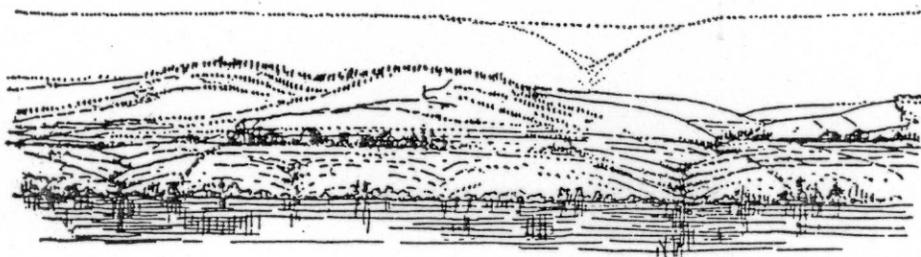


The
HARRISBURG AREA GEOLOGICAL SOCIETY
in cooperation with the
20th ANNUAL GEOMORPHOLOGY SYMPOSIUM

Presents a Field Trip with Guidebook

October 20, 1989

THE RIVERS AND VALLEYS
OF PENNSYLVANIA
THEN AND NOW



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THE RIVERS AND VALLEYS
OF PENNSYLVANIA
THEN AND NOW

by

W. D. Sevon

Pennsylvania Geological Survey

with contributions by

Duane D. Braun, Bloomsburg University

and

Edward J. Ciolkosz, The Pennsylvania State University

Copies may be obtained from:

Harrisburg Area Geological Society
c/o Pennsylvania Geological Survey
P. O. Box 2357
Harrisburg, PA 17105



Frontispiece. William Morris Davis in typical field pose. Sketch by Brian Kratzer from photo taken in 1931 (Chorley and others, 1973, Frontispiece; King and Schumm, 1980, Photo 2).

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Front cover: Davis (1889, Figure 8, p. 202)

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Top: Lesley (1892, p. 277)

Bottom: Lesley (1892, p. 281)

THE RIVERS AND VALLEYS OF PENNSYLVANIA: THEN AND NOW

"In much wisdom is much grief: and he that increaseth knowledge increaseth sorrow." Ecclesiastes 1:18

INTRODUCTION

It is now 100 years since the classic paper "The rivers and valleys of Pennsylvania" by William Morris Davis was published in the first volume of National Geographic Magazine (v. 1, no. 3, p. 183-253). It was this paper which brought to the attention of the geological community the concepts of Appalachian landscape evolution which are still being argued.

Davis presented a hypothesis of landscape evolution based on the paradigms of his time. He did so with insight and an intellectual desire to resolve the issue at hand. I will briefly review the principal ideas of Davis' paper as regards the evolution of Pennsylvania's landscape, discuss the ideas of some subsequent workers, and then look at Davis' ideas in the perspective of the paradigms of today. With the background set, the remainder of the guidebook will be devoted to the problems of interpreting the landscape we see today in southeastern Pennsylvania.

DAVIS' MODEL

Davis recognized, along with other geologists of his time, that the sedimentary sequence in the Appalachian Basin was derived from a source area which lay some 30 to 60 km southeast of the present position of Blue Mountain (Figure 1). He indicated that the area represented some ancient land which was added to by the Taconic Orogeny, and that the basin was filled by the end of the Pennsylvanian.

Davis was well aware that the culminating orogenic event in Pennsylvania was the Alleghanian, or as he called it, the Permian deformation. He noted (p. 194) that ". . . folds began to rise in the southeast . . . some of them having begun here while coal marshes were still forming farther west; . . ." These folds produced the ". . . enormous relief of the Permian surface that must have been measured in tens of thousands of feet at the time of its greatest strength." (p. 222).

In his reconstruction of the Permian constuctional topography (Figure 2), Davis recognized (p. 222) the ". . . great Kittatinny or Cumberland highland, C, C, on the southeast, backed by the older mountains of Cambrian and Archean rocks, falling by the Kittatinny slope to the synclinal lowland troughs of the central district." To the west Davis reconstructed ". . . the great Nittany highland, . . ." (N in Figure 2) as the highest part of the deformed foreland basin. As a result of his reconstruction of post-orogeny topography, Davis was forced to conclude that drainage development was the result of structural form and thus ultimately developed a course of flow to the northwest through the Anthracite basins which he conceived to be a lowland and even a lake.

TOPOGRAPHICAL MAP OF PENNSYLVANIA, COLORED FOR THE PRINCIPAL GEOLOGICAL FORMATIONS.

BY J. PETER LESLEY, PHILADELPHIA.

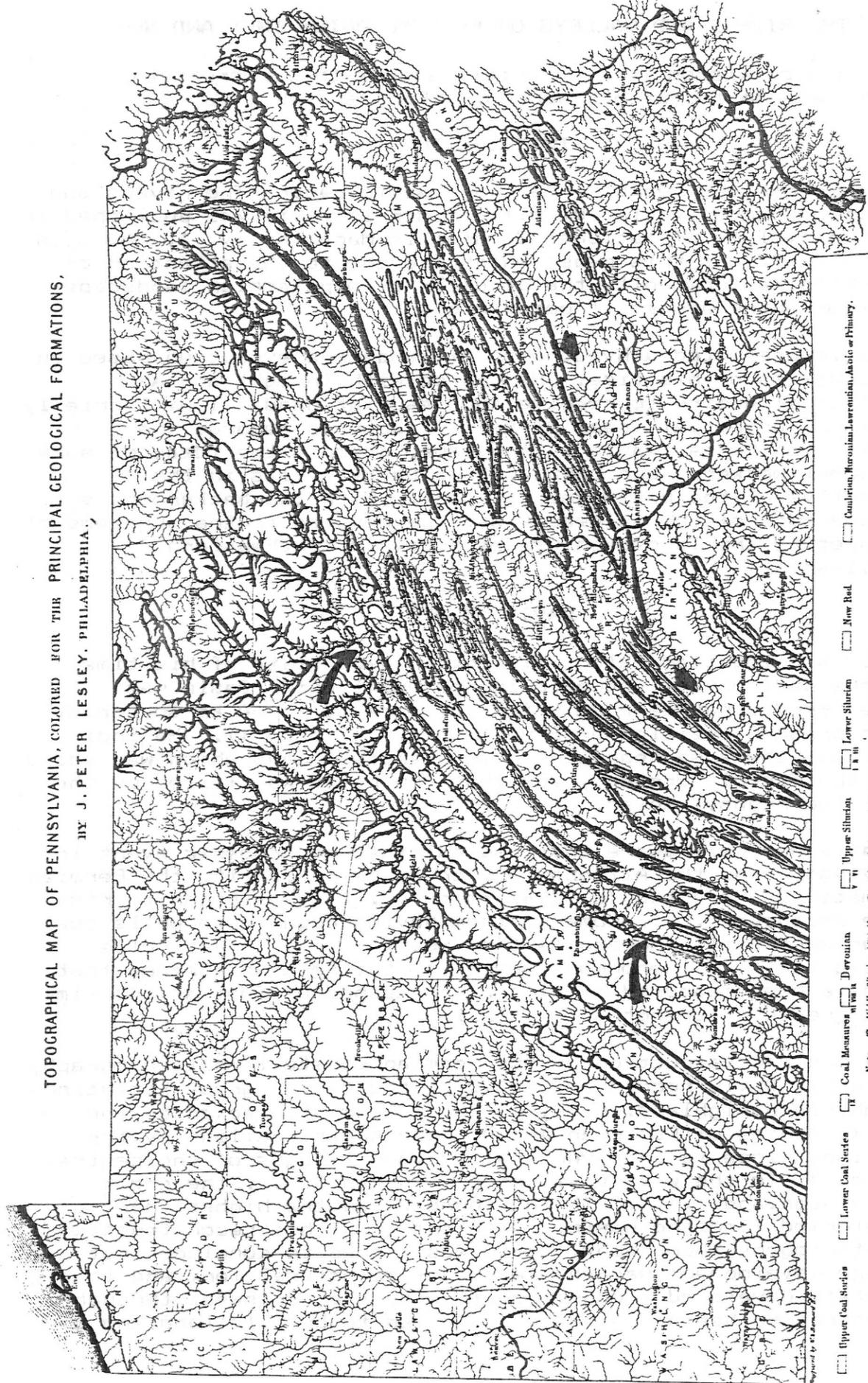


Figure 1. Topographic map of Pennsylvania (Lesley, 1876). Broad arrows point to Blue Mountain (Kittatinny Mtn. in northeast); curved arrows, to the Allegheny Front.

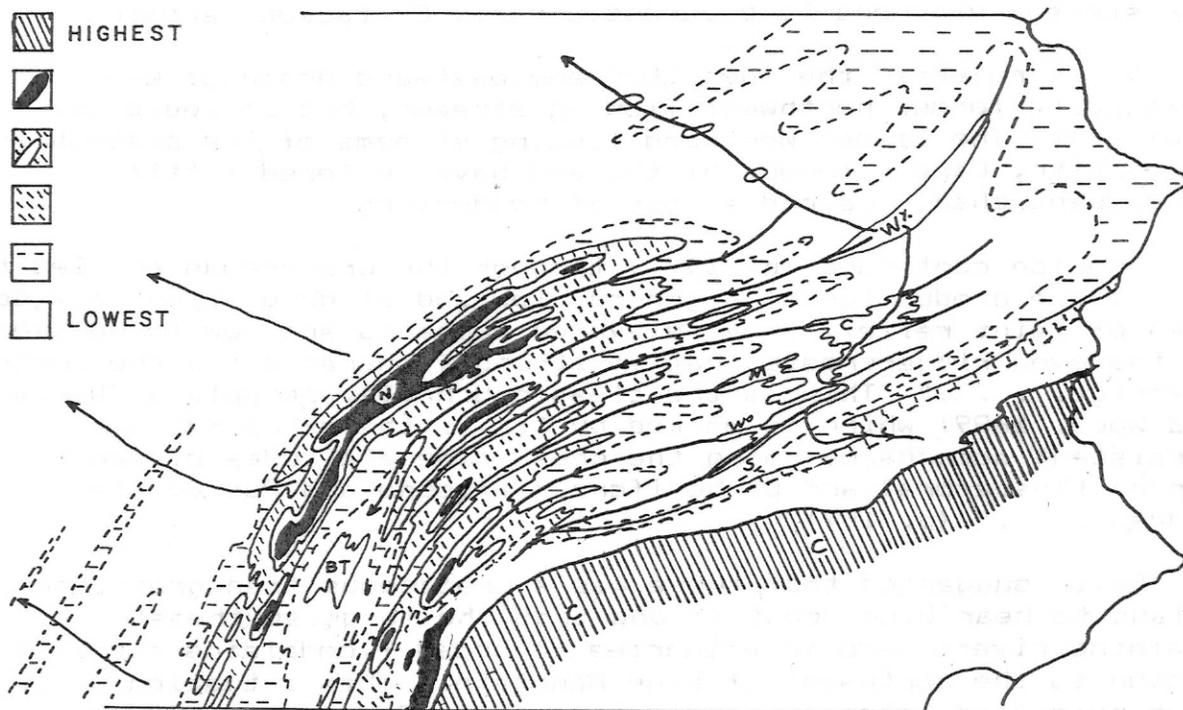


Figure 2. Post-orogenic topography and drainage as visualized by Davis (1889, Figure 21, p. 223). "Thus we have the great Kittatinny or Cumberland highland, C, C, on the southeast, backed by the older mountains of Cambrian and Archean rocks, falling by the Kittatinny slope to the synclinal lowland troughs of the central district. . . .What would be the drainage of such a country? Deductively we are led to believe that it consisted of numerous streams as marked in full lines on the figure, following synclinal axes until some master streams led them across the intervening anticlinal ridges at the lowest points of their crests and away into the open country to the northwest. All the enclosed basins would hold lakes, overflowing at the lowest part of the rim. The general discharge of the whole system would be to the northwest. . . .The master stream of the region is the great Anthracite river, carrying the overflow of the Anthracite lakes off to the northwest. . . ." (Davis, 1889, p. 222-224).

Davis considered (p. 194) that "During and for a long time after this period of mountain growth, the destructive processes of erosion wasted the land and lowered the surface. An enormous amount of material was thus swept away and laid down in some unknown ocean bed."

Davis observed (p. 194) that in the post-orogenic period there was ample time to erode most of the Paleozoic rocks and reduce the surface that the Newark was deposited on to one of ". . . no great relief or inequality; . . ." He noted (p. 196) that Newark (Triassic) deposition occurred in a trough and that border conglomerates indicated adjacent areas of ". . . strong topography and a strong transporting agent to the northwest . . ." It was at this time that a reversal in drainage to the southeast was initiated. This drainage reversal was further enhanced by tilting and progressive headward erosion brought on by Jurassic faulting and moderate uplift that ended deposition in the basin

and started vigorous late Jurassic-early Cretaceous erosion.

Davis rejected the idea that any eastward drainage was related to former northwest-flowing streams, but conceded (p. 253) that "The larger westward-flowing streams of the plateau are of earlier, Carboniferous birth, and have suffered little subsequent change beyond a loss of headwaters."

Erosion continued (p. 197), through the Cretaceous and led to ". . . the production of a general lowland of denudation, a wide area of faint relief, whose elevated remnants are now to be seen in the even ridge-crests that so strongly characterize the central district, . . ." This is the classic Schooley peneplain (Davis and Wood, 1889) which is marked by ". . . the extraordinary persistent accordance among the crest-line altitudes of many Medina [Tuscarora] and Carboniferous [Pocono and Pottsville] ridges . . ." (p. 197).

Davis suggested that there was a Cretaceous transgression inland to near Blue Mountain and that the large southeast draining rivers were in estuaries or broad floodplains across the region to the northwest of Blue Mountain. This situation would have permitted later superposition of the Susquehanna River across the group of five resistant ridges immediately north of Harrisburg.

Davis believed that the broad lowland, the Schooley peneplain, was uplifted in early Tertiary to elevations of 1000-3000 feet. Renewed erosion produced lowlands on the less resistant rock while the more resistant rock was left as higher remnants of the Schooley peneplain. This incomplete or partial peneplain, the Harrisburg surface (Campbell, 1903), is best represented ". . . on the weak shales of the Newark formation [Martinsburg] in New Jersey and Pennsylvania, and on the weak Cambrian limestones of the great Kittatinny valley; . . ." (p. 199). It was during this cycle of erosion that the rivers, particularly the Susquehanna, were superimposed from the "estuaries" valleys onto the buried, resistant ridges.

Finally, Davis envisioned that moderate uplift occurred at the end of the Tertiary and that subsequent erosion has produced the valleys incised into the Tertiary baselevel lowland.

The remainder of Davis' paper deals with the history of river cycles and some of the mechanics of development of Pennsylvania rivers, topics which will not be discussed here.

Thus, Davis presented a model for the development of landscape in Pennsylvania which included the following important elements:

1. A rising southeastern source for Paleozoic sediments.
2. A culminating late Paleozoic compressional orogeny.
3. A Triassic post-orogenic landscape and drainage.
4. A drainage reversal caused by Triassic downwarping followed by faulting.
5. A cyclic late Jurassic to present landscape evolution.

- a. Jurassic-Cretaceous complete peneplanation.
- b. Early-mid Tertiary partial peneplanation.
- c. Late Tertiary stream incision.

FROM DAVIS TO OBERLANDER

In reality, subsequent workers have contributed very little to the advancement of the original concepts of Davis. In fact, most have basically ignored the total overall landscape development and concentrated on specific topics, particularly the peneplain (Sevon and others, 1983). A few workers have achieved some acclaim because of their apparent attention to the topic of landscape development in its broadest sense and the relationship of their work to the elements of Davis' model (Table 1).

Table 1. Elements of Davis' model for landscape evolution in Pennsylvania as treated by some subsequent workers.

Elements of Davis's (1889) model	Johnson (1931)	Meyerhoff & Olmstead (1936)	Thompson (1949)	Hack (1960)	Oberlander (1985)
1. Sediment Source	N	N	N	N	N
2. Compressional Orogeny	N	Y	Y	N	Y
3. Post-orogenic Drainage	N	Y	Y	N	N
4. Drainage Reversal	N	N	Y	N	N
5. Landscape Evolution	Y	Y	Y	Y	Y

Y = Writer did treat this element.

N = Writer did not treat this element.

With the exception of Hack, workers mentioned in Table 1 were concerned mainly with the origin of transverse drainage across resistant ridges and neglected the possibility that such drainage might be clarified by a comprehensive model such as Davis developed. Hack (1960; 1965; 1975) was concerned with the whole landscape, but the application of the dynamic equilibrium concept in explaining the present landscape simply makes the earlier Paleozoic and Mesozoic events almost irrelevant except for having provided the structural framework upon which present processes work.

DAVIS' MODEL AND THE PARADIGMS OF 1989

1. The southeastern sourceland for Paleozoic sediments.

There has never been any real question that the source of sediment for the Appalachian Basin lay to the east the depositional basin and constituted some vague highland area often referred to as Appalachia. During the few decades since the advancement of the paradigm of plate tectonics, the general nature of this highland has become somewhat clearer. Of parti-

cular importance has been the considerable amount of work done on foreland basin development (e.g., Beaumont, 1981; Jordan, 1981; Schedl and Wiltschko, 1984; Quinlan and Beaumont, 1984; Stockmal and others, 1986; Tankard, 1986; Beaumont and others, 1988; Jamieson and Beaumont, 1988; Flemings and Jordan, 1989). Slingerland and Beaumont (1989) present an excellent summary of the foreland basin tectonics of the Appalachian Basin.

Simply put, from time to time during the Paleozoic the eastern continental margin of North America was subjected to various plate movements with the result that thrust loads created a mountain belt which supplied sediment to an adjacent foreland basin created by lithospheric relaxation in response to the marginal loading (Figure 3). Beaumont (e.g., Beaumont and others, 1988) has modelled the relationship between the amount of load and the amount of subsidence in the foreland basin. Flemings and Jordan (1989) present a modelling approach for developing better relationships between loading and actual sediment infilling of the foreland basin. Slingerland and Furlong (1989) modelled the mountain range during the Alleghanian and suggest that it resembled a central Andean topography with an average relief of 3.5-4.5 km and a width of 250-300 km.

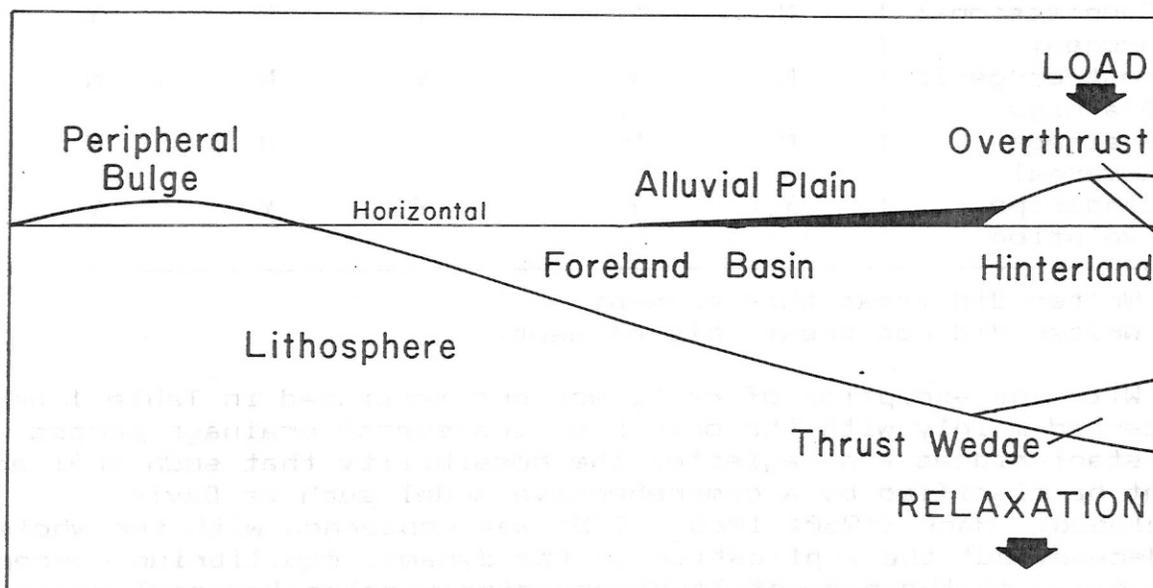


Figure 3. Generalized model of marginal thrust loading and adjacent foreland basin response. Thrust loading on the right causes lithospheric relaxation and development of a subsiding foreland basin into which sediments eroded from the thrust generated highlands are deposited. The areally remote peripheral bulge is a positive area subject to erosion.

