands and flowed toward today's northeast-oriented WBSR valley segment and the Bald Eagle through valley. That observation led to the new paradigm test reported here.

The Bald Eagle through valley also probably extends in a southwest and south direction across a low drainage divide (elevation about 360 meters), which separates northeast-oriented Little Juniata River headwaters from south-oriented Beaverdam Branch of the Juniata River headwaters. The Beaverdam Branch leaves the extended through valley to flow around the Brush Mountain southwestern end to join the north-oriented Frankstown Branch of the Juniata River, but another drainage divide with an elevation of about 345 meters separates south-oriented Beaverdam Branch headwaters from a tributary flowing to the north-oriented Frankstown Branch. Another drainage divide with an elevation of about 385 meters separates the north-oriented Frankstown Branch from south-oriented tributaries flowing to the Raystown Branch of the Juniata River. Further to the south another drainage divide (elevation about 415 meters) separates north-oriented Raystown Branch drainage from south-oriented Wills Creek drainage, which flows to the Potomac River, which eventually reaches the Atlantic Ocean via Chesapeake Bay.

1.3. The New Glacial History Paradigm Being Tested

The new glacial history paradigm being tested here describes immense and prolonged southwest-oriented continental icesheet meltwater floods which flowed across Pennsylvania. Using that new paradigm interpretation, it may be possible to explain the above-described Bald Eagle through valley northeast extension by huge and prolonged southwest-oriented meltwater floods which prior to headward erosion of the southeast-oriented NBSR valley (see **Figure 1**) eroded what was probably a rising and low relief surface which is now preserved if preserved at all by the highest Barclay Mountain and Blossburg synclinal upland elevations (now exceeding 700 meters). Deep erosion could have been accomplished by eroding what is now the Lycoming Creek drainage basin headward (in a northeast direction) between the Blossburg and Barclay Mountain synclinal uplands from the

Bald Eagle through valley and the now northeast-oriented WBSR valley segment location. Headward erosion of the southeast-oriented NBSR valley could have subsequently captured the southwest-oriented floodwaters which could have caused a massive flood flow reversal, so as to create the present-day northeast-oriented Towanda Creek drainage system and the Towanda Creek-Lycoming Creek (NBSR-WBSR) drainage divide.

The Allegheny Front and the Ridge and Valley topography according to such a new paradigm would have emerged as floodwaters systematically eroded deep valleys into a rising deep “hole” rim (the deep “hole” was created and occupied by a thick continental icesheet and a deep “hole” rim segment extended in a southwest-to-northeast direction across Pennsylvania) [3]. This new paradigm interpretation implies that prior to being captured by the headward erosion of deep valleys the southwest-oriented floodwaters flowed across central Pennsylvania in complexes of diverging and converging shallow channels on what was probably a low relief surface now preserved if preserved at all by today’s highest elevations. Until the headward erosion of deeper valleys lowered the regional baselevel the shallow flood flow channels permitted floodwaters to easily spill from one flood flow channel to another, including from channels on what was probably the rising Appalachian Plateau, across an actively developing Allegheny Front and into what is now the Bald Eagle through valley. This spillage of floodwaters from one channel to another would have supplied water to newly beheaded and reversed flood flow channels which explains how now northeast-oriented valleys obtained the necessary water for their erosion.

The new glacial paradigm interpretation also implies that immense and long-lived meltwater floods entered the now northeast-oriented WBSR valley and then flowed in today’s Bald Eagle through valley along the Allegheny Front in a southwest direction. If correct, the Bald Eagle through valley would have been eroded headward in a north and northeast direction from an actively eroding Potomac River drainage basin into a low relief and probably rising surface now preserved if preserved at all by the highest Allegheny Front elevations (similar to the highest Barclay Mountain and Blossburg synclinal upland elevations). Prior to being captured by valley headward erosion, the southwest-oriented floods would have flowed along both sides of today’s Allegheny Front escarpment (which was emerging by both uplift and erosion as floodwaters eroded deep valleys into the rising deep “hole” rim). In summary, the new paradigm implies that today’s topography was created as deep valleys eroded headward into the rising deep “hole” rim’s low relief surface to capture massive southwest-oriented floods in sequence from the southwest to the northeast.

1.4. Previous Interpretations

Most previous ideas about central Pennsylvania drainage system origins (including the research methods used to obtain those ideas) can be traced back in one way or another to an 1889 William Morris Davis “Rivers and Valleys of Pennsylvania”

paper, which was republished in 1909 [4]. In that paper, Davis, who ignored much of the then-available map evidence, struggled to explain how present-day Pennsylvania drainage routes and topography evolved during a more or less continuous erosion history that began in Permian time when a northwest-oriented drainage system flowed across Pennsylvania. Davis tried to explain how that Permian drainage system evolved into drainage systems seen today and concluded by saying “If this theory of the history of our rivers is correct, it follows that any one river as it now exists is of so complicated an origin that its development cannot become a matter of general study”.

According to Coates [5], a school of thought developed around modified forms of the Davis theory, which included work by Meyerhoff and Olmstead [6] who suggested there was no need for a reversal of drainage and that present-day streams had evolved from southeast-flowing Permian streams. In another modification, Ashley [7] proposed the landscape evolved from a former peneplain that no longer exists and had been differentially lowered over long periods of geologic time. Thompson [8] who worked primarily in the Potomac River drainage basin to the south of this paper’s study region assumed stream piracy could account for the drainage reversals which the Davis hypothesis required. Johnson [9] developed what Coates considered to be a second school of thought by proposing a sea transgressed across the region and deposited a Cretaceous sedimentary cover. He claimed present-day drainage routes are descendants of drainage routes that subsequently developed on that sedimentary cover although Strahler [10] and Groot [11] found no evidence to suggest that such a sediment cover had ever existed.

