APPALACHIAN FIELD TRIP

Geology 215, M.S.U.

S. G. Bergquist

GEOLOGY 215

APPALACHIAN FIELD TRIP

Following is a revised list of over night stops arranged for on the trip into the Appalachians.

Friday, March 25th	Hamilton, Ontario; Men-Astor Hotel; Women-Y.W.C.A.
Saturday, March 26th	Elmira, New York; Rathbun Hotel
Sunday, March 27th	York, Pennsylvania; Hotel Penn.
Monday, March 28th	Kernstown, Virginia; Tourist Camp, Mrs. Cy Mee
Tuesday, March 29th	Staunton, Virginia; Whitmore and Beverly Hotels
Wednesday, March 30th	Roanoke, Virginia; Y.M.C.A (Men) and Y.W.C.A.(Women)
Thursday, March 31st	Johnson City, Tennessee; John Sevier Hotel.
Friday, April 1st	Knoxville, Tennessee; J.C. La Point Tourist Camp
Saturday, April 2nd	Middlesboro, Kentucky; Cumberland Hotel
Sunday, April 3rd	Probably in Lexington Kentucky
Monday, April 4th	East Lansing, Michigan

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Please note that our itinerary has been changed. The insurance company has granted special permission to take the bus through Canada.

S. G. Bergquist

March 24th, 1938

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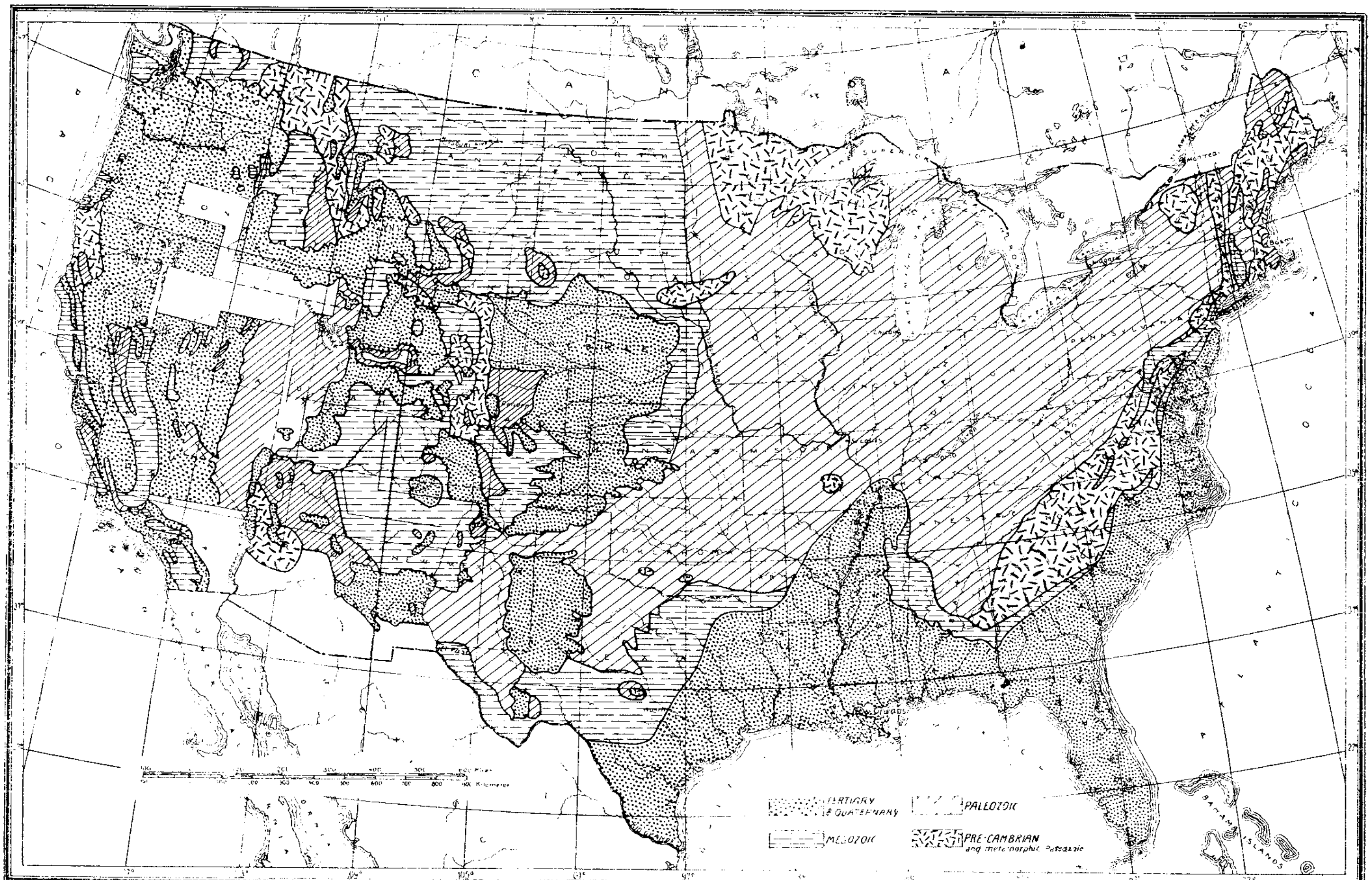
Atlas of American Geology