Also of considerable importance is the persistence of the marginal mountain belt. In general, the marginal mountains supplied sediments, in varying amounts and degrees of coarseness, from the start of the Silurian (438 ma) to at least the start of the Late Permian (258 ma) and probably longer. Thus the marginal mountain belt was probably above sea level during this whole

time. I have argued elsewhere (e.g., Sevon, 1979; Sevon, 1985b) that the positions of several sediment-input centers (Figure 4), are well defined by facies in Upper Devonian rocks. I have also suggested that some of these centers persisted from the Silurian through the Pennsylvanian. For example, the Monroe and Lehigh River centers were well defined in the Silurian and the Schuylkill was well defined in the Pennsylvanian. The lengthy persistence of the other centers is more nebulous because, in most cases, of the absence of the younger rocks or the lack of facies data about the older rocks. Assuming that at least some of the centers were persistent for a long period of time, then not only was the mountain belt constantly above sea level, but major river systems established in the mountains did not change position significantly for nearly 200 ma. The significance of this will be discussed later.

2. The culminating compressional orogenic event.

The orogenic event which set the stage for the development of the landscape of Pennsylvania was not only critical to what followed, it was a big event. Davis realized this.

Beaumont and others (1987) have modelled the Alleghanian orogeny and show that the very large thrust loads which come farther inland onto the continental margin than earlier in the Paleozoic cause the greatest subsidence in the foreland basin. The implications of this are immense with regards to the end-orogenic topography. Figure 5 presents a model which attempts to illustrate the results of the Alleghanian orogeny. The crux of the hypothesis is that, during the 20 million years over which the Alleghanian orogeny occurred (Levine, 1983), erosion of growing folds, foreland basin subsidence caused by marginal loading, and deposition of material derived from the thrust-generated mountains combined to produce an alluvial plain in the foreland basin, not a mountain range as conceived by Davis.

Modelling by Beaumont and others (1987) and evaluation of coal rank indicates that a large amount of material was deposited in the foreland basin during the Alleghanian orogeny (Figure 6). Available information in western Pennsylvania and adjacent West Virginia (e.g., Cross, 1975) indicates that the Permian sediments are all nonmarine and similar in coarseness to underlying Pennsylvanian sediments thus suggesting that the alluvial system which deposited them was of greater magnitude than any earlier in the Paleozoic. Because mountains existed to the southeast at the end of the orogeny, deposition continued on the alluvial plain for an unknown amount of time.

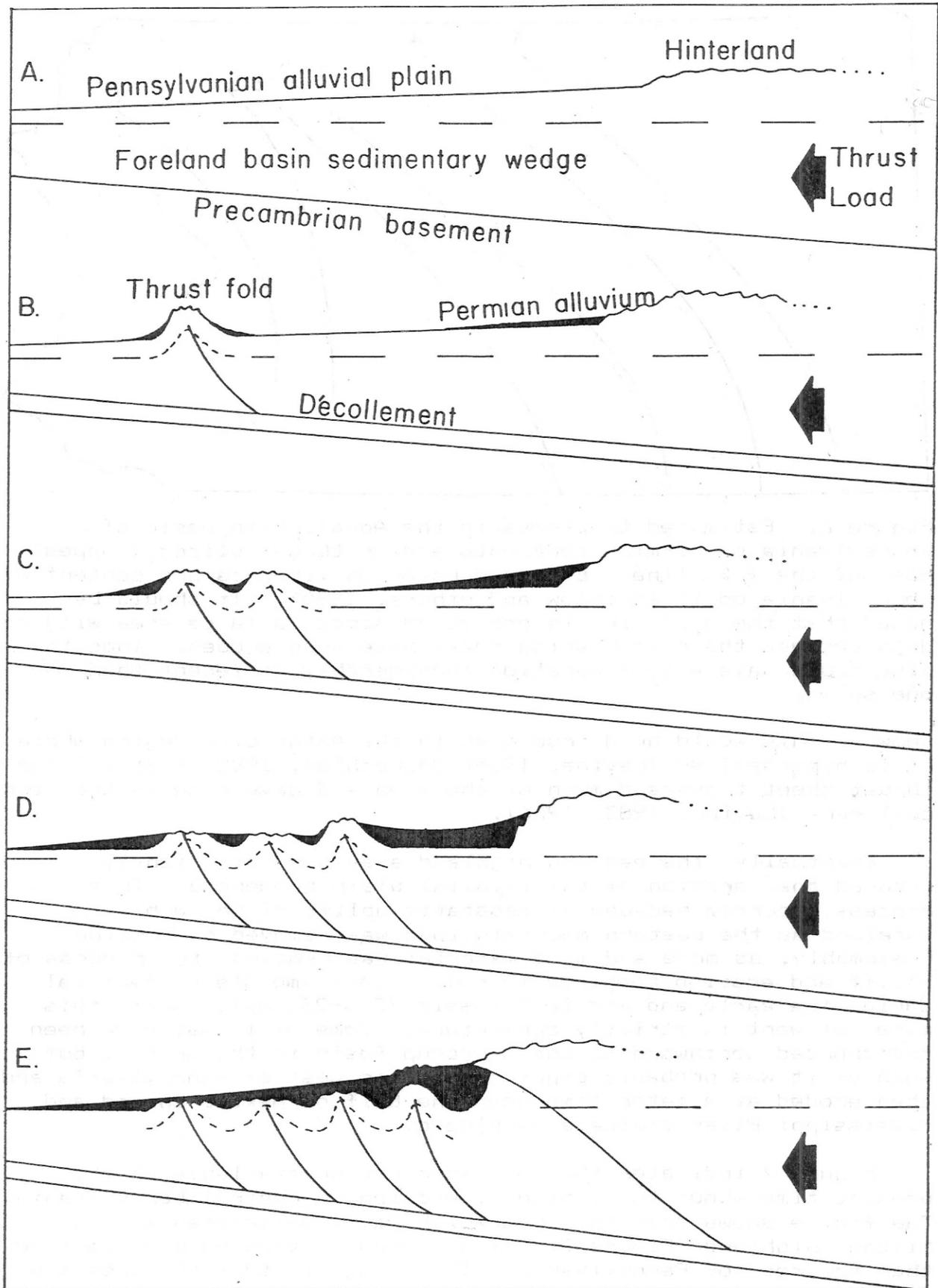
3. Post-orogenic landscape and drainage.

Drainage on the Permian alluvial plain had to flow northwest. And, if we may assume that the sediment-input centers which existed throughout the earlier Paleozoic were still intact, then the general location of those drainages is approximately



Figure 4. Positions of sediment input centers determined from facies relationships of Upper Devonian rocks.

Figure 5 (Opposite page). Conceptual model of foreland basin response in Pennsylvania to the Alleghanian orogeny. A. Initial situation with alluvial plain in foreland basin receiving sediments from the hinterland. B. As Alleghanian thrust-loading and decollement movement begin, thrust-folds are generated and eroded in the foreland basin and the hinterland rises to become a renewed source of alluvial sediment for the foreland basin. C-E. The process continues to the end of the orogeny. This model is related to Pennsylvania physiography in the general sense that in A. the hinterland-foreland basin boundary probably was located an unknown distance east of Philadelphia whereas in E. the boundary was located near Blue Mountain (Figure 1).



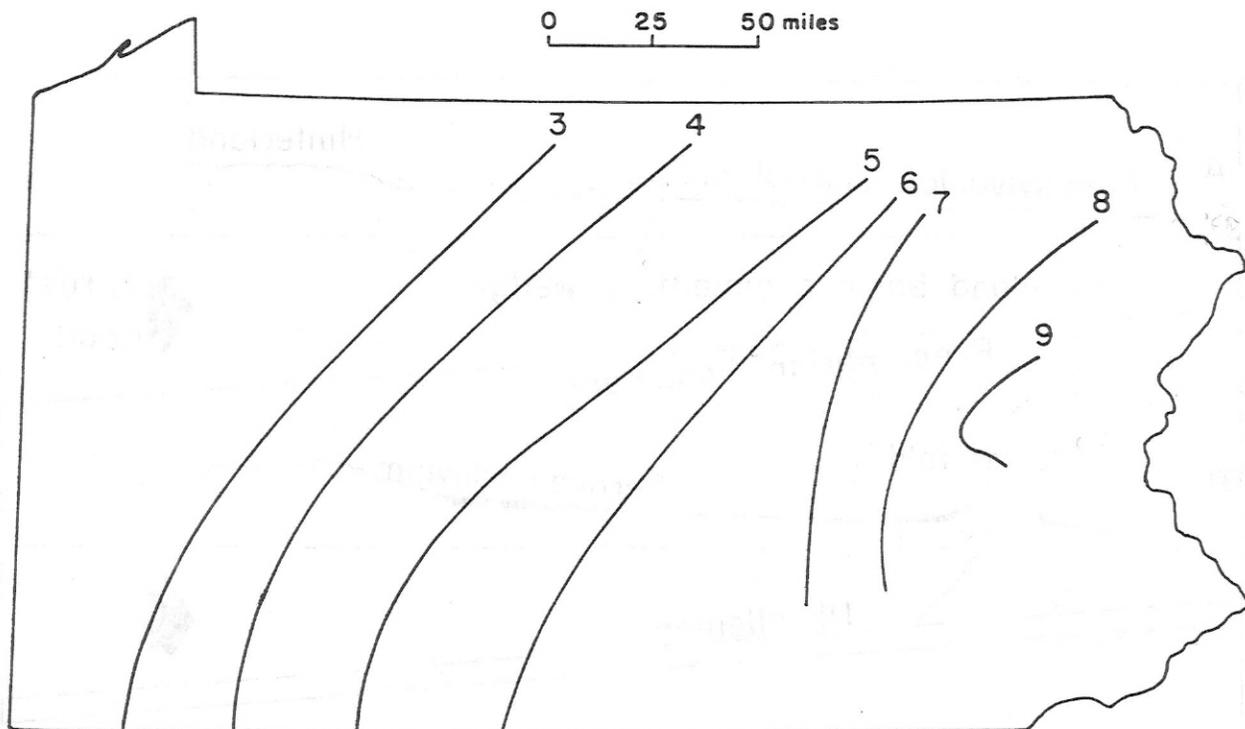


Figure 6. Estimated thickness in the Appalachian basin of Pennsylvania of Permian sediments and/or thrust slices (nappes) east of the 7 km line. Estimate based on fixed-carbon content of Pennsylvania coals (Socolow and others, 1980). It should be noted that the 6 km line is projected across a large area with no data because the coal-bearing rocks have been eroded. Thus the line could have a configuration considerably different than the one shown.

known. This would hold true even in the Anthracite region where it is hypothesized (Levine, 1985; MacLachlan, 1985) that a large thrust sheet traversed much of the area and gave rise to the high coal rank (Levine, 1983, 1986).

Eventually, the eastern highland area was sufficiently reduced that erosion of the alluvial plain commenced. This process occurred because of isostatic uplift of the whole foreland as the eastern mountain load was removed by erosion. Presumably, as more and more material was removed, the process of uplift and erosion combined to remove vast amounts of material during the early and middle Triassic (245-230 ma). Where this material went is strictly conjecture. Some of it may have been transported northward to the Sverdrup Basin in the Arctic, but much of it was probably deposited to the west of Pennsylvania and then eroded at a later time when the Gulf of Mexico opened and Mississippi River drainage developed.

Figure 7 indicates the best information available at the present time about the timing of erosion in central Pennsylvania. The figure shows that the area which Davis designated as the Nittany highland (Figure 2) was stripped by erosion much earlier than the rest of Pennsylvania. This suggests that the area may have projected above the alluvial plain previously hypothesized

(Figure 5).

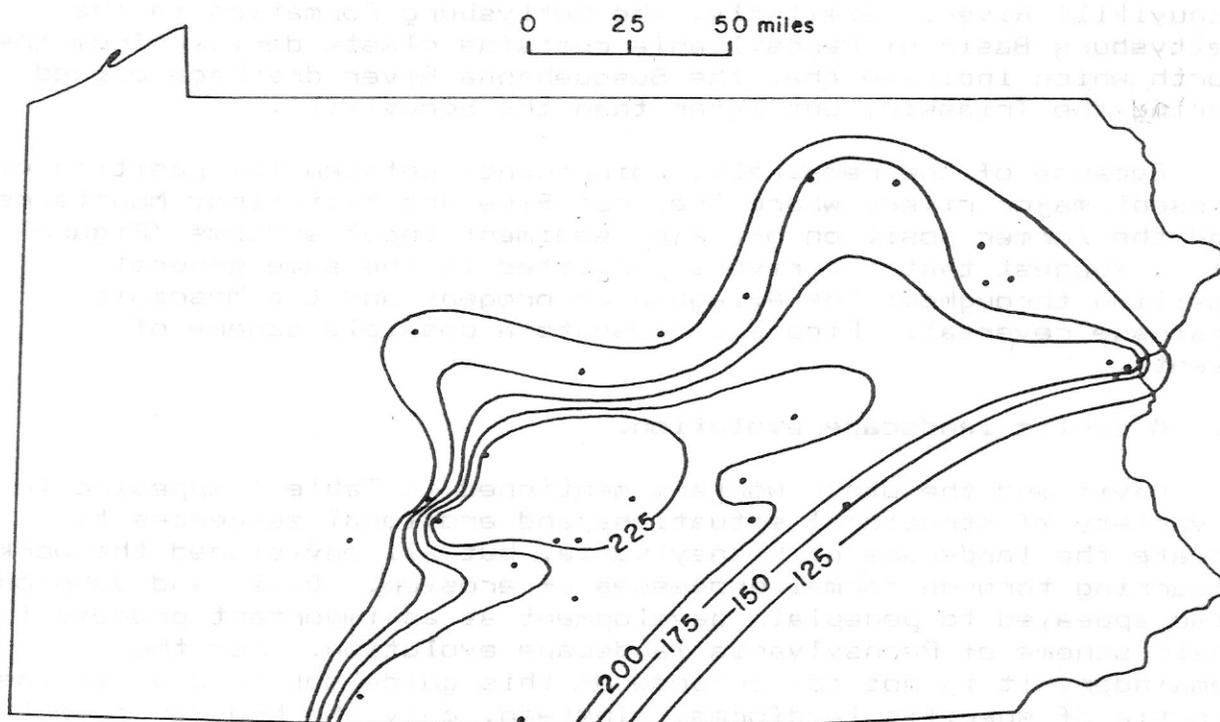


Figure 7. Contour map showing the time, in millions of years, at which there was about 3.5 km of rock above the present surface. Dots indicate location of apatite fission-track data sites presented by Roden and Miller, 1989. Compare this figure with Figure 6 and remember that the 5 km line in Figure 6 could have a much different configuration than that shown.

4. Triassic-Jurassic tilting and drainage reversal.

Davis was quite familiar with the Triassic-Jurassic Hartford Basin in Connecticut (Lorenz, 1988, p. 45-49) and was thus prepared to deal with the significance of the Gettysburg-Newark Basins in Pennsylvania. Although he could not appreciate the tectonic significance of the basins because he lacked the paradigm of plate tectonics, Davis showed considerable insight in recognizing that the Late Triassic basin development was a very important event in Pennsylvania. Davis' concept of a gently downwarped basin which was later faulted has been generally denied except by Faill (1973), but the exact mechanism of rift basin formation is still a matter of debate (e.g., Manspeizer and Cousminer, 1988; Manspeizer and Huntoon, 1989).

Davis did recognize that the Triassic basin development was the time of drainage reversal. This has been substantiated by the fact that many clasts present in conglomerates within the Gettysburg-Newark Basin are of Paleozoic origin and could only have been derived from rocks located to the north of the basin (Meyerhoff and Olmstead, 1936; Carlston, 1946; Glaeser, 1966; Meyerhoff, 1972). D. MacLachlan, Pennsylvania Geological Survey (personal communication, 1989), suggests that clasts in the

Hammer Creek Formation were derived from Upper Paleozoic rock units presently outcropping north of Blue Mountain (Figure 1) and that they were brought to the Newark Basin by the ancestral Schuylkill River. Similarly, the Gettysburg Formation in the Gettysburg Basin of Pennsylvania contains clasts derived from the north which indicate that the Susquehanna River drainage opened during the Triassic, but later than the Schuylkill.

Because of the remarkable coincidence between the position of present major rivers where they cut Blue and Kittatinny Mountains and the former position of major sediment-input systems (Figure 4), I suggest that the rivers persisted in the same general position throughout the Alleghanian orogeny and the Mesozoic drainage reversal. Figure 8 presents a possible scheme of events.