Butts and Moore [12] who worked in the Bald Eagle through valley region and who apparently favored the Ashley hypothesis explain how water gaps were eroded across Bald Eagle Mountain as follows: “The streams that occupy these gaps took their courses on the nearly level surface of the Kittatinny peneplain, which was topographically above the tops of ridges of the present day. During subsequent uplifts, they maintained their courses as the country rose and eroded their beds to lower levels, while the side streams wore down their valleys on the more easily erodible rocks between the resistant rocks of the ridges. Thus, the streams have sawed, so to speak, the gorges through the ridges”. They do not mention immense and prolonged southwest-oriented meltwater floods and imply the erosion was gradual over long periods of geologic time.

Pazzaglia *et al.* [13] in a more recent field guide discussion (related to the origin of a Susquehanna River water gap to the north of Harrisburg, Pennsylvania) briefly list hypotheses proposed up until that time as follows: 1) superposition which was proposed by Davis [4] (from an estuary on the Schooley peneplain) and by Johnson [9] (from an overall Cretaceous marine transgression); 2) headward erosion along zones of structural weakness which was proposed by Ashley [7], Meyerhoff and Olmstead [6], Thiesen [14], and Hoskins [15]; 3) thinning of the resistant sandstone ridges which has been proposed by Thompson [8] and Epstein [16]; and 4) determined by the front of a large overthrust sheet which was proposed by

Sevon [17]. Pazzaglia *et al.* [13] go on to say that proof or disproof of any of these “hypotheses is difficult because on the order of 9 km of rock has been removed since the Alleghenian deformation that produced the folds”.

Sevon [18] notes that “During the Pleistocene, at least one but possibly two glaciers impinged upon Bald Eagle Mountain in the area between Lock Haven and Williamsport. The ice dam formed by this impingement blocked the West Branch Susquehanna River and created glacial Lake Lesley”. The lake is assumed to have filled the Bald Eagle Creek valley and overflowed to the Little Juniata River. Williams [19] who first described glacial Lake Lesley noted gravels, unstratified slack water sands and silts and ice-rafted boulders in the Bald Eagle Creek valley. He also described evidence that large volumes of water must have flowed from the present-day Bald Eagle Creek valley into the Little Juniata River valley. Newlin and Hayes [20] recently described catastrophic flood evidence in the WBSR valley downstream from the hypothesized ice dam. However, Ramage *et al.* [21] note “The age and extent (depth and elevation) of the ice-dammed proglacial lake have been controversial” (the new paradigm suggests the controversies may have developed because headward erosion of deep valleys during massive southwest-oriented meltwater floods probably produced at least some the described Lake Lesley evidence).

2. Research Method

This study primarily used topographic maps and tools available at the USGS National Map website. However, previously published new paradigm literature was also reviewed to understand the new paradigm’s deep “hole” rim probable location. According to Clausen [3], the deep “hole” rim in the eastern United States followed the present-day Ohio River-Atlantic Ocean drainage divide northward into central Pennsylvania. Map study shows the Ohio River-Atlantic Ocean drainage divide follows the Allegheny Front crestline northward until near the Bald Eagle through valley’s southern end where it turns in a west direction to loop around the WBSR drainage basin. Based on that information it was assumed the deep “hole” rim in central Pennsylvania may have included Appalachian Plateau areas located to the northwest of the Allegheny Front as well as Ridge and Valley Province areas located to the southeast of the Bald Eagle through valley.

Several previously published papers used a new paradigm perspective when interpreting previously unexplained topographic map drainage system and erosional landform evidence and suggested that immense southwest-oriented floods flowed along the new paradigm’s identified deep “hole” rim (the Ohio River-Atlantic Ocean drainage divide) in regions located to the southwest of the Bald Eagle through valley. These regions include the Casselman River drainage basin [22], the Monongahela River drainage basin [23], and several Virginia and North Carolina Blue Ridge escarpment areas [24]-[26]. Based on these literature results and the author’s observation that the Lycoming Creek-Towanda Creek drainage divide through valley may have been eroded by massive southwest-oriented meltwater floods, it was assumed

immense southwest-oriented floods must have flowed across the central Pennsylvania Bald Eagle through valley region and that topographic maps of the Bald Eagle through valley region should record evidence of those floods.

Map study began by looking for through valleys which large south-oriented floods flowing across the study region (shown in **Figure 2**) might have eroded. In addition to the Bald Eagle through valley southern extension, which is located along the Allegheny Front base, a south-southwest oriented through valley extends from the Juniata River turn from a southeast to a northeast direction (seen along **Figure 2** southern edge) to the Potomac River and less obvious Appalachian Plateau through valleys link north-oriented Clearfield Creek with the south-oriented Little Conemaugh River (not shown in **Figure 2**). These valleys were considered to have also played a role in the Bald Eagle through valley's development.

Detailed topographic maps of areas in and adjacent to the entire Bald Eagle through valley from its southwestern end near Altoona to where the WBSR turns in a south direction near Williamsport were studied to determine the types of landform features needing to be explained. Identified features included numerous short southeast-oriented streams originating along the Allegheny Front slope or originating at gaps located along or near the Allegheny Front crest. Also identified were shallow southwest-to-northeast oriented through valleys along the lower Allegheny Front slope, which are now crossed by the drainage divides between the southeast-oriented streams. Also, needing to be explained is the water gap where the northeast-oriented Little Juniata River headwaters now turn in a southeast direction to flow between Brush Mountain and Bald Eagle Mountain.