GENERAL

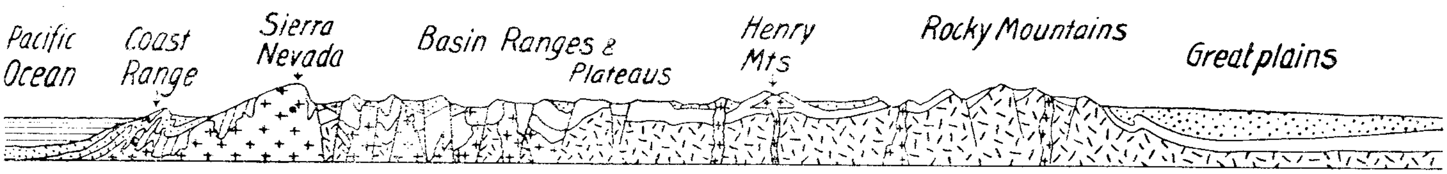


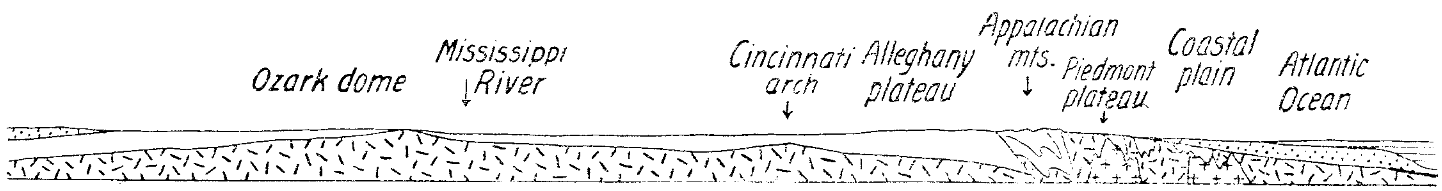
Generalized geologic map of the United States. (Adapted after WILLIS.) (From Blackwelder)

A. 1. Name eight separate regions where Pre-Cambrian or metamorphic rocks occur.

2. Are the Paleozoic formations scattered or continuous? Do any Mesozoic formations occur in the eastern United States? Where are they most extensive?

3. How do the Tertiary formations of the Great Plains differ from those of the Atlantic Coastal Plain? What kind of Tertiary rocks occurs in Oregon and Washington?





= Pre-Cambrian, = Paleozoic, = Mesozoic & Tertiary, = Igneous intrusions

Generalized profile across the United States near the 35th parallel of latitude. (Vertical scale 15 times the horizontal.)

B. 1. Indicate on the map above the position of this cross-section.

2. What is the essential structure of the Great Plains? of southern Illinois and Indiana? of the Rocky Mountains? the Henry Mountains? the Sierra Nevada?