5. A cyclic landscape evolution.

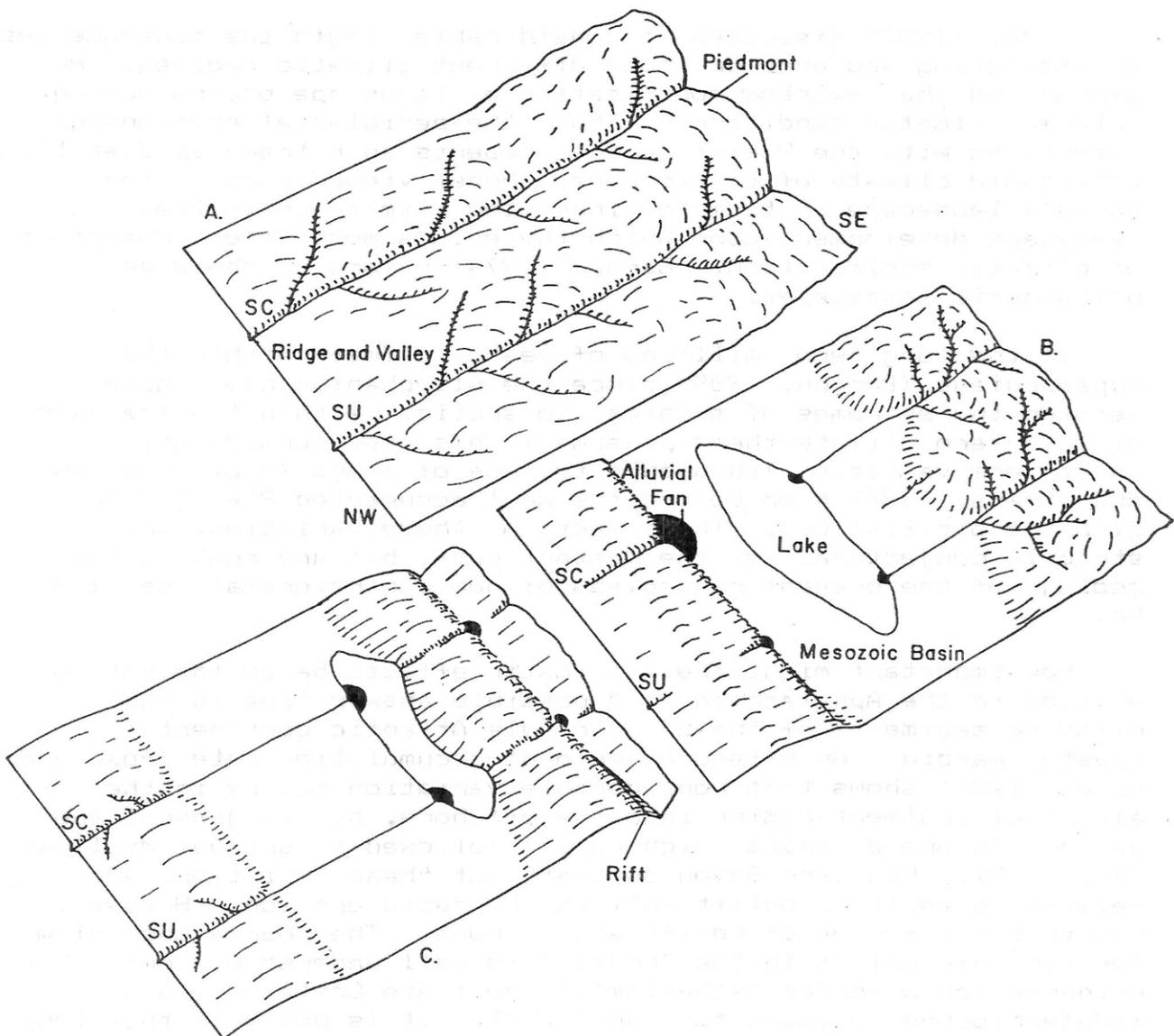
Davis and the other workers mentioned in Table 1 appealed to a variety of structural situations and erosional sequences to create the landscape of Pennsylvania, but all envisioned the work occurring through normal processes of erosion. Davis and Johnson also appealed to peneplain development as an important process in their scheme of Pennsylvania landscape evolution. For the remainder, it is not the purpose of this guidebook to discuss the minutia of specific landforms. Instead, only the broader aspect of landform evolution will be considered.

Although Davis and Johnson used cyclicity as a mechanism to develop landscape and Owens and Sohl (1969) and Newall and Rader

Figure 8 (Opposite page). A hypothetical scheme of drainage reversal in central Pennsylvania during the Mesozoic. A. A view showing drainage in part of Pennsylvania prior to development of the Mesozoic basin. Flow of the ancestral Schuylkill (SC) and Susquehanna (SU) Rivers is from southeast (SE) to northwest (NW). The view shown extends from the higher (elevation) area of the present Piedmont to the lower, but possibly not much lower, areas of the Ridge and Valley. B. During the Mesozoic, the Newark-Gettysburg Basin develops in southeastern Pennsylvania and disrupts through drainage. Flow into the basin continues normally from the southeast along ancestral channels. Drainage reversal occurs on the north side of the basin and headward erosion begins following pre-existing channels. Alluvial fans are developed on both sides of the basin and lakes occur in the center. C. At a late stage in the filling of the Newark-Gettysburg Basin, rifting occurs farther east and another drainage reversal occurs. By this time the main rivers flowing into the Newark-Gettysburg Basin have extended their headwaters far inland and are well established. Headward erosion along pre-existing channels by streams associated with the new rifting will eventually intercept streams farther inland and a completed drainage reversal will be firmly established.

(1982) appealed to the same mechanism to account for variations in coastal-plain sediments, they all failed to provide any mechanism for cyclicity other than a vague concept of uplift followed by rejuvenated erosion. Passive margins such as the eastern continental United States lack a tectonic driving force for periodic uplift. Instead, isostatic adjustment to eroded material appears to be the driving force of uplift. This may be supplemented by creep of oceanic material towards the continent (Vetter and Meissner, 1979), but this addition would not cause cyclicity. As long as erosion remains steady, uplift should also be steady. However, if erosion rate is variable, then uplift rate would also vary and the combination could produce cyclicity. Such may be possible through climatic variation.

Previous workers have given little attention to climate as a factor in the evolution of Pennsylvania landscape. In particular, they have failed to recognize that the landscape has been subjected to considerable variation in climate during the course of its history and that this variation could have a large effect on landscape evolution.



I earlier pointed out (1985a, p. 14) that Budel (1982) demonstrated the very strong influence that climate has on landscape development and believed strongly that widespread and long-lasting climatic intervals as ancient as those of the Late Cretaceous are still reflected in the landscape of many parts of the world. Brunsten (1979) presented a review of the variable nature of weathering and its relation to climate.

Of particular importance is the relationship between climate and sediment production and removal. Both Garner (1959; 1974) and Quinn (1957) pointed out that climate is the controlling factor in the variation of clastic-fragment size and in on-land sediment accumulation. In wet climates fine-grained sediments are produced and the overall landscape is altered slowly by erosion because of the protective nature of vegetation. In dry climates there will be much erosion of the landscape and production of much coarse detritus, but the materials will be stored nearby because of the lack of water necessary to transport the sediment out of the drainage basin. During periods of transition from dry to wet climates, material will be moved out of storage until immobilization of sediment by vegetation.

Budel (1982) discussed at considerable length the consequences of weathering and erosion under different climatic regimes. He emphasized that extreme modification of landscape occurs during extreme climatic conditions. Thus, the periglacial environment associated with the Pleistocene represents an extreme as does the warm humid climate of the tropics. Budel viewed much of the world's landscape in terms of inherited climate-controlled landscape development upon which there is a more recent overprint of climatic modification. Garner (1974) refers to these as polygenetic landscapes.

In the long term (millions of years) climate within the Appalachians (Barron, 1989) since the Alleghanian has ranged between the extremes of tropical to arctic. Within the framework of long-term climate there presumably has been considerable short-term variation (thousands to tens of years) (e.g., Pestiaux and others, 1988) even before the well-documented Pleistocene climatic oscillations. The effects of these variations are strictly conjectural for the distant past, but are real in the geology of the present regardless of how controversial they may be.

How important might these climatic effects be on the rate of erosion in the Appalachians? A possible answer lies in the offshore sediments of the U. S. middle Atlantic continental coastal margin. An offshore sediment-accumulation rate (Poag and Sevon, 1989) shows that considerable variation occurs in the amount of sediment coming into the offshore, but in general the pattern is one of peaks (high rates) followed by gradual declines (Figure 9). Poag and Sevon suggest that these variations are related to tectonic uplift followed by rapid erosion. However, the tectonic forces of uplift are tenuous. The source mechanism for tectonic uplift in the Jurassic is well understood, but evidence for a source mechanism in the late Cretaceous and middle Miocene is vague to nonexistent. It is possible that long

term (millions to tens of millions of years) deep weathering followed by shorter term (thousands to tens of thousands of years) dramatic climate change could cause intense erosion without leaving any record other than in the offshore sediment volume.

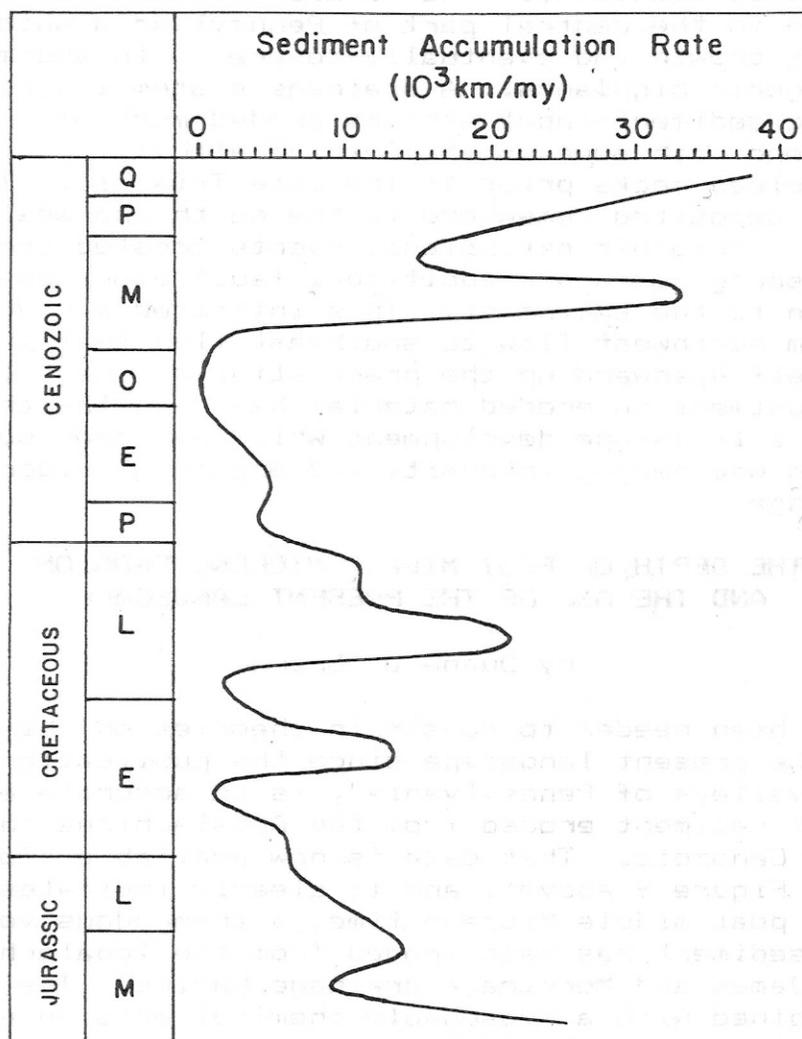


Figure 9. Sediment accumulation rates for the middle Atlantic offshore. Redrawn from Poag and Sevon (1989, Figure 3).

Such a scenario is not without its problems. For example, the late Cretaceous sediment pulse is problematic for the climate hypothesis in that it seems to require an episode of aridity. The general northwest drift of North America might produce an effect of passing from the equatorial humid tropical zone to the subtropical wet-dry savanna zone and then onto the warm temperate humid zone, but whether or not this amount of climate change would be adequate to account for the pulse of sediment input to the offshore is unknown.

A POLYGENETIC MODEL FOR THE GEOMORPHIC EVOLUTION OF THE APPALACHIANS

During the Paleozoic, thrust loading on the continental margin of North America caused the development of a foreland basin which was filled with a variety of sediments derived from thrust-generated mountains. The Permian Alleghanian orogeny created folds in the central part of Pennsylvania which were eroded during growth and eventually covered with sediment derived from the orogenic highlands. A drainage system inherited from the Paleozoic sediment-input streams eroded much of the orogenic highlands along with some of the Permian alluvial plain and underlying folded rocks prior to the Late Triassic. The eroded material was deposited somewhere to the north and west of Pennsylvania. Mesozoic extensional events created the Newark-Gettysburg Basin and additional fault-block basins stepping down to the southeast. This initiated a reversal of drainage from northwest flow to southeast flow that progressively extended itself headward up the preexisting drainage lines. Isostatic adjustment to eroded material has been the the driving force behind a landscape development which has been subjected to variations in weathering intensity and erosional vigor because of climatic change.

THE DEPTH OF POST MIDDLE MIOCENE EROSION AND THE AGE OF THE PRESENT LANDSCAPE

by Duane D. Braun

What has been needed to constrain theories on the evolution and age of the present landscape since the publication of Davis' "Rivers and valleys of Pennsylvania", is an accurate estimate of the volume of sediment eroded from the Appalachians in the Mesozoic and Cenozoic. That data is now available (Poag and Sevon, 1989; Figure 9 above), and it clearly indicates that since about 16 Ma, post middle Miocene time, a tremendous volume of siliclastic sediment has been eroded from the Appalachians between the James and Merrimack drainage basins. The sediment volumes, combined with a reasonable chemical erosion rate, produce an estimated post middle Miocene average erosion depth of 1.1 km for the Appalachians inland of the Coastal Plain (Table 2). The estimated average erosion depth for just the Quaternary is 120 to 150 m (Table 2).

Due to the amount of post middle Miocene erosion, there is little likelihood that the present landscape contains any vestiges of older, lower relief erosion surfaces. The approximate summit accordance of strike ridges may conceivably record a deeply weathered middle Tertiary low relief erosion surface, but those summits have been lowered 100's of meters since then. The remnants of deeply weathered material under some parts of the rolling lowland of the "Harrisburg surface" cannot represent in place middle Tertiary material because that would only require post middle Tertiary incision of the present valleys in the lowland. That amount of erosion could only account for a small fraction of the post middle Miocene sediment. As argued by Hack (1965), it is more likely that the deeply weathered material has

Table 2. Calculation of amount of regional landscape lowering required to produce the volume of offshore sediments for the period from Middle Miocene through the Quaternary. Table compiled by Duane D. Braun.

	1. Area inland of Fall Zone $\times 10^3$ km ²	2. Area of Coastal Plain $\times 10^4$ km ²	3. Area of shelf $\times 10^4$ km ²	4. Sediment volume $\times 10^4$ km ³	5. Porosity of sediment n_s percent	6. Porosity of source rock n_r percent	7. Sediment volume \times ($1 - (n_s - n_r)$) $\times 10^4$ km ³
Quaternary	2.73	8.15	4.23	4.37	0.40	0.20	3.50
Pliocene	2.73	6.51	4.71	7.16	0.40	0.10	5.01
Late Miocene	2.73	4.13	0.96	6.30	0.50	0.10	3.78
Middle Miocene	2.73	2.46	1.44	16.83	0.50	0.10	10.10

	8. Erosion equal all 3 areas 1+2+3 km	9. Area of Coastal Plain \times 0.33 $\times 10^4$ km ²	10. Area of shelf \times 0.1 $\times 10^4$ km ²	11. Inland erosion vol/area 1+9+11 km	12. Chemical erosion 20 m/my km	13. Phys. and chem. erosion km	14. Erosion rate m/my
Quaternary	0.088	2.45	0.423	0.116	0.033	0.149	90
Pliocene	0.130	2.15	0.471	0.167	0.073	0.240	66
Late Miocene	0.117	1.36	0.096	0.131	0.104	0.235	45
Middle Miocene	0.324	0.81	0.144	0.357	0.122	0.479	79
Total	0.659			0.771	0.332	1.103	

1. Area includes Merrimack drainage and areas in Finger Lakes and Champlain valleys where the divide has been placed at its estimated pre-pre-Wisconsinan position.
- 2 & 3. Areas from Poag and Sevon (1989, Figures 20-23), inland of zero deposition line except for Quaternary. In the Quaternary the mid-point line from present coast taken to 200 m line is taken as the zero deposition line.
4. Calculated from time scale used by Poag and Sevon (1989, Figure 3) and Kent and Gradstein (1986, Plate 1).
5. From COST B-2 well data (Poag, 1980), Steckler and others (1987).
6. Porosity estimates from Davis (1969); Quaternary porosity doubled to account for weathered material.
7. Sediment volume/($1 - (n_s - n_r)$) = sediment volume - porosity correction.
8. Equal erosion depth from zero deposition line to Atlantic drainage divide.
- 9 & 10. Maximum local relief on Coastal Plain is 1/3 to 1/10 of that in the Appalachians, therefore assume that Coastal Plain erosion is 1/3 of that in the Appalachians and shelf erosion is 1/10 of that in the Appalachians. Coastal Plain and shelf areas are multiplied by these proportions to yield erosion depth weighted areas for calculation of column 11.
11. Erosion depth corrected for partial contribution from Coastal Plain and shelf.
12. Chemical erosion estimate considering relative proportion of sandstone, shale, and limestone multiplied by age duration.
14. Quaternary - 1.65 my; Pliocene - 3.65 my; Late Miocene - 5.2 my; Middle Miocene - 6.1 my.

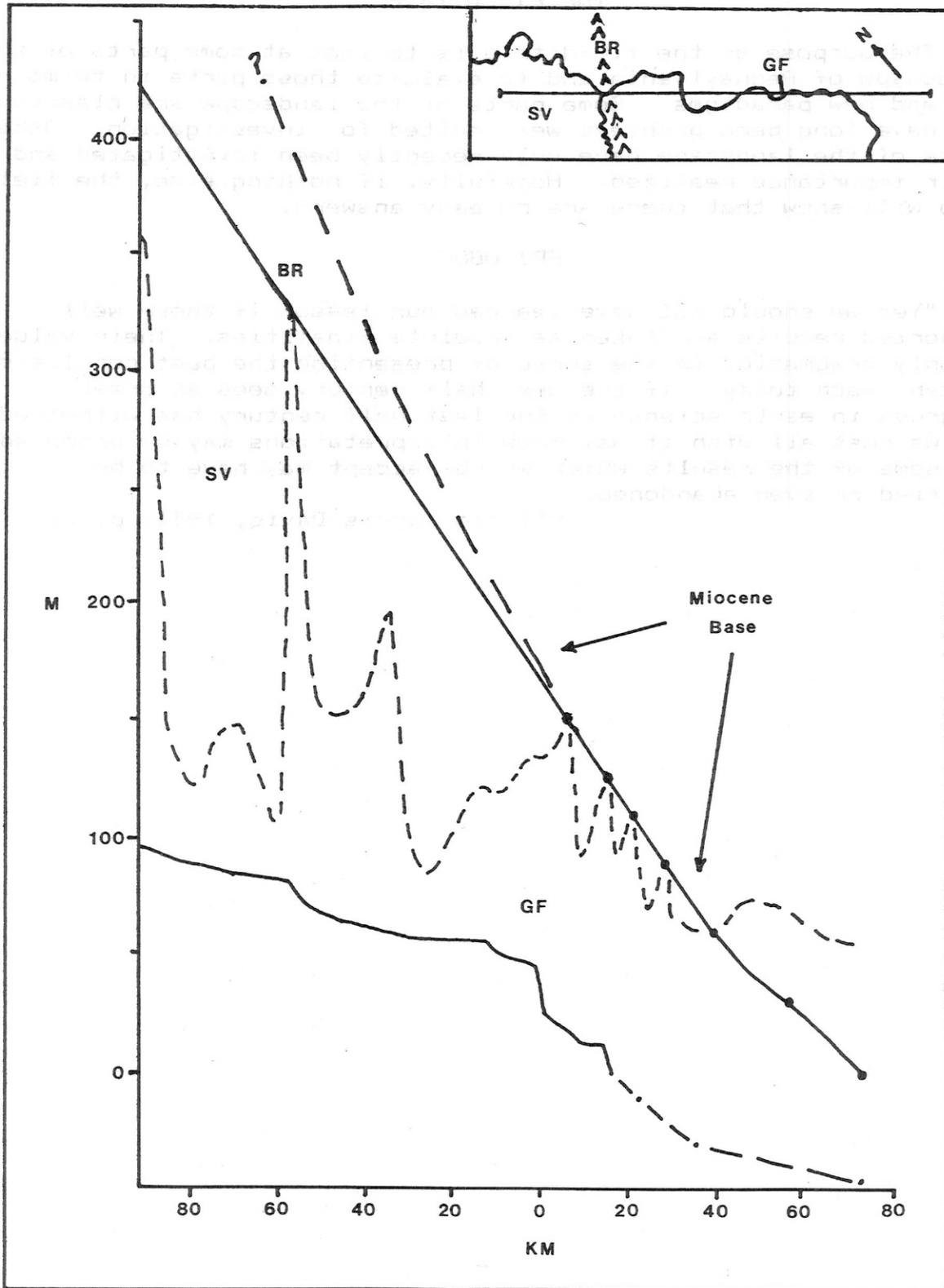
accumulated where temporarily stored in sinkholes or protected by lag deposits as the weathered material is created during continuous downwasting. Both Hack (1965) and Pavich (1989) argue that present geochemical processes are capable of forming much, if not all, of such weathered material.