Once typical landform features needing explanations were identified a decision was made that understanding why the Little Juniata River turns from flowing in a northeast direction in the Bald Eagle through valley's southern section to flow in a southeast direction through the 200 - 300-meter-deep water gap between Brush Mountain and Bald Eagle Mountain was critical if the Bald Eagle through valley and Allegheny Front origins were to be understood. As a result the study emphasized topographic map evidence which shows the Bald Eagle through valley section where the WBSR-Little Juniata River drainage divide now crosses the Bald Eagle through valley, several southeast-oriented streams flowing down the Allegheny Front slope, gaps along the Allegheny Front crestline, the Little Juniata River water gap, and now dismembered southwest-to-northeast oriented through valleys along the present-day Allegheny Front slope which are crossed by drainage divides between southeast-oriented streams which flow down the slope. These landform features became the starting point used to determine central Pennsylvania geomorphic history.

3. Results

3.1. West Branch Susquehanna River (WBSR)-Little Juniata River Drainage Divide

Figure 3 provides a detailed topographic map showing at the red number 1 where

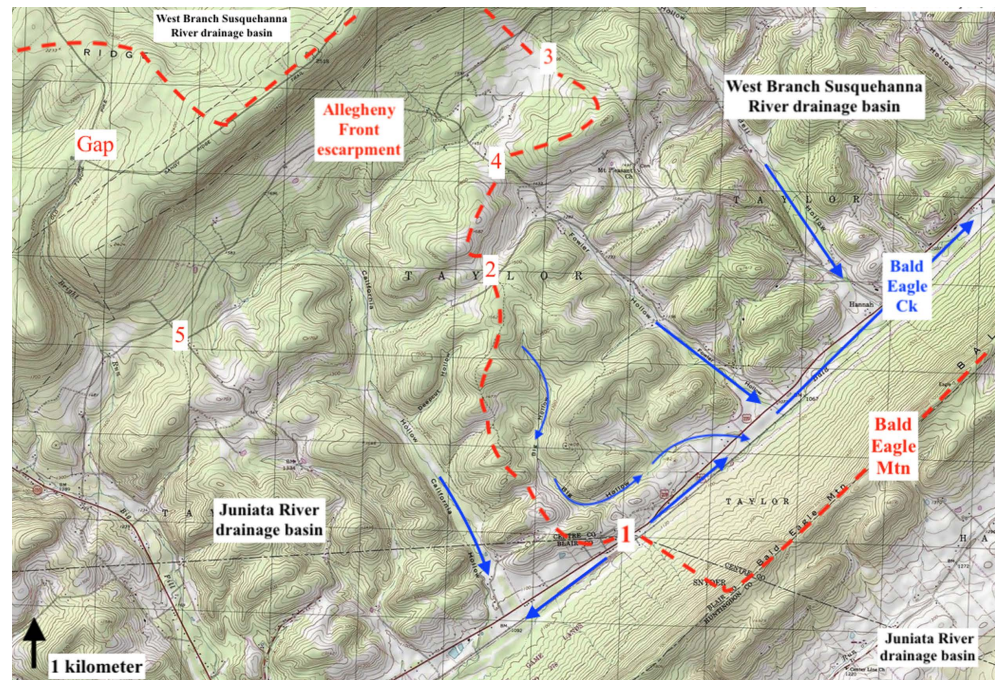


Figure 3. Modified topographic map from the USGS National Map website showing where the West Branch Susquehanna River (WBSR)-Juniata River drainage divide (red dashed line) crosses the Allegheny Front and Bald Eagle through valley. Red numbers identify locations discussed in the text. The contour interval is 20 feet (approximately 6 meters).

the WBSR-Little Juniata River drainage divide crosses the Bald Eagle through valley at an elevation of approximately 340 meters. Note how closely-spaced and roughly parallel southeast-oriented streams on both sides of the drainage divide flow down the Allegheny Front slope to join northeast-oriented Bald Eagle Creek as barbed tributaries (to the northeast of the number 1) and to join as normal tributaries the shorter southwest-oriented Little Juniata River tributary (to the southwest of the number 1 and which on the maps is also shown as Bald Eagle Creek, but which in this paper is referred to as Bald Eagle Creek South to distinguish it from the much longer northeast-oriented Bald Eagle Creek).

Closely spaced southeast-oriented streams flowing down the Allegheny Front slope are common all along the Bald Eagle through valley's length and are barbed tributaries where they flow to the northeast-oriented Little Juniata River headwaters, northeast-oriented Bald Eagle Creek, and the northeast-oriented WBSR segment. In fact, as seen in **Figure 2**, the WBSR enters the Bald Eagle through valley much like a barbed tributary. Barbed tributaries are evidence that a drainage reversal has taken place and the southeast-oriented tributaries suggest southwest-oriented flow was responsible for most of the Bald Eagle through valley erosion. Almost all of the southeast-oriented streams flowing into the Bald Eagle through valley begin today at least 150 meters higher than the Bald Eagle through valley floor elevation with some streams flowing from much higher elevations. These southeast-oriented streams are one piece of evidence seen in **Figure 3** that suggests massive southwest-oriented floods eroded the region as the Allegheny Front

was rising while massive and long-lived southwest-oriented floods were flowing across the region.