3. What difference do you note between the Cincinnati Arch and the Ozark Dome?

4. Draw a similar section from central Wisconsin to the South Carolina coast.

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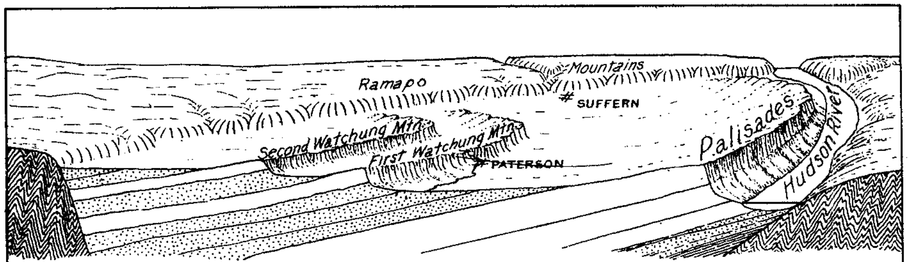
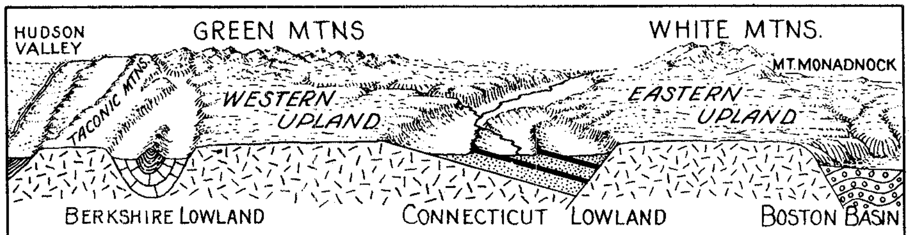


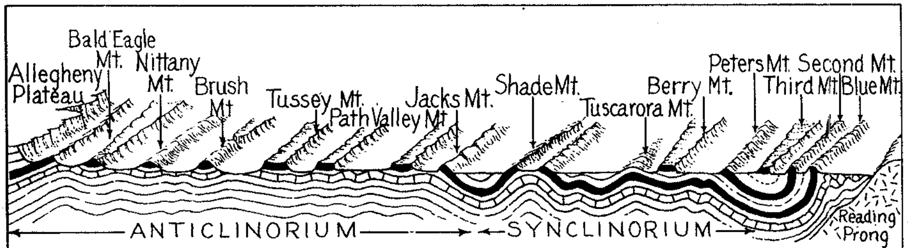
THE NORTHERN END OF THE TRIASSIC LOWLAND

A. Color this diagram to show geological formations on the surface as well as in the cross-section. Show by arrows the strike and the dip of the Triassic formations. Point out one unconformity and one fault. What genetic type of stream is the Hudson River? Label the "Cretaceous" and the "Tertiary" peneplains.



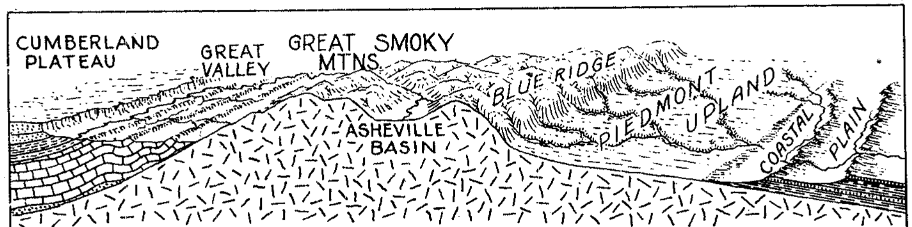
A SECTION ACROSS SOUTHERN NEW ENGLAND

B. Color this diagram to show geology. What is the structure of the Berkshire Lowland? Account for the presence of Mount Greylock in the middle of the Berkshire Lowland. How does the Connecticut Lowland differ from the Triassic Lowland? What peneplains are represented in this region? What is Mt. Monadnock?



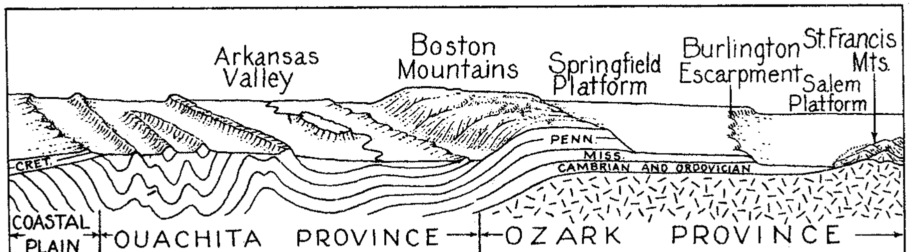
GENERALIZED SECTION SHOWING STRUCTURE OF PENNSYLVANIA FOLDED MTNS.

C. What is a Synclinorium and how does it differ from a syncline? Which of the mountains shown above are "Synclinal", which are "Anticlinal", and which are "Monoclinal"? Does the synclinorium pitch toward or away from the observer? Do the oldest formations of the region outcrop in the Anticlinorium or Synclinorium?