The present landscape can be simply explained as a result of continuous post middle Miocene erosion having variations in rate and process (Figure 9). This model is far closer to the continuous erosion, dynamic equilibrium model of Hack than the cyclic erosion, multiple peneplain model of Davis.

The present landforms are essentially Pliocene-Pleistocene in age and have been carved from a deeply weathered middle Tertiary (middle Eocene to early Miocene) erosion surface (Figure 9) that was about one kilometer above the present erosion surface (Table 2). The middle Tertiary landscape may have been a low relief fluvial erosion surface, Davis' Schooley peneplain. Another alternative is that the middle Tertiary landscape may have been a "double planation" etchplain surface (Budell, 1982; Sevon, 1985a) having a rolling lowland and strike-ridge relief like that at present but without an incised drainage network. In either case, due to the depth of post middle Miocene erosion, the form of the middle Tertiary erosion surface cannot be determined from the present erosion surface because no part of the middle Tertiary surface is preserved on the present surface.

The post middle Miocene erosion depth implies significant concurrent upwarp of the Appalachians and this is what is observed if the slope of the base of the Miocene sediments in the Coastal Plain is projected westward over the Appalachians. To produce a conservative estimate of upwarp, a composite profile was constructed along the axis of the Salisbury Embayment where upwarp has been the least (Figure 10). Along that line, Miocene outliers extend onto the Piedmont and provide the farthest westward evidence of post early Miocene tilt. To further provide a conservative estimate of upwarp, the projection does not continue the increasing steepness of the tilt evident under the Miocene outcrop but just linearly continues the tilt from the three Fall Zone data points. The projected base of the Miocene, presumably a low relief erosion surface, only rises 2.7 m/km. The projected surface lies at about ridge crest elevation from the Blue Ridge to the Allegheny Front (Figure 1) and 200-400 m above the strike-valley hilltops. This minimal estimate of upwarp suggests that at least the lowlands, about 500 m of material, have been carved out since the Miocene. It is these same lowlands whose hilltops supposedly still preserve the middle Tertiary (Oligocene?) Harrisburg peneplain. The projection of the Miocene surface could continue to steepen upward (dashed

Figure 10 (Opposite page). Composite profile of the Potomac River (lower solid line), generalized hilltop elevations (dashed line), and the base of the Miocene (dots) projected westward (upper solid and dashed lines) over the Blue Ridge and the Shenandoah Valley (SV). Great Falls (GF) is the zero distance point. Vertical exaggeration = 543x. Modified from Hack (1975) and Darton (1951).



line, Figure 10) and that steepening would readily provide a surface one kilometer over the Ridge and Valley as is indicated by the sediment volume data (Figure 9 and Table 2).

THE FIELD TRIP

The purpose of the field trip is to look at some parts of the landscape of Pennsylvania and to evaluate those parts in terms of old and new paradigms. Some parts of the landscape are classical and have long been problems well suited for investigation. Other parts of the landscape have only recently been investigated and their importance realized. Hopefully, if nothing else, the field trip will show that there are no easy answers.

EPILOGUE

"Yet we should not have learned our lesson if these well supported results are taken as absolute finalities. Their value is only pragmatic, in the sense of presenting the best conclusions we can reach today. If the next half century sees as great progress in earth science as the last half century has witnessed--and we must all wish it may--new interpretations may be proposed and some of the results which we now accept may have to be modified or even abandoned."

William Morris Davis, 1931, p. xi

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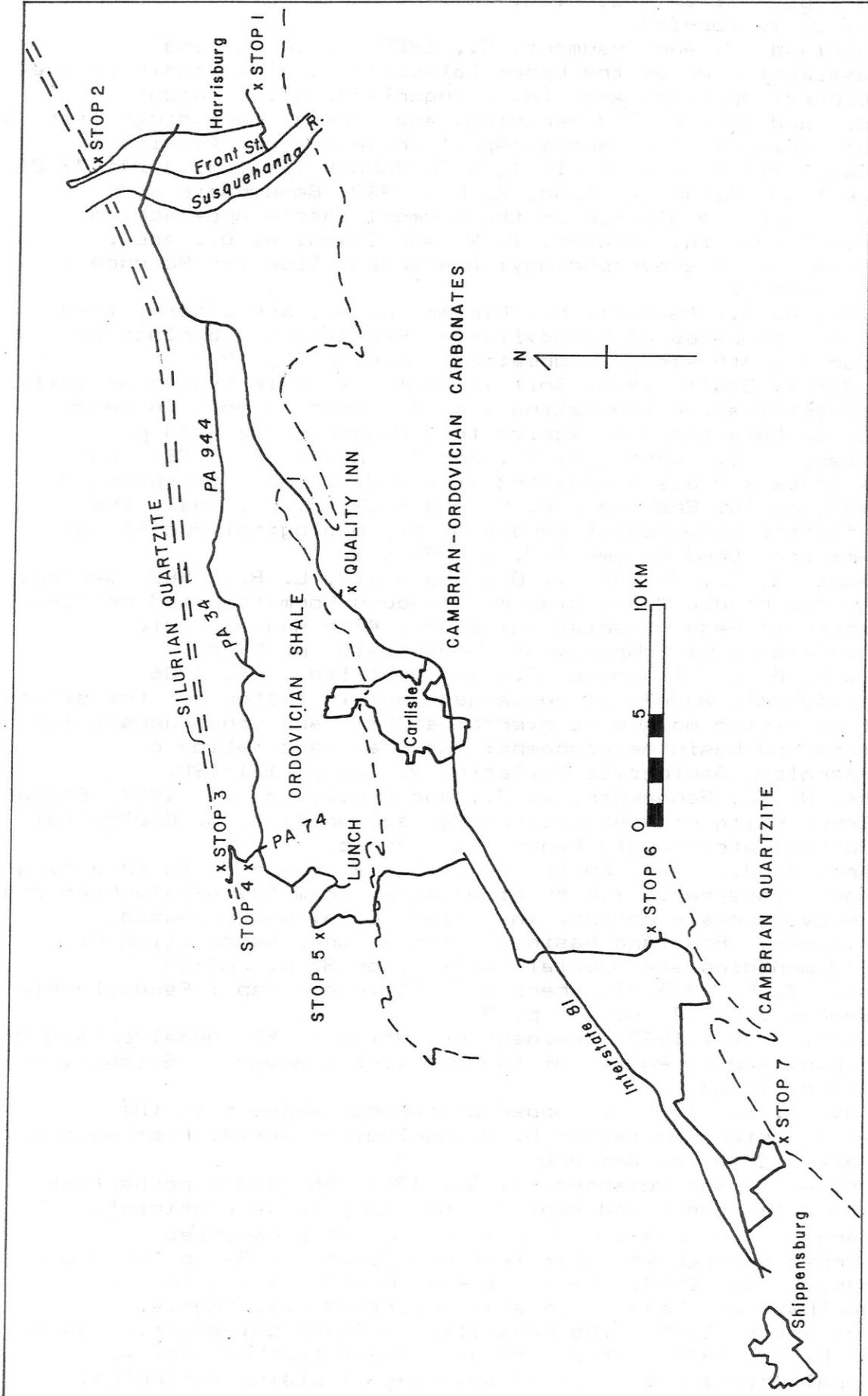


Figure 11. Map of field trip route with simplified geology.

ROAD LOG AND STOP DESCRIPTIONS

"The truth is desirable, even though it
destroys the pleasures of disputation."

H. L. Fairchild, 1905, p. 15

MILEAGE		
INC	CUM	
0.0	0.0	LEAVE parking lot of Quality Inn Motel (the Embers). TURN LEFT onto US Route 11 South.
0.2	0.2	TURN RIGHT onto entrance ramp to Interstate 81 North. From here to the Susquehanna River Interstate 81 crosses the rolling hills of Davis' dissected middle Tertiary partial peneplain, the Harrisburg surface. Somewhat lower areas of rolling hills on the least resistant rock in the region have at times been interpreted as the dissected late Tertiary Somerville partial peneplain.
2.8	3.0	Views to the left of irregular crestline of Blue Mountain which is formed by the Silurian Tuscarora quartzite.
1.5	5.5	View ahead on right of an incised meander bend of Conodoguinet Creek. Davis and others after him often made the assumption that the incised meanders, particularly entrenched meanders, inherited their form from alluvial meanders on an overlying peneplain surface and thereby are further evidence of peneplanation. Braun (1976, 1983) showed that the incised meanders on shaly rock have four times the planform size of alluvial meanders and that incised meanders on nonshaly rock have twice the planform size of alluvial meanders. Reaches having the different sized incised meanders on the different rock types alternate one after another along a number of Appalachian streams. Also, several incised meander reaches show clear evidence of successive cutoff and regrowth of the incised meanders that have left behind several levels of cutoff incised meander loops. These observations indicate that the incised meanders develop in and have their dimensions controlled by the enclosing rock type. This, in turn, implies that the incised meanders are not inherited from alluvial meanders and are not evidence for an overlying peneplain (comment by D. D. Braun).
7.9	13.4	Crossing the Susquehanna River. Views of the Susquehanna River Water Gap to the left.
0.6	14.0	EXIT RIGHT to Front Street.
0.1	14.1	BEAR RIGHT to Front Street South. The route will proceed south along the Susquehanna River on an intermediate elevation late Wisconsinan terrace and through prime Harrisburg real estate except for one factor - flooding. Figure 12 shows the area flooded in 1972 during Tropical Storm Agnes. A real case of "Let the buyer beware!"

The lowland along trunk streams in the region has been called the Parker Strath by some and has been interpreted as an incipient peneplain developed by

the present cycle of erosion. The question is: How can one differentiate between strath terraces cut during continuous downcutting and strath terraces cut as an "incipient penplain"?! (comment by D. D. Braun)

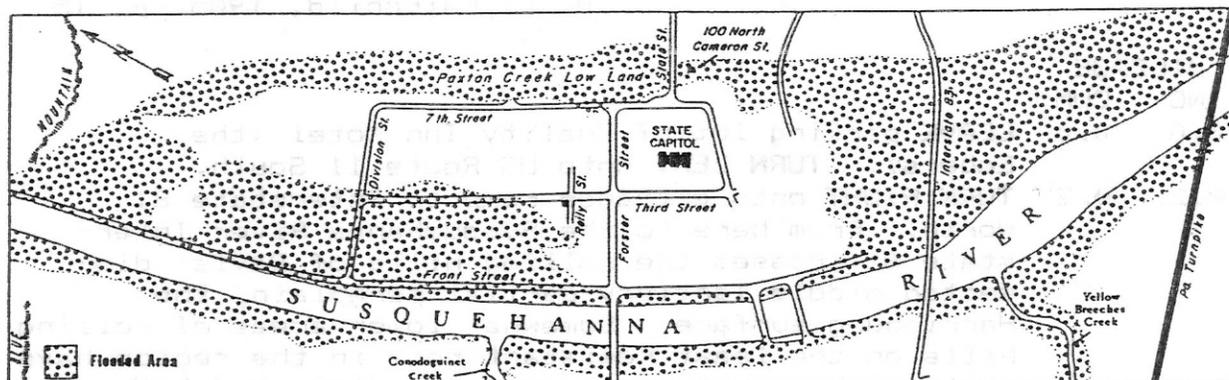


Figure 12. Map showing area of Harrisburg flooded in 1972 (Sevon, 1972, Figure 2). The central part of the unflooded State Capitol area is a pre-Wisconsinan terrace, probably of late Illinoian age. The remainder of the unflooded State Capitol area is underlain by the highest late Wisconsinan terrace that has been traced 140 km upstream to the late Wisconsinan terminus near Berwick, Pennsylvania. The Agnes storm inundated two lower terraces that have been related to late Wisconsinan ice recession from northern Pennsylvania (Peltier, 1949) (comment by D. D. Braun).

- 2.4 16.5 Governor's mansion on the left just after the stop light was flooded in 1972. Now is a good time to get into the left lane.
- 3.4 17.5 **STOP LIGHT. TURN LEFT** onto Forster Street. **PROCEED** through 4 stop lights. Get into right lane.
- 0.5 18.0 **BEAR RIGHT** onto North 7th Street just before 5th stop light. Get into left lane. **BEAR LEFT** to Stop Sign at crest of small hill.
- 0.2 18.2 **STOP SIGN. PROCEED** across State Street bridge. Get into right lane. Proceed through 4 Stop Lights.
- 0.8 19.0 4th Stop Light.
- 0.3 19.3 **TURN RIGHT** at Bar and Grill sign located at start of curve to right. Immediately intersect Walnut Street and **BEAR LEFT** to gated entrance to Reservoir Park. This trip will drive to high point for observation. Vehicular traffic is normally prohibited and it is necessary to walk to the top to view the water gaps.

STOP 1. TRANSVERSE DRAINAGE AND LANDSCAPE TERMINOLOGY

There is no certainty that William Morris Davis viewed the Susquehanna River Water Gap from here, but he may well have done so. Both Ashley and Fenneman did and each published a photograph taken from this site (Ashley, 1935, Figure 1, Plate 123; Fenneman, 1938, Figure 55). The general geology and structure associated with the several water gaps is shown in Figure 13 and

the areal arrangement of the ridges and gaps is shown in Figure 14.

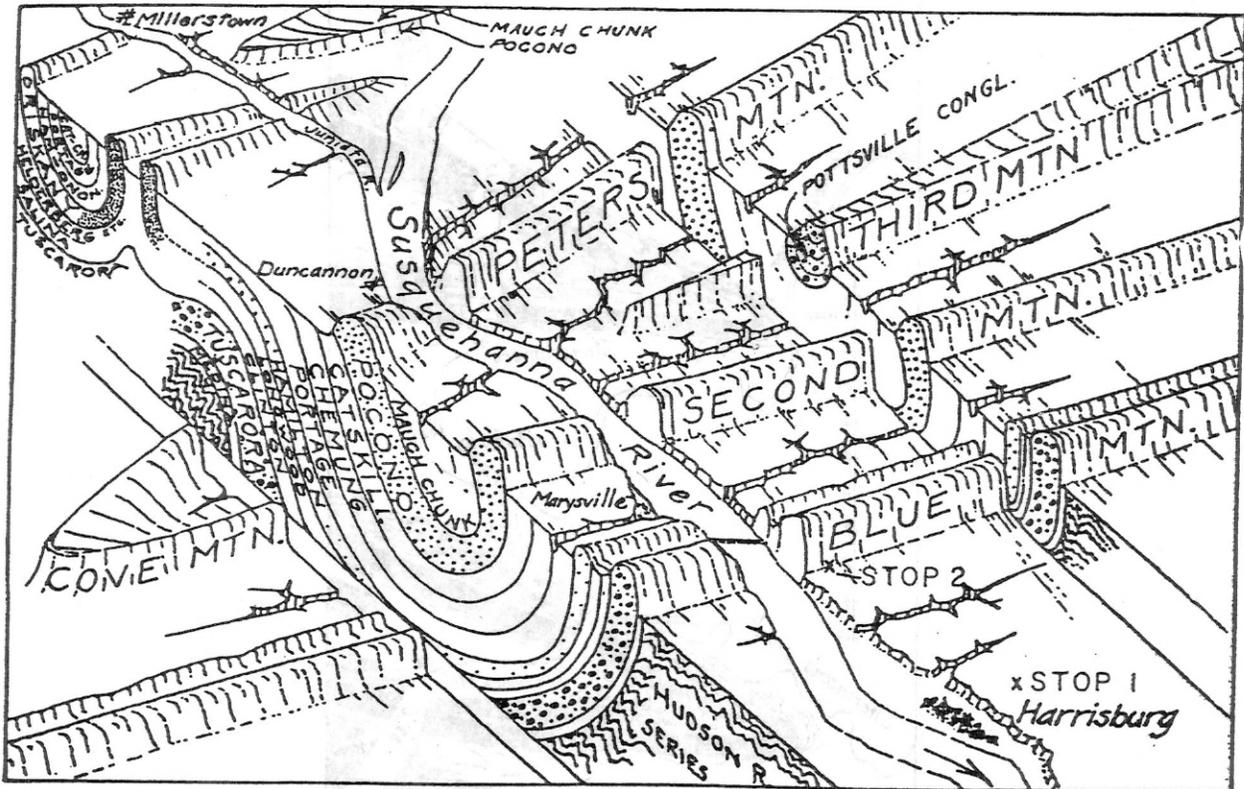


Figure 13. Generalized stratigraphy and structure for the Susquehanna River water gaps north of Harrisburg, PA. Diagram from Lobeck, 1932, Sheet No. 31.

From the viewpoint of geomorphic terminology, this is a good place to get oriented. The first ridge is Blue Mountain, or First Mountain, the next ridge north is Second Mountain and the ridge in the background is Peters Mountain. The accordant summits of these ridges are the presumed remnants of the former Schooley peneplain. The lower surface extending from the foot of Blue Mountain towards Reservoir Park is the Harrisburg peneplain as defined by Campbell in 1903. The rounded crests of these uplands are generally at 500-540 feet in elevation. Reservoir Park is slightly over 600 feet in elevation and is a high point with no lateral equivalents. The park is underlain by graywacke of the Ordovician Hamburg Formation. The graywacke is harder and more resistant to erosion than the surrounding shale.

The problem to consider here is that of transverse drainage. How does a river become entrenched into very resistant rocks in apparently anomalous positions? Davis (1889) invoked erosion to produce the Schooley peneplain and then a special process of "estuaried" lower reaches of streams during a Cretaceous transgression to allow meandering rivers to notch themselves into

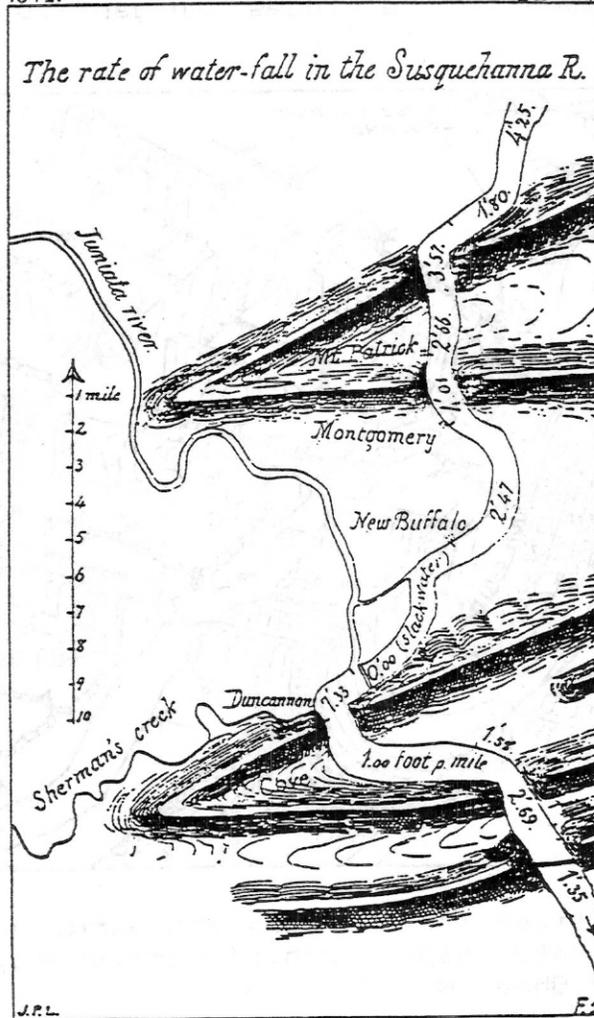


Figure 14. Areal arrangement of transverse drainage through the several ridges north of Harrisburg, PA. Illustration from Claypole (1885, p. 18).

the resistant ridges. Meyerhoff and Olmstead (1936) sided with Ashley (1935) and related transverse position to structural weakness such as faulting. Meyerhoff and Olmstead also suggested that overthrusting might have played a part, but did not develop the idea specifically for the Susquehanna River. Thompson (1949) developed the transverse drainage by headward erosion which picked its initial position in Blue Mountain because the Tuscarora was thinnest in the area of the present water gap. Theisen (1983) demonstrated structural weakness in the water gap. Oberlander (1985) hypothesized superposition of the river from a broad band of Mauch Chunk Formation when the river was at a much higher level, but the gentle plunge of the folds negates this possibility (see Figure 13). Hoskins (1987) argued for erosion at a structural weakness. Sevon (1986) rashly suggested that the river's position may have been determined by the front margin of a large thrust sheet which once covered the Anthracite region. This guidebook argued earlier that the Susquehanna River drainage is reversed by headward erosion along an inherited position.