Most of the southeast-oriented stream valleys appear to have eroded headward to capture southwest-oriented flow moving in less obvious higher elevation southwest-to-northeast oriented through valleys now crossing drainage divides between the southeast-oriented streams. Number 2 identifies where the WBSR-Little Juniata River drainage divide crosses a less obvious southwest-to-northeast oriented through valley at an elevation of about 465 meters (about 125 meters higher than where the drainage divide crosses the Bald Eagle through valley floor). Number 3 identifies another southwest-to northeast oriented through valley that crosses the drainage divide at an elevation of about 470 meters. Number 4 identifies a northwest-to southeast oriented through valley that crosses the drainage divide at an elevation of about 470 meters and the number 5 identifies a southwest-to-northeast oriented through valley crossing the drainage divide between two southeast-oriented Bald Eagle Creek South tributaries at an elevation of about 470 meters.

These less obvious higher elevation southwest-to-northeast oriented through valleys may have been carved along more easily eroded bedrock zones, but also indicate that headward erosion of the southeast-oriented stream valleys captured multiple southwest-oriented streams of water and diverted the captured water in a southeast direction into what is now the deeper Bald Eagle through valley. There is no reason why southwest-oriented streams would flow along the Allegheny Front slope at an elevation 125 meters higher than the adjacent Bald Eagle through valley unless those southwest-oriented streams originated as channels in an anastomosing channel complex at a time when that 125-meter elevation difference did not exist (which suggests the Allegheny Front escarpment was emerging as floodwaters flowed across the region). The capture of southwest-oriented flood flow by the headward erosion of southeast-oriented stream valleys probably occurred when Allegheny Front emergence raised what are now less obvious through valleys above the Bald Eagle through valley elevation, which in turn enabled southeast-oriented stream valleys to erode headward (probably in sequence from the southwest to the northeast), so as to divert floodwaters from those now higher elevation flood flow channels into what was becoming a deeper southwest-oriented Bald Eagle through valley channel.

3.2. Gaps Located along the Allegheny Front

The southwest and southeast-oriented valley extending down the Allegheny Front slope downstream from where the word “Gap” is located provides additional evidence in **Figure 3** for the new paradigm’s massive and prolonged southwest-oriented floods. Water to erode that valley must have come from what is today the WBSR drainage basin to the northwest of the Allegheny Front crest (north-oriented drainage to the north of the word “Gap” flows to now north-oriented Moshannon Creek, which in turn flows to the WBSR, see **Figure 2**). Even more obvious examples

of gaps where south-oriented floodwaters which had flowed across the now north-oriented Clearfield and Moshannon Creek drainage basins entered the Bald Eagle through valley are seen in **Figure 4**, which shows in less detail the region to the southwest of **Figure 3**. Such gaps support new paradigm predictions that southwest-oriented floodwaters initially flowed freely across the entire region and were captured by the headward erosion of deep valleys as the regional topography emerged.

Figure 4 shows the Tyrone, Pennsylvania area (to the southwest in **Figure 3**) where northeast-oriented Little Juniata River headwaters turn to leave the Bald Eagle through valley and to flow in a southeast direction through the 200 - 300-meter-deep water gap now separating Bald Eagle and Brush Mountains. Bald Eagle Creek South flows for about 12 kilometers (as a crow flies) in a southwest direction from the WBSR-Little Juniata River drainage divide seen in **Figure 3** to where it now joins the northeast-oriented Little Juniata River as a barbed tributary. In contrast, the Little Juniata River flows in a northeast direction for more than twice that distance before turning to flow in a southeast direction. Some southeast-oriented tributaries are highlighted as they flow from the Allegheny Front to join northeast-oriented Little Juniata River headwaters and southwest-oriented Bald Eagle Creek South to emphasize the presence of those southeast-oriented streams flowing down what is now the Allegheny Front slope and the presence of through valleys crossing the drainage divides between those southeast-oriented streams.

Several very closely spaced gaps in **Figure 4** at letter A show where a stream of

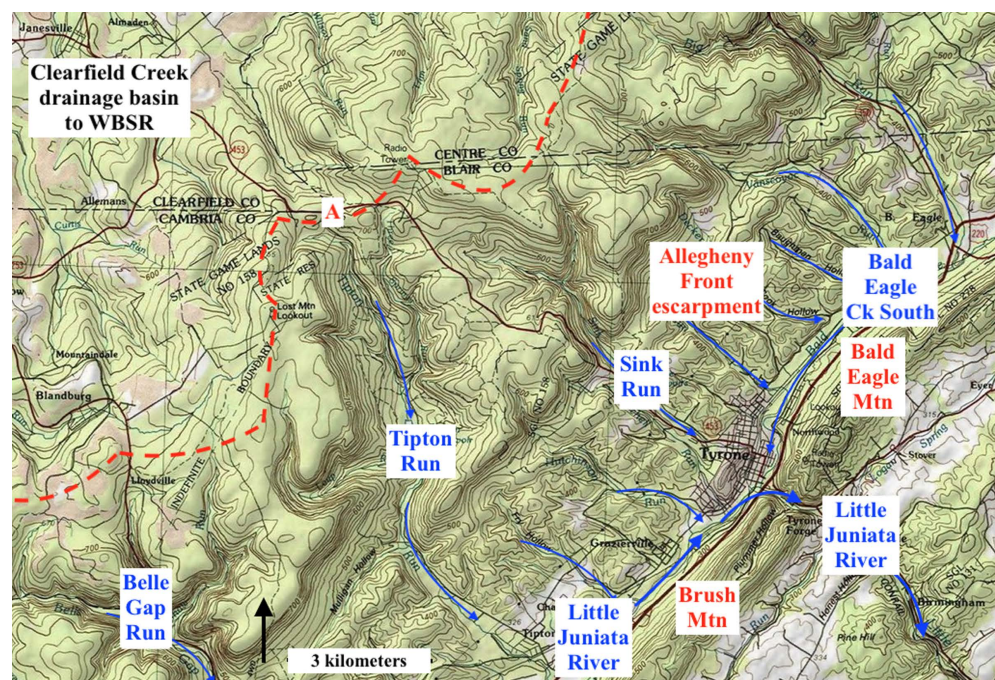


Figure 4. Modified topographic map from the USGS National Map website showing the WBSR-Little Juniata River drainage divide and the Little Juniata River water gap near Tyrone, PA immediately to the southwest of the contour interval is 20 meters in **Figure 3**.

south-oriented water from what is now the north-oriented Clearfield Creek drainage basin diverged into two streams with one stream flowing in a southeast direction along the Sink Run alignment and the other flowing in a south and then southwest direction along the Tipton Run alignment. Note how southeast-oriented Sink Run joins the Little Juniata River at Tyrone where the Little Juniata River turns from flowing in a northeast direction to flow in a southeast direction between Brush and Bald Eagle Mountains. This relationship suggests headward erosion of a southeast-oriented valley on the Little Juniata River-Sink Run alignment reached the map area in **Figure 4** before the Bald Eagle through valley existed and continued to erode headward in a northwest direction to capture south-oriented water that had been flowing across the now north-oriented Clearfield Creek drainage basin.

A southeast-oriented valley could not have eroded headward on the southeast-oriented Little Juniata River-Sink Run alignment to reach the gaps at the letter A if Bald Eagle-Brush Mountain, the Bald Eagle through valley, and the Allegheny Front had existed at that time. Tipton Run and the less obvious through valleys crossing drainage divides between the southeast-oriented streams, which now flow into the Bald Eagle through valley provide clues that can help in determining what happened. Note how Tipton Run flows from the gaps at the letter A first in a south, then southwest, and finally southeast direction as it enters the Bald Eagle through valley. Those direction changes can be interpreted to have developed as the Tipton Run route evolved during various stages of the Allegheny Front emergence and the Bald Eagle through valley formation.

The first Bald Eagle through valley and Allegheny Front development stage recorded by Tipton Run direction changes are seen in the Tipton Run southwest-oriented valley segment which is aligned with a high elevation through valley which links the Tipton Run valley with the Belle Gap Run valley. The floor elevation of that through valley at the Tipton Run-Belle Gap Run drainage divide is about 535 meters (about 150 meters higher than the nearby Little Juniata River elevation today). The gap leading to Tipton Run at the letter A is about 15 meters deeper than the lowest gap leading to Sink Run, which suggests Tipton Run valley headward erosion captured southeast-oriented floodwater which had been flowing along the Sink Run-Little Juniata River alignment. That capture, which diverted floodwaters in a southwest direction probably occurred when a southwest-oriented valley on the now southwest-northeast oriented Tipton Run-Belle Gap Run through valley alignment eroded headward into the map area in **Figure 4**. At that time, Allegheny Front emergence must have been just beginning and the elevation difference between that through valley and today's northeast-oriented Little Juniata River valley did not exist (otherwise, the captured water would have flowed into what is now the much deeper valley).

The second Bald Eagle through valley and Allegheny Front development event recorded by Tipton Run direction changes is Allegheny Front emergence, which raised the Tipton Run-Belle Gap Run through valley above what must have been

a parallel southwest-oriented flood flow channel located on the present-day north-east-oriented Little Juniata River alignment. That emergence enabled a southeast-oriented stream valley to erode headward from what at that time was becoming the deeper channel on the present-day Little Juniata River alignment, so as to capture southwest-oriented flood flow that was moving in the now abandoned Tipton Run-Belle Gap through valley. That capture, like the Tipton Run capture of southeast-oriented water moving on the Sink Run alignment could not have occurred unless there were sufficient floodwaters to spill across drainage divides. In summary, the Tipton Run direction changes are evidence that Allegheny Front emergence was occurring as southwest-oriented floodwaters were flowing across the region.

3.3. The Little Juniata River Water Gap at Tyrone

The lowest point along the WBSR-Little Juniata River drainage divide at the letter A in **Figure 4** has an elevation of about 685 meters. Allegheny Front crest elevations exceed 800 meters on either side of the letter A gaps suggesting the southeast-oriented valley on today's southeast-oriented Little Juniata River-Sink Run alignment must have eroded a 100-meter-deep or deeper valley into whatever surface existed after it captured some of the south-oriented floodwaters which had been flowing across what is today's north-oriented Clearfield Creek drainage basin (which means the WBSR valley to the north of the Clearfield Creek drainage basin did not exist at that time). Today the Little Juniata River flows at an elevation of about 265 meters through a 200 - 300-meter-deep water gap between the adjacent Bald Eagle and Brush Mountains (their top elevations are now between 500 and 600 meters).

The southeast-oriented valley on the Little Juniata-Sink Run alignment established the Little Juniata River's water gap's location before the Bald Eagle through valley and the Allegheny Front existed. As seen in **Figure 2**, after leaving the water gap the Little Juniata River flows in a southeast direction for a considerable distance as it becomes the Juniata River, which eventually turns abruptly in a northeast direction. That southeast-to-northeast turn is made in a southwest-oriented through valley now drained by a north-oriented Juniata River tributary (Aughwick Creek) and further to the south by a south-oriented Potomac River tributary (Licking Creek). Headward erosion of that through valley was from the Potomac River which suggests the southeast-oriented valley on the Sink Run-Little Juniata River alignment eroded headward from it in a northwest direction. Headward erosion of the much deeper Juniata River valley subsequently captured and reversed southwest-oriented flood flow moving in that southwest-to-northeast through valley, so as to create the northeast-oriented Juniata River segment seen in **Figure 2** and in doing so captured the southeast-oriented flow moving on the Sink Run-Little Juniata River alignment. This sequence of captures supports a new paradigm prediction that river valleys now draining to the Atlantic Ocean eroded headward in a southwest-to-northeast sequence.