No matter what hypothesis is used, it should be kept in mind that on the order of 17 km of rock has been eroded from the area since the Permian (see cross section on back cover and Figure 6). The course of the Susquehanna River may have been initiated on some geologic structure kilometers above and totally unrelated to the surface structures. The present course of the river may be related only coincidentally to any present geologic structure. That is, as George Crowl used to say, its position is the luck of the draw.

- LEAVE entrance to Reservoir Park. **TURN LEFT** onto Walnut Street and **BEAR RIGHT** immediately towards Bar and Grill sign.
- 0.1 19.4 **STOP SIGN. TURN LEFT** onto State Street. Proceed to 4th Stop Light. Note views of the state capitol building straight ahead across the bridge.
- 0.6 20.0 **STOP LIGHT. BEAR RIGHT AND THEN IMMEDIATELY LEFT** onto downhill road.
- 0.2 20.2 **STOP SIGN. TURN RIGHT** onto Cameron Street and enter an abandoned channel fo the Susquehanna River. As we turn, if you look to the left, you will see a white building on the opposite side of the street next to a parking lot just beyond the base of the bridge. The building is 100 North Cameron Street where the Pennsylvania Geological Survey was housed during the flood of 1972. The Survey occupied the ground floor which flooded to the ceiling. The flood of 1936 rose only half way to the ceiling. A bus stalled in the south-bound lane a few hundred feet north of the bridge during the flood was covered with water to above seat level.
- 1.1 21.3 **STOP LIGHT.** Large complex ahead on left is the Farm Show building. In January of every year Pennsylvania holds one of the largest farm shows in the nation. Tradition holds that Farm Show week will be the worst weather of the winter. Statistical averages show otherwise.
- 0.5 21.9 **STOP LIGHT.** Road to left leads to Harrisburg Area Community College. **PROCEED STRAIGHT AHEAD** on US Route 322/22.
- 2.2 24.1 On right is exit to Linglestown and Rockville. **PROCEED STRAIGHT AHEAD.**
- 0.9 25.0 **PARK ON RIGHT JUST BEFORE START OF ROCKFALL FENCE.** Park well off berm. Disembark and proceed to area behind fence.

STOP 2. SUSQUEHANNA RIVER WATER GAP

The excellent outcrop exposed behind the rockfall fence provides information which may or may not be relevent to the present position of the Susquehanna River. Theisen (1983) studied this outcrop in detail and concluded (with the help of R. P. Nickelson, Bucknell University) that the complicated structure results from pre-folding wrench faulting. He also noted that the continuous resistant-rock outcrops of the Tuscarora Formation which cross the Susquehanna River riverbed from the west terminate abruptly near the east shore of the river. Cotter

(1982; 1983) has studied the facies of the Tuscarora Formation and noted that this is an area of transition in depositional environments.

The geology displayed in the outcrop illustrates several reasons why the Susquehanna River might choose this site to traverse a resistant ridge. There is an abundance of faults (Figure 15) and a lack of the resistant quartzitic sandstone so characteristic of the Tuscarora Formation elsewhere, even on the west side of the river (Figure 16). The siltstones and shales of the Tuscarora which replace the usual sandstone presumably represent an unusual occurrence of fine-grained rocks formed in nearshore environments. These rocks provide a zone of weakness, both for faulting and erosion.

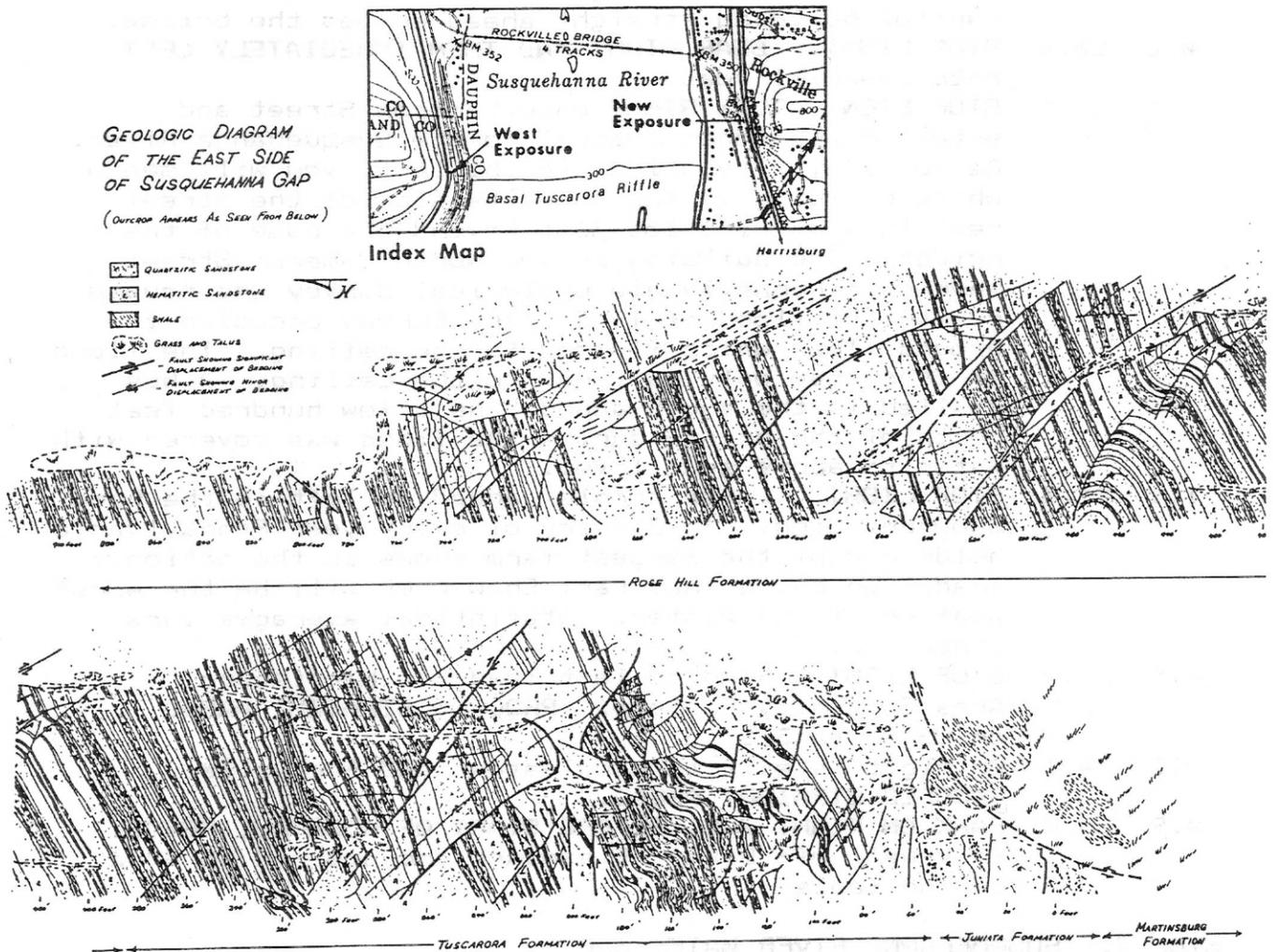


Figure 15. Cross section of Blue Mountain roadcut, US Route 22-322 (from Theisen, 1983).

The rocks are overturned slightly at this point, but probably not enough to influence drainage development in the manner

- built in 1902 at a cost of \$800,000.
- 1.5 28.7 **BEAR RIGHT** to Interstate 81 South.
 - 0.5 29.2 View to the right of Susquehanna River water gaps and the Rockville Bridge.
 - 4.2 33.4 **EXIT RIGHT** to PA Route 944/Wertzville Road.
 - 0.4 33.8 **STOP SIGN. TURN RIGHT** onto PA Route 944 West. The route will proceed for the next 15 miles parallel to Blue Mountain on the right and across the rolling topography cut into the Ordovician Hamburg and Martinsburg Formations. The hilltops represent the eroded remnants of the presumed Harrisburg peneplain and the valleys represent post-peneplain dissection.
 - 6.8 40.6 **BEAR LEFT** following PA Route 944 West.
 - 3.1 43.7 **STOP SIGN. TURN LEFT** onto PA Routes 34/944.
 - 0.3 44.0 **TURN RIGHT** following PA Route 944 West.
 - 5.2 49.2 **STOP SIGN. TURN RIGHT** onto PA Route 74. Note distinctive stone house ahead on right constructed with rock of the Silurian Tuscarora Formation.
 - 0.6 49.8 North Mountain Inn.
 - 0.4 50.2 Exposure on left of Late Wisconsinian colluvium overlying pre-Wisconsinian colluvium. This site is Stop 4 in the guidebook of Sevon, 1985a.
 - 0.6 50.8 Exposures ahead on right of red sandstones of the Ordovician Juniata Formation.
 - 0.5 51.3 Outcrops ahead on right of quartzitic sandstones of the Silurian Tuscarora Formation. This is the rock which forms the crest of Blue Mountain.
 - 0.2 51.5 **TURN LEFT** into parking area. **TURN CAREFULLY! THIS IS A BLIND CURVE AND TRAFFIC DOES NOT ALWAYS APPROACH THE CURVE SLOWLY!** This is Waggoners Gap. Buses will turn around in preparation for a downhill departure. Field trip participants will proceed carefully across the road and follow the trail to the crest of the gap.

STOP 3. WAGGONERS GAP: PENEPLAINS AND MOUNTAIN CRESTS

Waggoners Gap is a very popular place. On a clear day the view may not be forever, but it is excellent. The concrete pad below the crest is good for hang glider launches and the crest is a good place to observe hawk migration. There are excellent exposures of the Silurian Tuscarora Formation and the upper part of the Ordovician Juniata Formation along the road on the south side of the gap. The rocks have been discussed by Cotter (1982; 1983) and also Stephens and others (1982). The roadside exposures will not be examined on this trip, but the thickness of the very resistant rock can be noted during driveby.

The crest of Blue Mountain at Waggoners Gap, in classical terms, constitutes a small sag in a remnant of the former Schooley peneplain. The distant mountain to the north, Tuscarora Mountain, has the same rock at its crest and constitutes another presumably accordant summit. The ridge crest here is at about 1500 feet elevation. Crest elevations on Tuscarora Mountain are generally more than 2000 feet. These differences, as well as those of other ridge crests, have been interpreted to reflect the sloping surface of the former peneplain.

The barren slope below the crest on the north side of the ridge shows the nature of the disintegrated rock comprising the surface material, boulder colluvium, on both sides of the ridge. The large blocks on the north side occur only a relatively short distance downslope and disappear laterally under a cover of vegetation. The slope shows no evidence of present movement of the blocks, except where disturbed by man. The limited extent of boulder colluvium on the north-facing slope at this site probably reflects a relatively small amount of outcrop from which material was derived by mechanical disintegration. In contrast, the south-facing slope at this site has boulder colluvium which extends to the base of the mountain slope. Its limits are generally defined by the limits of forest cover. The extensive amount of boulder colluvium on that slope is presumably related to the much greater thickness of outcrop available to produce boulders.

The pseudo-outcrop at the ridge crest shows the nature of bedding and fracturing which contributed to the mechanical disintegration of the Tuscarora. Although there is probably some disintegration occurring under the present climate, presumably most of the mechanical breakup and downslope transport occurred under periglacial conditions during the Pleistocene, and, as will be argued at Stop 4, much of it during the Late Wisconsinan. An attempt was made to estimate the volume of boulder colluvium present on the north-facing slope in order to estimate how much higher the crest may have been. Photographs were taken of 18 locations on the boulder colluvium surface. Each photograph was assumed to represent a two-dimensional part of the colluvium and the amount of void for the photograph was determined graphically. The 18 amounts were averaged to yield a value of 17 percent and it was assumed that this amount would be the same in the third dimension and thus represents the amount of void present. The size of an area of boulder colluvium was determined and it was assumed that the area had an average thickness of 1 m. A volume was calculated, the amount of void subtracted, and an assumed thickness of 10 m of available outcrop was used to calculate that the ridge crest was at least 12 m higher than at present prior to disintegration which formed boulder colluvium. The main difficulty with this procedure at this location is determining how much outcrop was available to produce the boulder colluvium on the north-facing slope. At a site to the northeast of Waggoners Gap, from direct measurement of total colluvium volume, Braun (1989) calculated a ridge-crest lowering of about 9 m.

Despite the considerable mechanical breakup of the rock at Waggoners Gap, the quartzite shows very little evidence of weathering in the form of granular disintegration. This is a very tough rock and probably has a rate of atmospheric weathering even lower than that of 26 cm/my demonstrated for a resistant sandstone in northeastern Pennsylvania (Sevon, 1984). Godfrey (1975) suggested that similar quartzite in Maryland is being weathered chemically at a rate of 6 m/my. He also demonstrated an erosion rate of 2.5 m/my for a drainage basin underlain by quartzite. Whether or not the weathering rates determined by

Godfrey are comparable to the Waggoners Gap site is open to speculation. What must be considered is that if at present there is relatively little mechanical disintegration of the rock, little or no movement of the material down slope, and a very slow rate of weathering, then the ridge must be in a state of landscape quiescence. This is the situation which Budel (1982) would expect for the present climate following an episode of periglacial climate.

The view to the south is across the Cumberland Valley to South Mountain 19 km away. From the crest of Blue Mountain the area looks like a great plain, perhaps a peneplain. However, as the route traversed has already shown, and will continue to show, the area is not as much a plain as it appears from here. The shale area we crossed coming to Waggoners Gap stands a few tens of meters higher than the limestone area which we will cross after leaving Stop 5. There is moderate relief on both rock types of the apparent plain, but there is enough accordance of hilltop surfaces on the shales to make Campbell (1903) believe that the Harrisburg peneplain is real. Sevón (1985a) extrapolated, from present erosion rates, landscape lowering for the Cumberland Valley of 30 m/my in the shale areas and 40 m/my in the limestone areas. Under the present climate, there is considerably more erosion occurring in the valley than on the mountain top, a landscape disequilibrium situation. Over the longer term, with Pliocene-Pleistocene climate oscillations, episodic ridge crest lowering may be keeping up with more continuous lowland erosion. How does all this relate to dynamic equilibrium?

Was there ever a Schooley peneplain? Did it have any close relationship to the crest of Blue Mountain at Waggoners Gap? Consider the following before coming to a hasty conclusion.

(1) Despite the elevation variability and possible relationship to geology (rock type, thickness, dip, etc.) there is a remarkable pattern of ridge crest elevations in the Appalachian Mountain Section of the Ridge and Valley Province.

(2) Following the Alleghanian orogeny, the area from here to South Mountain and probably for another 100-200 km to the southeast was covered by at least 10 km of rocks which were eroded prior to the Late Triassic.

(3) Braun (see earlier discussion) has calculated that a minimum of 1.1 km of rock must have been eroded from this region in the last 16 my to account for the volume of middle Miocene and younger Atlantic coast and offshore sediment (Table 2). This means that the Cumberland Valley to the south would have been covered with rock to a depth greater than the present height of Waggoners Gap and, if there is long term disequilibrium in rates of erosion of different rock types, the crest of Blue Mountain was an unknown height above its present elevation.

(4) A slightly different rate of landscape lowering has resulted from an evaluation of the Pond Bank deposit. Pond Bank is the site of a former iron-ore mine located near Chambersburg

about 30 km southwest from here. During the course of mining in 1865, a shaft was sunk for the purpose of draining two surface pits (Lesley, 1865). At a depth of 12.5 m a bed 1.2 m thick of lignite was encountered followed by 1.2 m of sand followed by another 5.5 m of lignite. A drift was driven south through 14.6 m of lignite before the operation stopped. Spoil pile lignite was collected nearly 100 years later by Pierce (1965) and identified by Tschudy (1965) as being Late Cretaceous in age. The deposit occurs in surficial materials above dolomite of the Cambrian Tomstown Formation.

Pierce (1965) calculated the probable amount of lowering of the lignite on the basis of dissolution of the dolomite to be at least 425 m since the end of the Campanian (Late Cretaceous) about 75 my ago. This is less than half the amount that Braun (Table 2) is suggesting for the last 16 my.

- LEAVE STOP 3. PROCEED DOWNHILL on PA Route 74
South (back the way you came).
1.6 53.1 TURN RIGHT into parking lot of North Mountain
Inn.

STOP 4. NORTH MOUNTAIN INN COLLUVIUM

Comment by Edward J. Ciolkosz

The soil at this site is a composite with a weakly developed Wisconsinan upper profile and a much better developed truncated buried lower pre-Wisconsinan profile (at 325 cm). The upper profile is developed in colluvium much of which was derived from the pre-Wisconsinan soil material upslope from this site. The upper profile is a mixture of both blended (mixed) and pods of brown (unweathered) and red pre-Wisconsinan paleosol material. Until recently very little pre-Wisconsinan colluvium was recognized in Pennsylvania because it is buried beneath Wisconsinan colluvium and few good exposures exist. The work of Hoover (1983) significantly changed this view by showing that there is a significant amount of pre-Wisconsinan colluvium on the sideslopes of the ridges in the Ridge and Valley Province. The relative amount of Wisconsinan to pre-Wisconsinan has yet to be determined, but limited data suggest that there may be a greater amount of pre-Wisconsinan colluvium. There is, as yet, no discrimination of multiple pre-Wisconsinan colluviums although in theory such should exist. In addition, the relationship of the colluviums southward in the Ridge and Valley Province is not known. Soil Survey data cited by Clark and others (1989) indicates that counties in southern Virginia have about half the acreage of colluvial soils as do comparable counties in central Pennsylvania.

The pre-Wisconsinan soil at this site has been truncated. It appears that the lower Bt is intact. It is not known how much of the paleosol was truncated, but a reasonable estimate would be about 2 meters. In addition, this profile shows a welded condition in which the soil forming reactions are impressing themselves through the Wisconsinan colluvium and into the buried paleosol welding the two soil units together. Fragipans are

common in Wisconsinan colluvium, but this soil has no pan. It appears that there is too much weathered paleosol material in the upper profile for a fragipan to form (Ciolkosz and others, 1989). The requirement for fresh material in order for a fragipan to form is evidenced by the greater degree of brittleness (characteristic of fragipans) found in the brown material than in the red material of the Bw horizons.

Site Description

The site was described by Edward J. Ciolkosz, Robert R. Dobos, and Jon Pollack on July 11, 1989. The site is located in an upslope (from the Inn) cut in the parking area of North Mountain Inn on the south slope of Blue Mountain. The site is on a 17 percent slope with a south southeast (165°) aspect at 760 feet elevation. The vegetation is maple, oak, ash, and yellow poplar with roots many to 20 cm, common to 236 cm, and few to 325 cm. The site is a concave footslope position on the last southeast major ridge in the Ridge and Valley Province. The ground soil is a Typic Dystrachrept (Laidig taxadjunct) developed in Wisconsinan colluvium with a buried paleosol developed in pre-Wisconsinan colluvium. There is a lens of Bt1b material mixed in the brown material of the Bw4 horizon which indicates that this horizon is not an in-place pre-Wisconsinan paleosol, although the horizon at first appearance looks like a part of the paleosol.

Profile Description.

Horizon	cm	Description
1. A	0-5	Dark brown (10YR 3/3) very gravelly loam; weak fine granular structure; friable, nonsticky nonplastic; 35 percent rock fragments (mainly near surface); pH = 4.6; abrupt wavy boundary.
2. E	5-20	Yellowish brown (10 YR 5/4) gravelly sandy loam; weak medium subangular blocky structure; friable, nonsticky nonplastic; 20 percent rock fragments; pH = 4.6; clear wavy boundary.
3. Bw1	20-99	Mixture of red (2.5 YR 4/6) very gravelly clay loam and strong brown (7.5 YR 5/6) very gravelly loam; weak medium subangular blocky (red) and very weak medium subangular blocky (brown) structure; firm and brittle, slightly sticky, slightly plastic (clay loam), nonsticky nonplastic (loam); 45 percent rock fragments; pH = 5.0; many vesicular pores; few thin clay films in pores; common black coating on ped faces and on rock fragments; diffuse wavy boundary.
4. Bw2	99-170	Mixture of strong brown (7.5 YR 5/6) very gravelly loam and red (2.5 YR 4/6) very gravelly clay loam; very weak medium subangular blocky (brown) and weak medium subangular blocky (red) structure; firm and brittle; nonsticky nonplastic (brown), slightly sticky slightly nonplastic (red); pH =

- 4.6; many vesicular pores; few thin clay films in pores; common black coatings on ped faces and on rock fragments; diffuse wavy boundary.
5. Bw3 170-236 This horizon is the same as Bw2 except it has 55 percent rock fragments, pH = 4.6 (red and brown) and a clear wavy boundary.
 6. Bw4 236-325 Red (2.5 YR 4/8) gravelly clay loam; weak subangular blocky structure; firm and brittle; slightly sticky slightly plastic; 25 percent rock fragments; pH = 4.6; many vesicular pores; few black coatings on ped faces and rock fragments; with a lens (5-30 cm thick) of strong brown (7.5 YR 4/6) massive loam at the base of the horizon; abrupt wavy boundary.
 7. Bt1b 325-360 Red (2.5 YR 5/8) gravelly heavy clay loam; moderate medium subangular blocky structure; firm, sticky and plastic; 30 percent rock fragments; pH = 4.6; common thin clay films on ped faces and on rock fragments; clear wavy boundary.
 8. Bt2b 360-398 Yellowish red (5 YR 5/8) gravelly clay loam; weak medium subangular blocky structure; firm, slightly sticky slightly plastic; 30 percent rock fragments; pH = 4.6; few thin clay films on ped faces and rock fragments; gradual wavy boundary.
 9. BC1b 398-444 Yellowish red (5 YR 5/6) gravelly loam; weak medium subangular blocky structure; friable, slightly sticky slightly plastic; 30 percent rock fragments; pH = 5.2; few thin clay films on rock fragments; common black coatings on peds and rock fragments; gradual wavy boundary.
 10. BC2b 444-525 This horizon is the same as BC1b except it is Reddish brown (5 YR 5/4).

Comment by W. D. Sevon and D. D. Braun

Colluvium is ubiquitous in Pennsylvania and its significance as a surficial deposit has been recognized for some time (e.g., Pierce, 1966), but the importance of the work of Hoover (1983) cannot be overemphasized. The recognition of multiple generations of colluvium demonstrates a certain longevity of landscape even though it may not be possible, as yet, to determine the actual time frame of that longevity. Some geologists in Pennsylvania have been quicker to make age assignments for surficial materials than have contemporaneous soil scientists and have long associated the red color present in the surficial materials here with an Illinoian age.

Recent work in Pennsylvania on the age and extent of Wisconsin and older glaciations indicates that much of the reddish weathered material that was once considered Illinoian is pre-Illinoian (Braun, 1988). That produces considerable uncertainty as to the age significance of the red coloration. Also, in the Anthracite portion of the Ridge and Valley, strip mine exposures show thick sections of colluvium that is domin-

antly pre-Wisconsinan in age (Braun, 1988; 1989), but with a weathering character that differs from what is observed at this stop. The different weathering character is caused by differences in moisture content and parent material between the two sites and makes relative age correlations uncertain at best. An additional complication is added if at least some of the red color in the colluvium is derived from red-colored saprolite as suggested for red-colored colluvium farther south in the Appalachians (King, 1964).

The significant fact here, irregardless of how closely the materials can be dated, is that materials from farther upslope have been deposited on the lower slope and have remained, relatively unchanged for a period of time. The length of time is very important, but currently indeterminant except that it has been there at least since the end of the Illinoian.

- LEAVE STOP 4. TURN RIGHT** onto PA Route 74 South.
- 0.6 53.7 **TURN RIGHT** onto PA 944 West.
- 1.5 55.2 **TURN LEFT** onto McClure's Gap Road at crest of hill. PA 944 bears right. Good view of Blue Mountain on right.
- 0.3 55.5 Exposure on left of Martinsburg Formation. Note the thin amount of residuum and soil.
- 0.4 55.9 **TURN RIGHT** onto Easy Road. The view to the right along this road is typical of what is happening throughout the area - development. The 1952 1:24,000 scale topographic maps covering the Opossum Creek drainage basin show 34 houses within the basin. The photorevised (1975 and 1977) maps show an additional 75 houses, and there have been more houses built since the photorevision. Interpretation of 1958 aerial photographs indicates 24 percent of the land in the drainage basin in nonagricultural use and 76 percent in agricultural use, both plowed and grassland. Similar interpretation of 1984 photographs indicates only 35 percent in agricultural use and 65 percent in nonagricultural use. Although rural development is common throughout the area, Opossum Lake, which was completed and filled in 1961, has undoubtedly influenced changing land use within the drainage basin.
- 0.8 56.7 **STOP SIGN. TURN RIGHT** onto Opossum Lake Road.
- 0.1 56.8 **TURN LEFT** to Opossum Lake.
- 0.5 57.3 Parking lot. **LUNCH STOP.**

Opossum Lake is very popular for fishing throughout the year. The opening of trout season finds the banks of the lake lined with fisherpersons and the surface of the lake covered with boats. The lake was full for final inspection on 6/28/61. It underwent a partial drawdown in October, 1972 and a 0.6 m drawdown in October, 1974. A complete drawdown (9.75 m) was commenced on 7/26/85 and completed on 9/10/85. Refill started on 12/23/85. On the basis of observations and a few measurements, an isopach map of sediment thickness was prepared for the lake (Figure 18). Using this generalized estimate of sediment

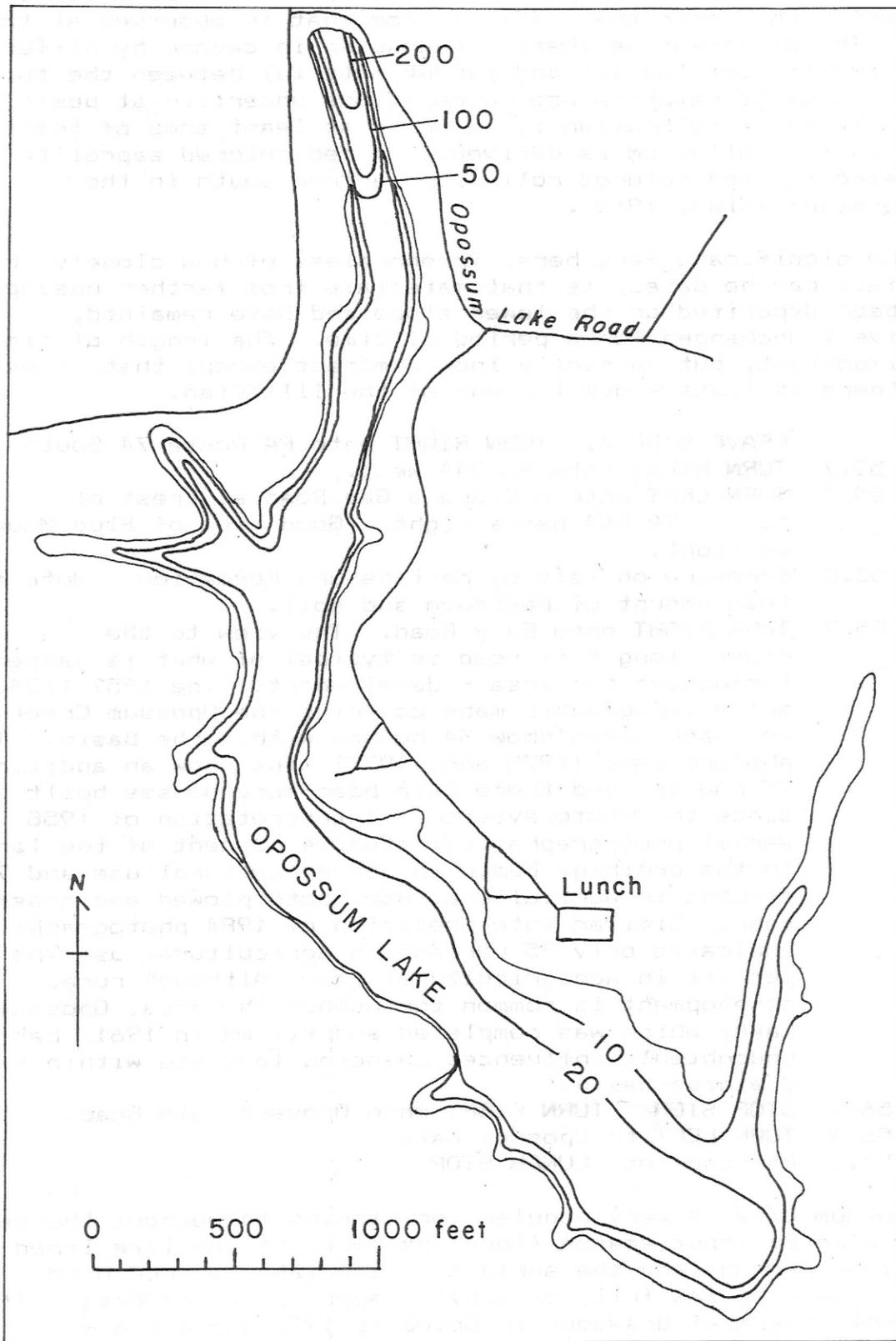


Figure 18. Isopach map of sediment thickness in Opossum Lake. Isopach contours are in centimeters.

thickness, the dried weight of a known volume of lake sediment, and a 7 percent correction (subtraction) for diatoms and total organic carbon, a total volume of 33,000 M.T. of sediment was calculated to be present on the lake bottom. This is equal to a yearly addition of 1,333 M.T./yr or 100 M.T./km²/yr. The trap efficiency of the lake has not been calculated, but it is probably small so presumably much more sediment has escaped entrapment. A size analysis of one sample of the lake sediment performed by the hydrometer method indicates that 60 percent of the sediment is clay size (finer than 0.0039 mm diameter) and about 20 percent of the sediment is between 0.014 and 0.0039 mm diameter.

The lake bottom sediment showed many interesting features. In some places near the margin there was no sediment deposition. In a few places Caterpillar tractor tread marks from original lake construction were preserved undisturbed and partially covered with sediment. The sediment showed no structure, apparently having been totally homogenized by burrowing. A cement block with its center openings parallel to the surface was filled inside to the same level as the sediment surrounding it. Leaves were likely to occur anywhere, as were plastic bags. The surface was covered with beautiful, sharp-edged mudcracks as the sediment dried, but when it was well dried and then subjected to rain the edges of the cracks crumbled and began to infill the cracks.

The inlet at the north end of the lake was particularly interesting because the lake fill comprised alternating layers of leaf mat and sediment. The leaves were tightly matted and ranged from less than a cm in thickness to several cm thick. The leaf mats were thickest near the bridge, thinned lakeward, and disappeared within a few tens of meters.

- LEAVE parking lot and return the way you came.
- 0.5 57.8 TURN LEFT onto Opossum Lake Road.
- 0.2 58.0 Cross bridge at upper end of Opossum Lake. In 1985 when this lake was drained for repairs to the dam, this area showed a sequence of thick leaf mat interbedded with fine-grained sediment.
TURN RIGHT onto Pinedale Road.
- 0.4 58.4 View to the left of dissected surface on Martinsburg Formation in the Opossum Creek drainage basin.
- 1.0 59.4 TURN LEFT onto Ponderosa Road.
- 0.1 59.5 STOP ALONG ROAD OR PULL INTO PARKING AREA OF RELAY STATION ON LEFT.

STOP 5. THE HARRISBURG LOWLAND (PENEPLAIN?)

This area is typical of the dissected lowland which occurs immediately south of Blue (Kittatinny) Mountain from New Jersey to Maryland. The lowland is underlain by shales, siltstones, and some sandstones of the Ordovician Martinsburg/Hamburg Formation and comprises a series of small drainage basins which head on the mountain and drain southward into larger streams. These drainage basins are characterized by gently rolling topography, rounded hilltops and valleys, an overall "smoothness" of topography, and

a visual concordance of hilltops. This area may be considered typical remnants of the Harrisburg peneplain defined by Campbell in 1903. Campbell (1933) later suggested that the term Harrisburg be dropped in favor of the name Chambersburg which is represented by a higher surface near the city of Chambersburg. His suggestion received little attention and the name Harrisburg has lived on, generally with little regard for actual elevation of the presumed remnants, but with considerable regard for its position at the base of the mountain slope.

The Harrisburg peneplain, also called the Valley Floor and Highland Rim peneplain in some southern states, has received widespread recognition as a real topographic form throughout the Appalachians (Fenneman, 1938). The occurrence of secondary residual mineral deposits in the Appalachians generally has been considered to have a close association with the development of the surface (Hewett, 1916; Miller, 1939, 1941; Bridge, 1950; King and Ferguson, 1960). Hack (1965; 1975) denied the association. Pierce (1966) noted the presence of diamicton preserved on uplands of the surface, but doubted that the surface represented even a partial peneplain. The Harrisburg peneplain has generally been assigned an early to middle Tertiary age and the best dating of associated residual mineral deposits (Bridge, 1950) indicates an Eocene age.

The earlier discussion by Braun and Table 2 weigh heavily against these hilltops being related to a former surface of early or middle Tertiary age. However, if a surface of low relief did develop over a kilometer above the present surface during the middle Tertiary and if that surface was only the upper part of a "double planation" weathering development (Budell, 1982), then the hilltops of the Harrisburg surface could be remnants of the lower surface of the double planation. The lower surface of double planation is the weathering front. There are some scattered saprolites which occur on hilltops of the Harrisburg surface (e.g., Sevon, 1975) and these may be remnants of a much older weathering.

This stop is on a drainage divide on the west side of the Opossum Creek drainage basin (Figure 19). These hilltops are separated from the base of the mountain slope by an area of lower elevation. Isolated angular to rounded boulders, cobbles, and pebbles of sandstone, conglomerate, and quartzite derived from the Tuscarora and Juniata Formations occur on the hilltops throughout the drainage basin as well as similar drainage basins in the area of Martinsburg/Hamburg Formation outcrop from near Allentown, Pennsylvania to Maryland. Many of these rocks are up to 5 km from their source on the upper slopes of Blue Mountain. A few of these clasts can be seen at this stop and Figure 19 shows the location of many more within this drainage basin.

The following assumptions are made about these clasts:

1. They do not represent remnants of material let down continuously since the area was overlain by the Tuscarora and Juniata Formations.
2. They have not been spread over the area by man, although many have been moved locally by man.

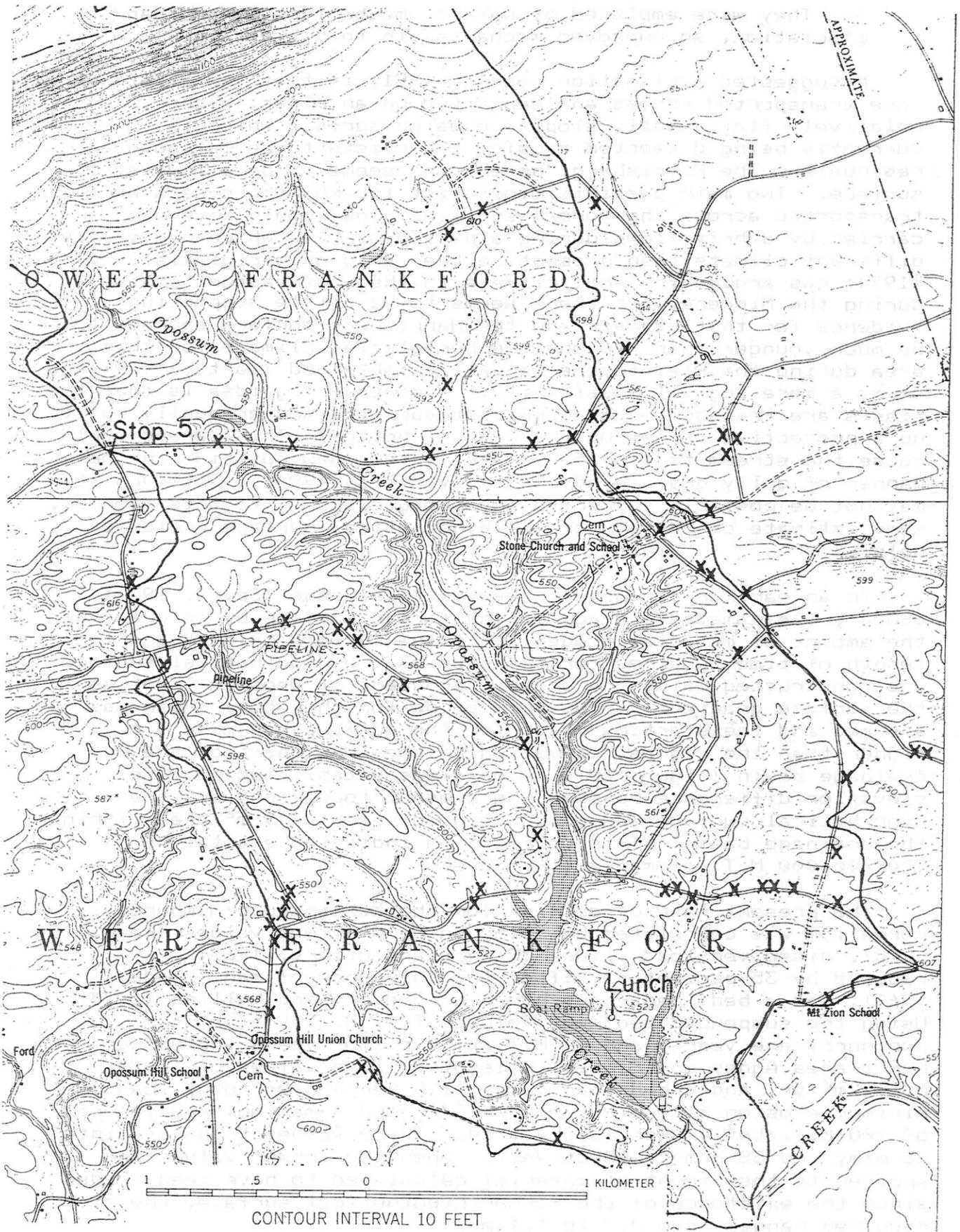


Figure 19. Topographic map of the Opossum Creek drainage basin. Location of isolated boulders derived from Blue Mountain are indicated by an X.