Headward erosion of the southeast-oriented valley on the Sink Run-Little Juniata River alignment from the actively eroding Potomac River drainage system lowered local baselevel by about 100 meters (as determined by the depth of the gaps at letter A in **Figure 4**). By the time southeast-oriented valley headward erosion on the Sink Run-Little Juniata River alignment reached the Tyrone area headward erosion of a different Potomac River drainage system valley was also eroding headward in north-northeast direction along the developing Allegheny Front. That different valley was responsible for the first Tipton Run direction change and for perhaps capturing some or all of the floodwaters flowing on the southeast-oriented Sink Run-Little Juniata River alignment.

As south-oriented valleys from the actively eroding Potomac River drainage basin eroded headward into the Bald Eagle through valley region, the much deeper downstream Juniata River valley reversed the flow direction in the present-day through valley where the northeast-oriented Juniata River segment is now, and by doing so captured the southeast-oriented flow that was moving to that valley on the Sink Run-Little Juniata River alignment. The much deeper Juniata River valley head then eroded headward first in a southwest direction (along the reversed flood flow channel) and then in a northwest direction on the Little Juniata River-Sink Run alignment to reach what by that time was the developing water gap between Brush and Bald Eagle Mountains (which at that time were probably emerging as valleys were being eroded around them). Previous to that time southwest-oriented floodwaters flowing through the Bald Eagle through valley upon reaching the Tyrone area probably diverged with one flood flow channel located along the Allegheny Front along the Bald Eagle through valley southern extension and the other channel being on the southeast-oriented Little Juniata River-Juniata River alignment. However, headward erosion of the deeper Juniata River valley head into the Tyrone area lowered baselevel even more and caused a flow reversal in what is now the Bald Eagle through valley section where today the Little Juniata River headwaters flow in a northeast direction.

At the same time deep “hole” rim uplift continued to raise the Allegheny Front and the even deeper Susquehanna River and WBSR valley continued to erode headward in a north direction until it reached the Bald Eagle Mountain northeast end. WBSR valley headward erosion around the Bald Mountain northeast end then captured flood flow, which was moving from the through valley between the Blossburg and Barclay Mountain synclinal uplands to the Bald Eagle through valley and reversed the flow direction in much of the Bald Eagle through valley section located to the northeast of Tyrone, so as to create what are today northeast-oriented Bald Eagle Creek and the northeast-oriented WBSR segment drainage routes (from which the southeast-oriented WBSR valley segment to the northwest of the Bald Eagle through valley eroded headward to capture and also reverse southwest-oriented floodwaters still flowing across the Appalachian Plateau). The final stage in the development of central Pennsylvania’s Susquehanna River drainage route occurred as headward erosion of the southeast-oriented NBSR segment

seen in **Figure 1** captured the southwest-oriented flood flow moving to the newly eroded WBSR valley and created the NBSR-WBSR drainage divide. With that capture floodwaters could no longer reach the Bald Eagle through valley and the regional topography has not significantly changed.

3.4. The Evolution of the Susquehanna and Juniata River Drainage Systems

The Bald Eagle through valley and its southern and northeastern extensions provide a good starting point when wanting to determine how the Pennsylvania Susquehanna and Juniata River drainage systems developed. Water flowing in one direction or the other eroded the through valley now located along Allegheny Front base. That water probably flowed toward the Atlantic Ocean, which means it must have flowed in a south direction from or across the WBSR drainage basin and what are now Juniata River tributary drainage basins to reach the Potomac River drainage basin. Drainage divides now separate independent drainage routes, which drain the now individual through valley floor segments. If south-oriented water originally flowed in the easily seen-through valley, simple logic requires the drainage divides now separating the through valley's different drainage basins to have been formed by multiple captures of the south-oriented water in a south-to-north sequence.

The capture sequence can be summarized as follows: First, Juniata River Raystown Branch valley headward erosion captured south-oriented water moving toward a previously eroded Potomac River valley. Second, Juniata River Frankstown Branch valley headward erosion next captured south-oriented water moving to a previously eroded Raystown Branch valley. Third, Beaverdam Branch valley headward erosion captured south-oriented water moving to the Frankstown Branch valley. Fourth, Little Juniata River valley headward erosion captured water moving to the Beaverdam Branch valley and reversed flow on much of the beheaded segment to create the northeast-oriented Little Juniata River headwaters. Fifth, headward erosion of the WBSR valley around the Bald Eagle Mountain northeast end captured southwest-oriented water which had been moving to the previously eroded Little Juniata River valley and reversed flow in much of the Bald Eagle through valley to create northeast-oriented Bald Eagle Creek and the northeast-oriented WBSR segment. And sixth, headward erosion of the southeast-oriented NBSR valley captured water moving between the Blossburg and Barclay Mountain synclinal uplands toward the WBSR valley, which caused a reversal of flow on the northeast end of that beheaded flow route, so as to create today's northeast-oriented Towanda Creek drainage basin.

4. Discussion

Previous investigators, had they trusted what the topographic map drainage system and erosional landform evidence showed, could have developed some of the new paradigm key points by explaining how the Bald Eagle through valley (and

its northeastern and southern extensions) capture events occurred. What probably stopped investigators was that the new paradigm key points conflict with what were and still are commonly accepted interpretations of Pennsylvania's glacial history. Key accepted paradigm interpretations as briefly expressed by Braun [27] include multiple glacial advances which reached to very similar locations in both northeastern and northwestern Pennsylvania so that the mapped boundaries of the different glacial advances are remarkably close together and parallel to each other. This accepted paradigm interpretation also assumes the glacial advances moved across a preglacial topographic surface somewhat similar to today's topographic surface and which was mostly drained by preglacial rivers and streams, including the Susquehanna and Juniata Rivers, which flowed in many of the same valleys that exist today.

The accepted glacial history paradigm used by Braun and other previous investigators and the new paradigm (which was used in this paper to interpret detailed topographic map drainage systems and erosional landform evidence) are incommensurable and describe fundamentally different glacial histories. Kuhn [28] discusses scientific paradigms and how such paradigms enable scientists to interpret observed evidence and to advance their discipline by building new interpretations on top of previously made interpretations. Kuhn points out that most scientists do what he calls normal science which is to use new evidence to further flesh out accepted paradigm details. When doing normal science, scientists rarely question their accepted paradigm, even when encountering anomalous evidence that their accepted paradigm cannot satisfactorily explain. Frequently, anomalous evidence is set aside and left for future scientists to explain. Rarely do scientists explore different paradigms which may explain what their accepted paradigm cannot explain.

The detailed topographic map drainage system and erosional landform evidence used in the study reported here from the accepted paradigm perspective represents anomalous evidence which instead of being explained by previous workers was set aside and left for future researchers to explain. According to Clausen [3], most of the readily available and well-mapped USGS detailed topographic map drainage system and erosional landform evidence in Pennsylvania (and throughout the United States) has been set aside and was and continues to be ignored. It is difficult to understand how the geology research community can claim to understand Pennsylvania glacial history when nearly all of the well-mapped drainage systems and erosional landform topographic map evidence which covers the entire state has been set aside as anomalous evidence (because the accepted paradigm cannot explain it) and has never been satisfactorily explained.

According to Kuhn paradigms are neither correct or incorrect, but need to be judged based on their ability to explain observed evidence and to open up new research opportunities. The study reported here demonstrates the new paradigm can explain most Bald Eagle through valley region detailed topographic map

drainage system and erosional landform evidence and for the first time has used that detailed topographic map evidence to describe Pennsylvania Susquehanna River drainage system development details. At the same time, the study reported here makes no claim the new paradigm has yet satisfactorily explained the field evidence that glacial geologists have used when constructing their currently accepted interpretation of Pennsylvania's glacial history.

Ideally Pennsylvania glacial geologists need to adopt a glacial history paradigm able to satisfactorily explain both types of evidence. At least to date, the two fundamentally different paradigms explain two completely different sets of observable geologic evidence. Future work is needed to determine if some or all of the field evidence that Pennsylvania glacial geologists have used to describe what are now considered to be different glacial advances can be reinterpreted to have been deposited by massive and prolonged continental icesheet meltwater floods, which is what the new paradigm implies.

5. Conclusion

Drainage divides now crossing the Bald Eagle through valley and its northeast and southern extensions and a new paradigm, which describes immense and prolonged southwest-oriented continental icesheet meltwater floods, which initially flowed across a low relief and probably gradually rising surface (now preserved if preserved at all by central Pennsylvania's highest elevations), can be used to construct an internally consistent Pennsylvania Susquehanna River drainage system development history, which also appears to explain most if not all of the detailed topographic map drainage system and erosional landform evidence. Types of drainage system and erosional landform evidence that appear to have been explained include through valleys (valleys now crossing drainage divides), drainage route directions, barbed tributaries, water and wind gaps, and river and stream direction changes. The new paradigm is fundamentally different from Pennsylvania's commonly accepted glacial history paradigm and further work is needed to demonstrate how the new paradigm explains additional Pennsylvania drainage system and erosional landform features and how it can explain field evidence, which glacial geologists have used to describe the commonly accepted Pennsylvania glacial history paradigm.

Acknowledgements

This paper would not have been possible without the work of thousands of unknown United States Geological Survey and Pennsylvania Geological Survey employees and contractors who mapped and made available the drainage system and erosional landform evidence seen on the topographic maps now available at the United States Geological Survey National Map website.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