3. They were emplaced by natural mechanisms other than glaciation, an unproven mechanism in this area.

A suggested explanation (Sevon, 1981) is that the clasts were once transported across and deposited on an older, higher, relatively flat, gently sloping erosion surface which is currently being dissected causing the clasts to be let down as residuals. The Harrisburg "peneplain" seems to be a logical surface. Two main possibilities exist for how the clasts were transported across the former surface. They could have been carried by debris flows during a period of time which had vastly different climate than present, either arid or periglacial. Alt (1974) has argued for arid climate in the southeastern states during the Miocene, but there seems to be little supporting evidence for that climate and the Harrisburg surface appears to be much younger than Miocene. A periglacial climate for this area during the Pleistocene is well established (Watts, 1979) and seems a more logical possibility. A contrasting idea is that the clasts are transported by normal stream flow and gradually built up a protective veneer on the channel bottom. This veneer would cause the stream to migrate laterally to a new position in the manner of gully gravure advocated by Mills (1981). Although it may not be possible to derive an absolute answer to this problem, some estimate of the age of the hypothetical surface would be helpful.

In an earlier attempt to resolve this issue (Sevon, 1981; 1985a), I estimated the age of the former surface by calculating the amount of material eroded since the surface existed and the length of time required for the erosion. A hypothetical surface was constructed using the present gradient of Opossum Creek as the surface gradient. A uniform slope for the whole basin was assumed and the starting place for the surface was made 3 m higher than the highest elevation in the lower part of the drainage basin (Figure 20). A grid was established and the elevation difference between the present topography and the hypothetical surface was calculated for each 3419 m² area within the drainage basin. This calculation indicated a total of 930,000,000 M.T. of material removed.

The present rate of erosion for the Martinsburg/Hamburg Formation was calculated by using suspended-load values (Reed, 1980), dissolved-load values (Stuart and others, 1967) reduced by 35 percent to offset the influence of man (Meade, 1969), and a bed-load value based on Gregory and Walling (1973). Using the suspended-sediment values of 41 M.T./km²/yr (for non-hurricane years) and 66 M.T./km²/yr (for years including hurricanes Agnes and Eloise), dissolved-load values of 17-29 M.T./km²/yr, and a bed-load value of 5 percent of total load, a minimum erosion rate of 61 M.T./km²/yr and a maximum erosion rate of 100 M.T./km²/yr were calculated. These values translate into 23 m/my and 38 m/my respectively. When the former values are applied to the amount of material calculated to have been eroded since the existence of the former hypothetical surface, the time required ranges from 0.7 to 1.1 my.

The above mathematical exercise suggests that if a surface

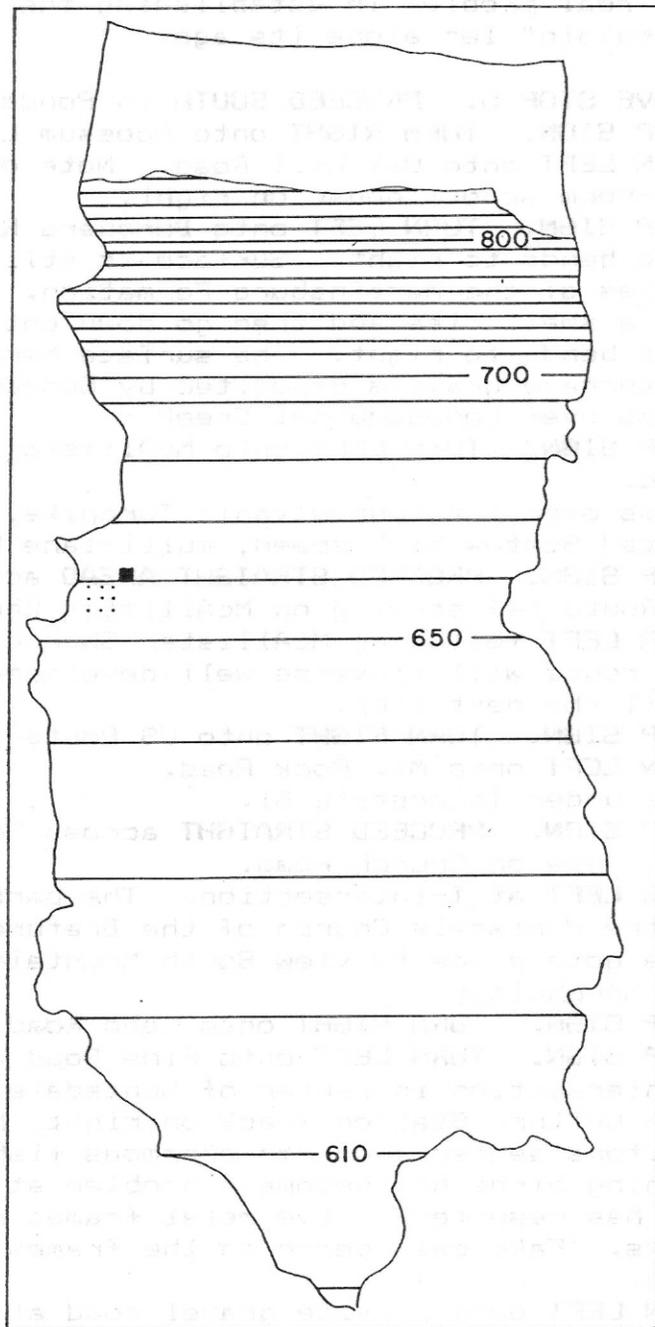


Figure 20. Hypothetical Harrisburg surface across which large clasts were presumably transported. See text for explanation of how surface was constructed.

did formerly exist at an elevation not too much higher than the present hilltops, then it was not too remote from the present when the clasts were transported onto the surface. If, on the other hand, the erosion rate was much lower prior to disturbance by man, then the former surface would be older, but not necessarily too much older. This may mean that the present climate, even though it appears to be eroding the lowlands more rapidly than the ridge tops, is relatively ineffective in carving the present landscape and is not the climate under which the bulk of the post middle Miocene erosion has occurred. In any case, it is apparent

that there is a real problem in establishing the existence of the Harrisburg "peneplain" let alone its age.

- LEAVE STOP 5. PROCEED SOUTH** on Ponderosa Road.
- 0.7 60.2 **STOP SIGN. TURN RIGHT** onto Opossum Lake Road.
- 0.6 60.8 **TURN LEFT** onto Oak Hill Road. Note old, brick, one-room school house on right.
- 0.5 61.3 **STOP SIGN. TURN LEFT** onto Burgners Road.
- 1.3 62.6 Road bends to right. Surface is still underlain by shales of the Martinsburg Formation. The road will top a small rise and then go down onto the carbonates.
- 0.3 62.9 Road bends to right. The surface here is underlain by terrace gravels deposited by Conodoguinet Creek.
- 0.2 63.1 Cross over Conodoguinet Creek.
- STOP SIGN. TURN LEFT** onto McAllister Church Road.
- 0.4 63.5 Cross over the Pennsylvania Turnpike, the first United States high speed, multi-lane highway.
- 0.3 63.8 **STOP SIGN. PROCEED STRAIGHT AHEAD** across PA Route 641 staying on McAllister Church Road.
- 0.1 63.9 **BEAR LEFT** following McAllister Church Road. The route will traverse well-developed karst terrain until the next stop.
- 1.4 65.3 **STOP SIGN. TURN RIGHT** onto US Route 11 South.
- 3.1 68.4 **TURN LEFT** onto Mt. Rock Road.
- 1.0 69.4 Pass under Interstate 81.
- 1.9 71.3 **STOP SIGN. PROCEED STRAIGHT** across PA Route 174. Now on Church Road.
- 1.0 72.3 **BEAR LEFT** at T-intersection. The parking lot of the Huntsdale Church of the Brethren on the right is a good place to view South Mountain and alluvial fan morphology.
- 0.1 72.4 **STOP SIGN. TURN RIGHT** onto Lebo Road.
- 0.3 72.7 **STOP SIGN. TURN LEFT** onto Pine Road at T-intersection in center of Huntsdale. Huntsdale Fish Culture Station (back on right) has a small visitors center and some enormous fish on display. Fishing birds has become a problem at the station and has resulted in the metal frames over the fish tanks. Fake owls perch on the frames to protect the fish.
- 0.5 73.2 **TURN LEFT** onto private gravel road at No Trespassing sign. This is Pennsylvania Fish Commission property and permission to visit here should be obtained from the Huntsdale Fish Culture Station.

STOP 6. HUNTSDALE ALLUVIAL-FAN GRAVELS

Comment by W. D. Sevon

This former borrow pit, now used for burial of dead fish by the Huntsdale Fish Culture Station, is also the site of a former iron furnace. Evidence of the iron furnace operation is the black (charcoal) and red (burned) soil colors above the gravel at the west end of the pit. Mr. Ted Dingle, retired chief of the fish culture station said that he found metal artifacts at the

site when he was a boy.

The vertical exposure on the north side of the pit contains subrounded to rounded clasts of quartzite derived from the Cambrian Antietam Formation which occurs to the south within South Mountain (Figure 21). This site is on the distal part of an alluvial fan formed by a stream flowing from Irishtown Gap. The gravels are variably but generally poorly sorted. Bedding is evident, but not everywhere clearly defined. Places along the exposed face show (1) good stratification, (2) chaotic clast orientation with no stratification, and (3) probable channelling. Both mudflow and waterflow mechanisms of deposition are present here. Both mechanisms would be expected on an alluvial fan.

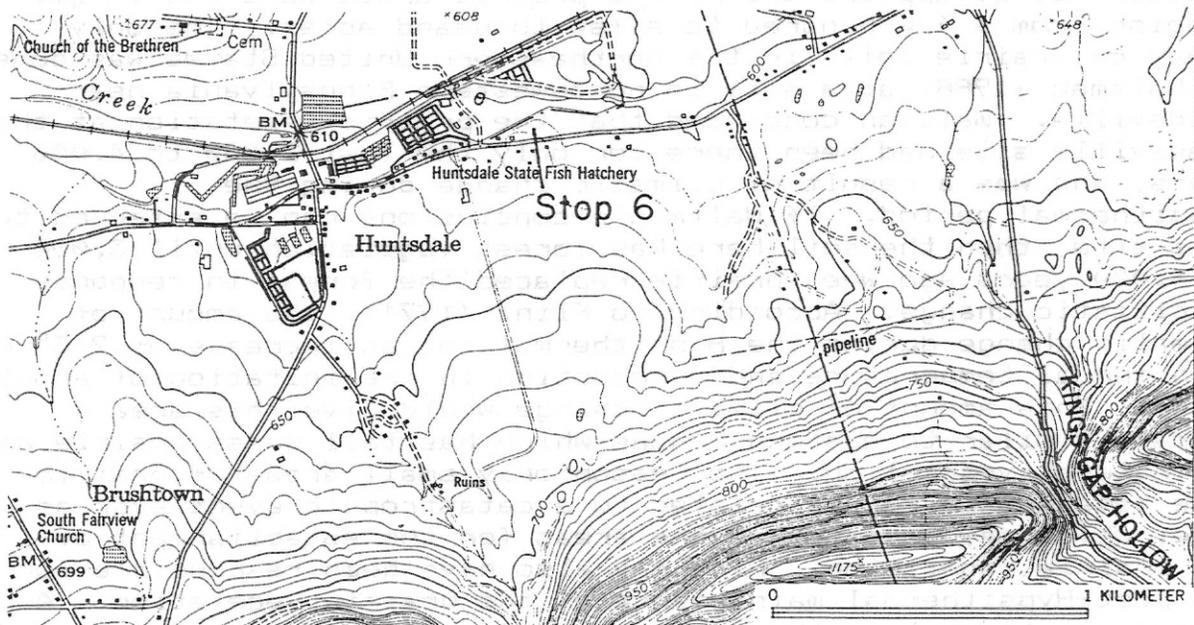


Figure 21. Location map for Stop 6. Note excellent definition of alluvial fans by the 10 foot contour interval. Strike ridge is underlain by the Cambrian Antietam quartzite.

The topographic signature of the alluvial fan (Figure 21) is distinctive, but also shows clearly that the former transporting and depositing stream is now incised into the fan surface. The surface of the fan also has some depressions which are presumably upward propagations of sub-fan sink hole development. Such depressions are common on the alluvial and colluvial deposits where they overlie limestone and dolomite along the margin of South Mountain.

Comment by Edward J. Ciolkosz

The soil at this site shows a well-developed pre-Wisconsinan profile. The pre-Wisconsinan age is suggested by the thickness and degree of development of the B horizon and the pedogenic high chroma reddish color. Although the degree of development of the subsoil is not uncommon, its A horizon development appears to be anomalous. Soils developed under well-drained forest conditions with similar B horizon development have thin (5-8 cm) A horizons

underlain by a light colored 8-15 cm thick E (A2) horizon. Forest soil A horizons are not very dark colored, particularly when dry. This soil has a much thicker (although somewhat disturbed) very dark colored, both dry and moist, A horizon. This feature may indicate that the A horizon of this soil did not develop under forest vegetation, but rather under prairie grass vegetation.

Forest was the natural vegetation of Pennsylvania at the time of settlement (Braun, 1950). Although this was the case, there were isolated areas of tall grass prairie. Losensky (1961) located 10 of these areas, one of which was near Chambersburg about 40 km southwest of this site. Although not well documented, it appears that these prairie areas were not large, ranging from a few hundred to a few thousand acres. The only study of prairie soils in the northeastern United States was done by Waltman (1988) at a site in northwestern Pennsylvania near Meadeville. Waltman concluded that the prairie vegetation at the Meadeville site had been there for only the last 2,000 to 4,000 years, and was a result of climatic change during the Hypsithermal period. If Waltman's conclusions can be extended to this site, then the soil here had forest vegetation until 3,000 to 4,000 years ago when prairie replaced the forest in response to climatic change. According to Flint (1971), the amount of climatic change during the Hypsithermal was an increase of 2-3° C mean annual temperature and a reduction in precipitation of about 13 cm. This amount of climatic change would give this area a climate similar to eastern Kansas which has tall grass prairie as its natural vegetation. The reason only small areas of prairie were established may be related to a catastrophic event such as fire, which may have opened the areas for the establishment of the prairie vegetation. Fire may also have been responsible for the post-Hypsithermal maintenance of the prairie vegetation. A second way to explain the occurrence of prairie vegetation is as follows. Forest vegetation occupied the site during the last interglacial (Sangamonian). With the onset of the Wisconsinan, the forest was replaced by tundra which basically is a cold grassland in which trees can't survive because of low temperature (Coupland, 1979). With the moderation of climate in post-Woodfordian time, prairie vegetation replaced the tundra. Fire must again be invoked to maintain the prairie against forest encroachment. Another factor might be that prairie vegetation is more competitive on coarse textured, droughty soils than is forest vegetation.

Regardless of the chronology, the only apparent influence the prairie vegetation has had on this soil is on the development of the A horizon. Although this appears to be the case, prairie vegetation significantly impacts the pathway of soil genesis. In the midwestern states where prairies and forest meet, it has been documented that prairie soils are drier and hotter than adjacent forest soils (Risser and others, 1981; Anderson, 1987). The warmer temperatures result from less shade in the prairie and the drier conditions are the result of greater evapotranspiration due to higher temperatures and higher wind velocities near the soil surface. Prairie soils contrast strongly with forest soils. They have higher pH (less leached), tended to have more poorly

developed argillic horizons, and much more organic matter (Anderson, 1987). Recently it has been reported that forest soils have higher CO₂ contents than grassland soils (Gordon and others, 1989), which, if correct, may help explain why forest soils are more acid than prairie soils.

A second and less elegant scenario to explain the dark color of the A horizon is that fires in the area have contributed charcoal which has been disseminated in the A giving it its dark color. In various areas of the borrow pit, pieces of charcoal, some up to 1.5 cm in diameter, occur. Which scenario is correct will have to wait until more investigations are done in the area.

Comment by D. D. Braun

I would suggest an even less elegant scenario to explain the thick, dark, charcoal-rich A horizon at the site -- human disturbance. The site was once occupied by a charcoal-burning iron furnace. Iron furnace sites at Bloomsburg, Pennsylvania have similar thick charcoal-rich A horizons. Drawings of the iron furnace sites show stockpiles of iron ore, limestone, and charcoal on the ground surface. Thick charcoal-rich A horizons also underlie numerous sites along the flanks of the strike ridges where wood was burned to produce the charcoal.

Site description

This site was described by Edward Ciolkosz, Robert Dobos, and Jon Pollack on July 7, 1989. In the south-facing wall of a borrow pit which is just north of Route 21008 and 0.8 km east of the junction of Routes 21008 and 21004 in Huntsdale, Cumberland County. The site has a 5 percent slope with a north (0°) aspect and is located on the toe of a large alluvial fan that has been cut off in its distal part by Yellow Breeches Creek. The alluvial fan originates to the south in South Mountain which is an extension of the Blue Ridge physiographic province. The vegetation is locust, poison ivy, and raspberry with common roots to 35 cm and a few to 150 cm. The alluvial fan is a coarse textured, high rock-fragment content material. The rock fragments appear to be mainly quartzite. The soil is a skeletal Typic Hapludult (unnamed soil series). The clay films in the Bt1 and Bt2 contrast in color with the matrix more than the clay films in lower horizons, and the Bt3 horizon is a sandy lens in the deposit. The E&Bt horizon also is developed in a low rock-fragment material. The Bt part of this horizon has been called textural bands or lamellae (see Bond, 1986) and are found in sandy materials of many origins (aeolian, outwash, residual). They are found in the lower part of the profile and may be below an argillic or a cambic B horizon, and according to Foss and Segovia (1984) can form in 3,000 to 6,000 years. Approximately 20 cm of spoil material is piled on the profile and is not included in the description.