- [1] Thornbury, W.D. (1965) Regional Geomorphology of the United States. John Wiley and Sons.
- [2] Berg, T.M., Edmunds, W.E., Geyer, A.R., Glover, A.D., Hoskins, D.M., Maclachlan, D.B., Root, S.I., Sevon, W.D. and Socolow, A.A. (1980) Geologic Map of Pennsylvania (2nd Edition). Pennsylvania Geological Survey.
- [3] Clausen, E. (2023) The Topographic Map Mystery: Geology's Unrecognized Paradigm Problem. Xlibris.
- [4] Davis, W.M. (1909) The Rivers and Valleys of Pennsylvania. Kessinger Publishing.
- [5] Coates, D.R. (1963) General Geology of South-Central New York. In: *35th Annual Meeting*, Binghamton, 3-4 May 1963, 19-57.
https://www.nysga-online.org/wp-content/uploads/2022/03/1963_bookmarked.pdf
- [6] Meyerhoff, H.A. and Olmsted, E.W. (1936) The Origins of Appalachian Drainage. *American Journal of Science*, **5**, 21-42. <https://doi.org/10.2475/ajs.s5-32.187.21>
- [7] Ashley, G.H. (1935) Studies in Appalachian Mountain Sculpture. *Geological Society of America Bulletin*, **46**, 1395-1436. <https://doi.org/10.1130/gsab-46-1395>
- [8] Thompson, H.D. (1949) Drainage Evolution in the Appalachians of Pennsylvania. *Annals of the New York Academy of Sciences*, **52**, 33-62.
<https://doi.org/10.1111/j.1749-6632.1949.tb55486.x>
- [9] Johnson, D.W. (1931) Stream Sculpture on the Atlantic Slope. Columbia University Press, 142 p.
- [10] Strahler, A.N. (1945) Hypotheses of Stream Development in the Folded Appalachians of Pennsylvania. *Geological Society of America Bulletin*, **56**, 45-87.
[https://doi.org/10.1130/0016-7606\(1945\)56\[45:hosit\]2.0.co;2](https://doi.org/10.1130/0016-7606(1945)56[45:hosit]2.0.co;2)
- [11] Groot, J.J. (1955) Sedimentary Petrology of the Cretaceous Formations of Northern Delaware in Relation to Paleogeographic Problems. *Delaware Geological Survey Bulletin*, **5**, 25-26.
<https://www.dgs.udel.edu/sites/default/files/publications/bulletin5e.pdf>
- [12] Butts, C. and Moore, E.S. (1936) Geology and Mineral Resources of the Bellefonte Quadrangle, Pennsylvania. United States Geological Survey Bulletin 855.
<http://dx.doi.org/10.3133/b855>
- [13] Pazzaglia, F.J., Braun, D.D., Pavich, M., Bierman, P., Potter, N., Merritts, D., *et al.* (2006) Rivers, Glaciers, Landscape Evolution, and Active Tectonics of the Central Appalachians, Pennsylvania and Maryland. In: Pazzaglia, F.J., Ed., *GSA Field Guide 8: Excursions in Geology and History: Field Trips in the Middle Atlantic States*, Geological Society of America, 169-197. [https://doi.org/10.1130/2006.fld008\(09\)](https://doi.org/10.1130/2006.fld008(09))
- [14] Thiesen, J.P. (1983) Is There a Fault in Our Gap? *Pennsylvania Geology*, **14**, 5-11.
- [15] Hoskins, D.M. (1987) The Susquehanna River Water Gaps near Harrisburg, Pennsylvania. In: Roy, D.C., Ed., *Centennial Field Guide Volume 5: Northeastern Section of the Geological Society of America*, Geological Society of America, 47-50.
<https://doi.org/10.1130/0-8137-5405-4.47>
- [16] Epstein, J.B. (1966) Structural Control of Wind Gaps and some Water Gaps and of Stream Capture in the Stroudsburg Area, Pennsylvania and New Jersey. United States Geological Survey Professional Paper 550-B, B80-B86.
- [17] Sevon, W.D. (1986) Susquehanna River Water Gaps: Many Years of Speculation. *Pennsylvania Geology*, **17**, 4-7.
- [18] Sevon, W.D. (1994) River on a Rampage. *Pennsylvania Geology*, **24**, 2-7.

-
- [19] Williams, E.H. (1895) Notes on the Southern Ice Limit in Eastern Pennsylvania. *American Journal of Science*, **3**, 174-185. <https://doi.org/10.2475/ajs.s3-49.291.174>
- [20] Newlin, J.T. and Hayes, B.R. (2015) Hydraulic Modeling of Glacial Dam-break Floods on the West Branch of the Susquehanna River, Pennsylvania. *Earth and Space Science*, **2**, 229-243. <https://doi.org/10.1002/2015ea000096>
- [21] Ramage, J.M., Gardner, T.W. and Sasowsky, I.D. (1998) Early Pleistocene Glacial Lake Lesley, West Branch Susquehanna River Valley, Central Pennsylvania. *Geomorphology*, **22**, 19-37. [https://doi.org/10.1016/s0169-555x\(97\)00053-6](https://doi.org/10.1016/s0169-555x(97)00053-6)
- [22] Clausen, E. (2021) Topographic Map Interpretation Techniques Used to Determine Casselman River Drainage Basin History, Maryland and Pennsylvania: A New Paradigm Demonstration Paper. *The Pennsylvania Geographer*, **59**, 33-56.
- [23] Clausen, E. (2022) How a New Cenozoic Geology and Glacial History Paradigm Explains Anomalous Monongahela River Drainage Basin Topographic Map Evidence, PA, WV and MD, USA. *Earth Science Research*, **11**, 47-63. <https://doi.org/10.5539/esr.v11n1p47>
- [24] Clausen, E. (2023) Eastern Continental Divide Origin in the Blacksburg, Virginia Area Determined by Topographic Map Interpretation, USA. *Journal of Geography and Geology*, **16**, 1-16. <https://doi.org/10.5539/jgg.v16n1p1>
- [25] Clausen, E. (2023) Use of the 1893 Cranberry, North Carolina Topographic Map to Determine Blue Ridge Escarpment Area Drainage System and Erosional Landform Origins, USA. *Open Journal of Geology*, **13**, 1220-1239. <https://doi.org/10.4236/ojg.2023.1311052>
- [26] Clausen, E. (2023) Use of French Broad River Drainage Basin Topographic Map Evidence Upstream from Asheville, North Carolina to Test a New Geology and Glacial History Paradigm, USA. *Journal of Geography and Geology*, **15**, 1-15. <https://doi.org/10.5539/jgg.v15n2p1>
- [27] Braun, D. (2022) Pleistocene Evolution of the Slippery Rock Creek Gorge. In: Anthony, R. and Fehrs, E., Eds., *Dating in the Pleistocene. Establishing a Glacial Chronology in Northwestern Pennsylvania*, 86th Annual Field Conference of the Pennsylvania Geologists, 37-43. https://www.fcopg.org/files/ugd/e9c798_a1d6e0a59f4a48d19d7a3eb6d09cbf29.pdf
- [28] Kuhn, T. (1970) *The Structure of Scientific Revolutions: Second Edition, Enlarged*. University of Chicago Press, 210 p.