Profile Description

Horizon	cm	Description
1. Ap	0-35	Top 7 cm black (10 YR 2/1) 10 YR 4/1 dry, bottom 28 cm very dark gray (10 YR 3/1) 10 YR 5/2 dry, very gravelly loam; weak very fine subangular blocky to granular structure; very friable, nonsticky nonplastic; 35 percent rock fragments; pH = 5.2 (top 7 cm) 6.4 (bottom 28 cm); abrupt wavy boundary.
2. BA	35-58	Yellowish brown (10 YR 5/6) extremely gravelly sandy loam; very weak subangular blocky structure formed by rock fragments; friable, nonsticky, nonplastic; 75 percent rock fragments; pH = 5.2; clear wavy boundary.
3. Bt1	58-78	Strong brown (7.5 YR 5/6) extremely gravelly sandy loam; weak subangular blocky structure formed by rock fragments; firm, nonsticky nonplastic; 75 percent rock fragments; pH = 5.2; moderately thick 5 YR 5/4 clay films on rock fragments and as clay bridges; clear wavy boundary.
4. Bt2	78-152	This horizon is the same as the Bt1 except it has a higher concentration of clay bridging at the bottom of the horizon, and an abrupt wavy boundary.
5. Bt3	152-185	Strong brown (7.5 YR 5/8) sandy loam; weak medium platy structure; firm, nonsticky nonplastic; 10 percent rock fragments; pH = 5.2; thin clay bridges between sand grains in bands; abrupt wavy boundary. this horizon is a lens of less gravelly material in the coarser deposit.
6. Bt4	185-254	Brownish yellow (10 YR 6/6) extremely gravelly coarse loamy sand; very weak subangular block structure formed by rock fragments; firm, nonsticky nonplastic; 75 percent rock fragments; pH = 5.2; thin to moderately thick clay films on rock fragments and binding most sand grains; clear wavy boundary.
7. BC	254-304	Strong brown (7.5 YR 5/6) very gravelly coarse sand; single grain; loose, nonsticky nonplastic; 35 percent rock fragments; pH = 5.2; abrupt wavy boundary.
8. E&Bt	304-368	Bands (7-15 cm thick) of yellow (10 YR 7/6) gravelly loamy sand, single grain; loose, nonsticky nonplastic; alternating with reddish yellow (7.5 YR 6/8) gravelly loam; massive; friable to firm; slightly sticky, slightly plastic; moderately thick clay bridging; pH = 5.2 in both zones; 15 percent rock fragments.

More comment by W. D. Sevon

The soil information provides something to chew on, but may not help resolve larger issues. The possible prairie soil development may indicate one of the subtle changes that can occur with small climate variations. We can only wonder how many other variations have had even greater effects on the landscape, effects which we do not recognize. Possibly of greater importance is the older, pre-Wisconsinan soil developed on this part of the present surface of the alluvial fan. At the very least we can suggest that the soil may be greater than 120,000 years in age, but we really have no means at present to determine how much older. Thus soils provide us only with a minimum time frame for the origin of the alluvial fan. As we shall see during the commute to Stop 7, the surface of the fan has an abundance of undrained (by surface drainage) depressions which presumably are related to solution activity in the underlying carbonate bedrock. Indeed, the margin of South Mountain is a sink for alluvial materials exiting the mountain area (Figure 22). What can we say about the age of the alluvial fans from the amount of solution activity? Anything? Whatever their age, the water gap and the underlying carbonate surface had to be eroded to a level appropriate for development of the alluvial fans we see today. But when? And how does this relate to the Harrisburg surface and the data in Table 2 which suggests a kilometer of material above this site a scant 16 million years ago? Good questions, but no good answers.

Another comment by D. D. Braun

At this stop the thickness of gravel trapped by the continuously dissolving limestone suggests a long continued outpouring of gravel from South Mountain in order to maintain the fans at about the level of the nearby shale lowlands. At Stop 5 a few Tuscarora sandstone clasts remain on the Martinsburg shale hilltops and the classical Davisian explanation is that the clasts rest on remnants of the Harrisburg surface. In that case, erosion and gravel accumulation are discontinuous with an earlier gravel-capped surface being incised to form the present surface. But continuous erosion, as suggested by the South Mountain fans, can leave such gravel relicts in the region by successive abandonment of gravel surfaces by lateral stream migration during incision (gully gravure) as has been argued by Hack (1960, 1965) and Mills (1981). A low relief Harrisburg erosion surface is not necessary to explain the present landscape.

LEAVE STOP 6. RETURN TO PINE ROAD AND TURN RIGHT.

View just ahead on left of alluvial fan surface.

- 0.4 73.7 **TURN LEFT** onto Leeds Road. The route will now proceed up the surface of an alluvial fan and then across the surface of coalescing alluvial fans.
- 0.8 74.5 **BEAR RIGHT** following Leeds Road.
- 0.2 74.7 **STOP SIGN. PROCEED STRAIGHT** across Centerville Road onto South Side Drive.
- 0.4 75.1 Note cobbles of Antietam Quartzite in field on right opposite South Fairview Church of God on left. This

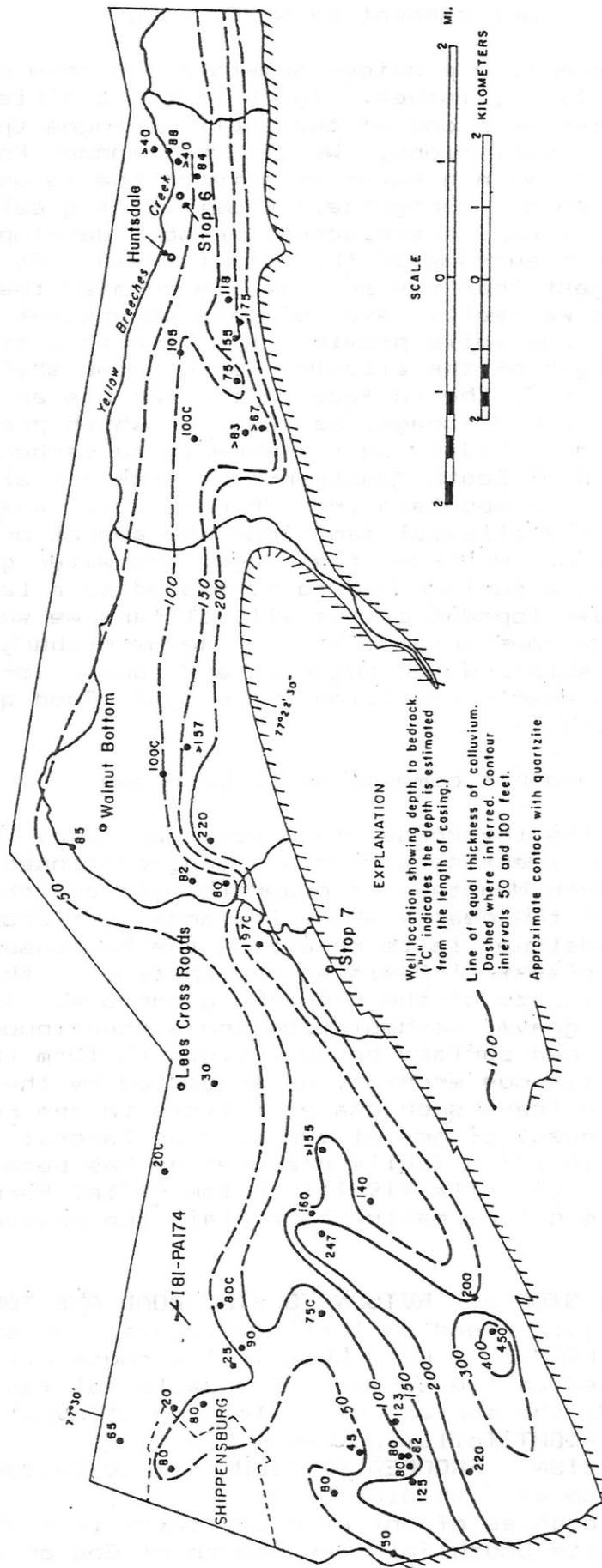


Figure 22. Isopach map of a combination of residuum, colluvium, and alluvium on the north flank of South Mountain (modified from depth to bedrock data of Becher and Root, 1981, Figure 8).

- site, along with several others on this trip, was visited by John Hack in 1982.
- 0.1 75.2 Note the very irregular fan surface on the left. This irregularity is presumably related to sub-fan solution of dolomite in the underlying Cambrian Tomstown Formation.
 - 0.1 75.3 Note more karst-like topography on alluvial fan surface on right.
 - 0.8 76.1 **TURN RIGHT** onto Blue Pond Road. Proceed down alluvial fan surface.
 - 0.8 76.9 **STOP SIGN. TURN LEFT** onto Pine Road.
 - 2.6 79.5 **BEAR RIGHT** onto Mountain View Road and pass under railroad bridge.
 - 0.3 79.8 **STOP SIGN. TURN LEFT** onto PA Route 174 West.
 - 0.8 80.6 Center of Walnut Bottom.
 - 1.5 82.1 **TURN LEFT** onto Big Pond Road. Proceed up alluvial fan surface.
 - 0.4 82.5 **BEAR RIGHT** onto Chestnut Grove Road. Good view to left of alluvial fan surface.
 - 0.4 82.9 **TURN LEFT** onto Gutshall Road.
 - 0.1 83.0 Note undrained depression on left.
 - 0.5 83.5 **TURN RIGHT** onto Sand Bank Road and cross small bridge.
 - 0.5 84.0 Entrance on left to sand quarry of Shippensburg Sand and Gravel.

STOP 7. SAPROLITE AND COLLUVIUM

Quartzite of the Antietam Formation is quarried at this location (Figure 23) and processed to produce sand. However, the items of interest are the deep red colluvium and the saprolite developed on the Antietam.

Red (2.5 YR 4/8) colluvium is exposed along the lowest level on the north side of the quarry in its eastern part. The colluvium comprises clay, silt, sand, and angular to subangular clasts of Antietam quartzite. The weathering extends downward into broken bedrock. The colluvium contains some suggestion of bedding, but rarely is there a subtle hint of stratification or alignment of clasts. Quartzite clasts vary in degree of weathering from relatively hard to totally disintegrated. There is some reticulate mottling in the form of vein-like, red zones surrounding gray masses. The reticulate mottling is very angular with numerous perpendicular intersections. This reticulate mottling bears a resemblance to plinthite although it is not true plinthite. Plinthite is an iron-rich, humus poor mixture of clay with quartz and other dilutents (Soil Survey Staff, 1975, p. 50). It forms by segregation of iron and forms in a horizon that is saturated with water at some season. Irreversible hardening will occur after enough exposure to wetting and drying has occurred. Much that has been called laterite is included in the meaning of plinthite.

The presence of plinthite-like material at this site may indicate the presence of a former climate with seasonal wetting and drying, but one that did not last long enough to develop a true laterite. Again the question: when did the colluvium form?

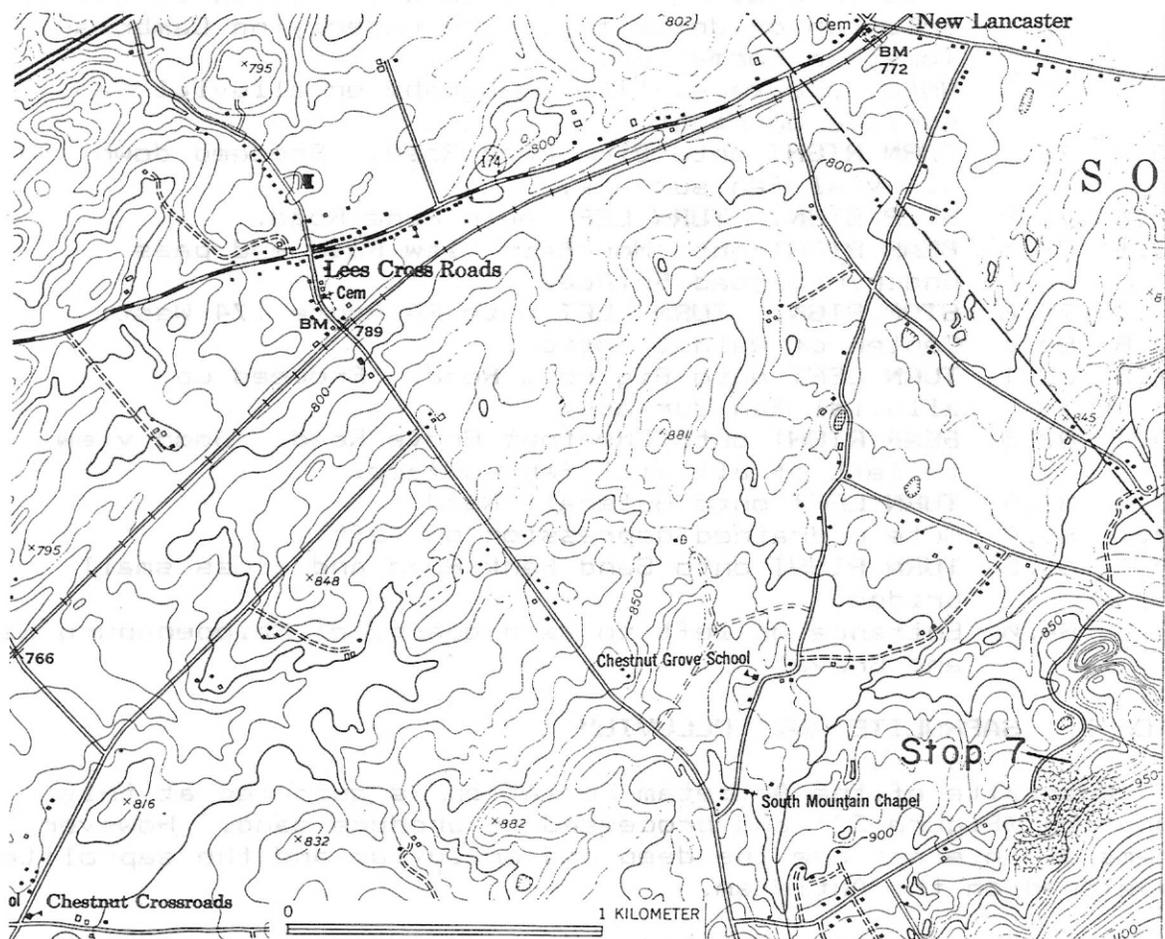


Figure 23. Location map for Stop 7. Note the dissection of the alluvial fan surface.

Can this colluvium be related to the colluvium at Stop 4 which is thought to be pre-Wisconsinan but definitely Pleistocene in age? The colluvium here is much redder in color and has suggestions of a different weathering history. Is the weathering history the result of different climates, different positions on the slope, different source materials, different length of weathering time, or all of the above?

At intermediate levels in the eastern part of the quarry is more colluvium of a much different character in that it lacks the red color and is a dull yellowish gray instead. It extends in prisms downward into saprolite developed on the Antietam. The top has been truncated and there is no suggestion of what soil development, if any may have once been present. When was this colluvium formed? Probably later than the red colluvium, but the two colluviums do not occur in contact.

Saprolite developed in the Antietam quartzites is well exposed in erosional gullies at the east end of the quarry where the

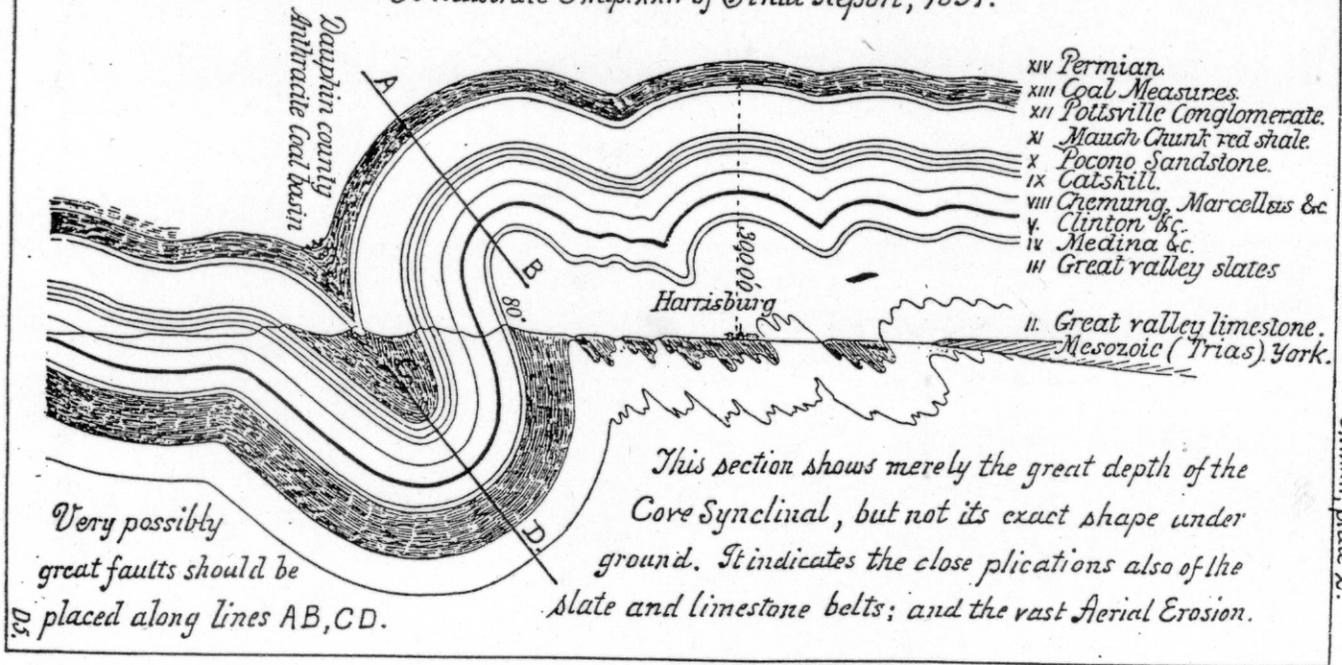
material is close to the original north-sloping surface. Deeper quarrying encounters relatively fresh rock although weathering zones occur apparently to considerable depth. The saprolite is typical in that the quartzite is totally disintegrated, but preserves the details of all structures. Similarly, the interbedded shales have been weathered to clay. When did this weathering occur? Is it as old as Late Cretaceous or Early Tertiary as has been suggested in the past for saprolites this far north in the Appalachians (Costa and Cleaves, 1984), or is it an ongoing process as suggested by Pavich (1989) and thus fairly recent in age? And don't forget that the scenario must include saprolite, colluvium, and the likelihood that Table 2 is correct.

Interpretative scenario for Stop 7 by D. D. Braun.

1. By the early Miocene a very deeply weathered relatively low relief erosion surface (peneplain ?, etchplain ?) existed about 1 km above the present surface.
2. About 400 to 500 m of rapid middle Miocene erosion of the weathered mantle, probably caused by climatic change in the direction of colder conditions (possibly even occasional periglacial conditions), destroyed essentially all vestiges of the older erosion surface.
3. About 400 to 500 m of late Miocene and Pliocene erosion, probably under climate conditions similar to those of today, completed the destruction of the early Miocene surface and developed the basic pattern of ridges and lowlands present today.
4. About 100 to 150 m of Pleistocene erosion, from at least 10 cycles of alternating warm temperate and cold periglacial climates, has produced most of the local relief features, slope profiles, and debris mantles that make up the present landscape.

LEAVE STOP 7. TURN LEFT onto Sand Bank Road.
 0.7 84.7 STOP SIGN. TURN RIGHT onto Strohm Road. Note exposure of alluvial fan materials ahead on left.
 1.1 85.8 STOP SIGN. TURN LEFT onto High Road.
 0.2 86.0 Excavation for a house foundation on right showed alluvial fan materials. Note relief of area.
 0.7 88.7 TURN RIGHT onto Goodhart Road.
 0.6 87.3 Ridge underlain by limestone.
 0.3 87.6 STOP SIGN. TURN LEFT onto Walnut Bottom Road (PA Route 174 West).
 1.0 88.6 TURN RIGHT onto Interstate 81 North.
 22.4 111.0 EXIT RIGHT to New Kingston, US Route 11.
 0.5 111.5 TURN RIGHT into parking lot of Quality Inn.
 END OF FIELD TRIP. HAVE A GOOD MEETING!!!

*Hypothetical Palaeozoic Section across the Great Valley at Harrisburg.
To illustrate Chap. XXII of Final Report, 1891.*



This cross section is geographically accurate; the topographical elevations are on a true scale; but the geological Subdivisions are merely indicated to show the amount of Erosion that has occurred, and the reason for believing that the whole Palaeozoic system once covered the area now occupied by the Great Valley. - N.B. Nos. II & III are too thick.

(Looking East.)