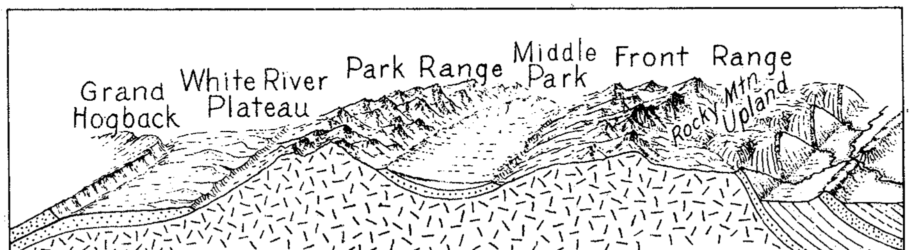
SECTION THROUGH THE SOUTHERN APPALACHIANS

D. What four main physiographic provinces are represented here? Is the Blue Ridge a fault scarp? To what is it due? What is the age of the rocks underlying the Coastal Plain? the Great Valley? the Cumberland Plateau? How many peneplains may be noted in this region? Where is the "Fall Line" peneplain?



GENERALIZED SECTION SHOWING STRUCTURE OF OZARKS AND OUACHITAS

E. To what is the Burlington Escarpment due? Do the rocks in the Ouachita province dip toward the Boston Mtns., in the same way that the rocks in the Folded Appalachians dip toward the Allegheny Plateau? What is the structure of the Arkansas Valley? What kind of rocks underlie the St. Francis Mts?



A SECTION SHOWING STRUCTURE OF THE SOUTHERN ROCKY MTNS.

F. What is the essential structure of the Southern Rocky Mtns? To what is Middle Park due? Point out the "Flatirons" and explain. Why is the Front Range steeper on its eastern side? Label the Dakota Hogback. To what formation is it due and what is its geological age? Show mountain front without hogbacks, due to faulting.

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Sheet No. 1c

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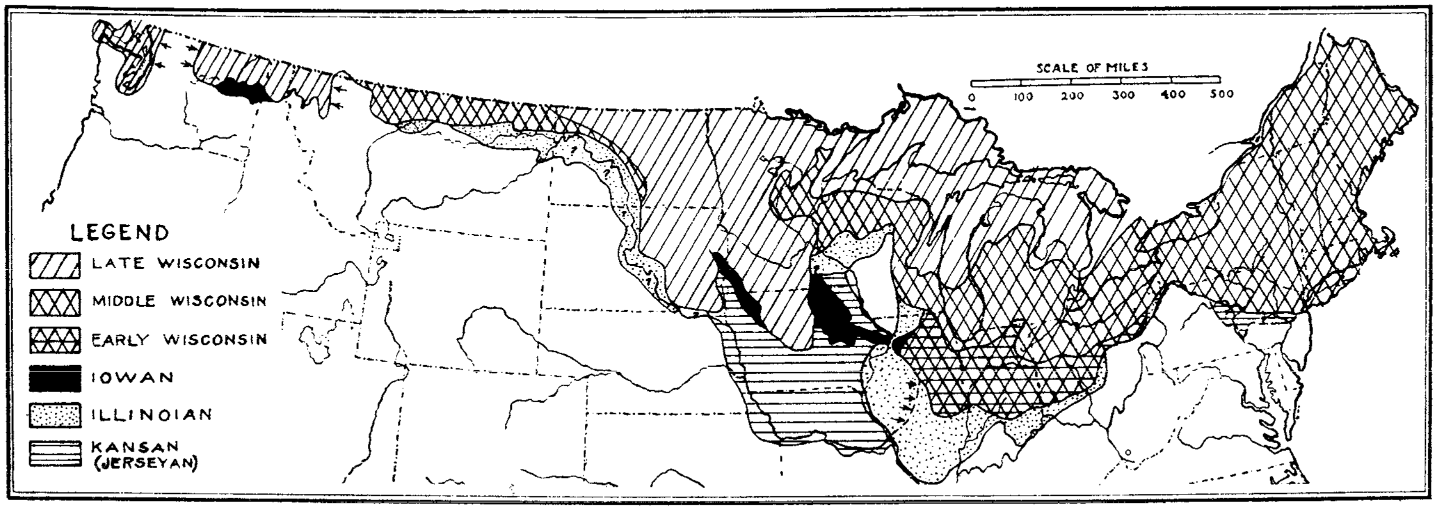
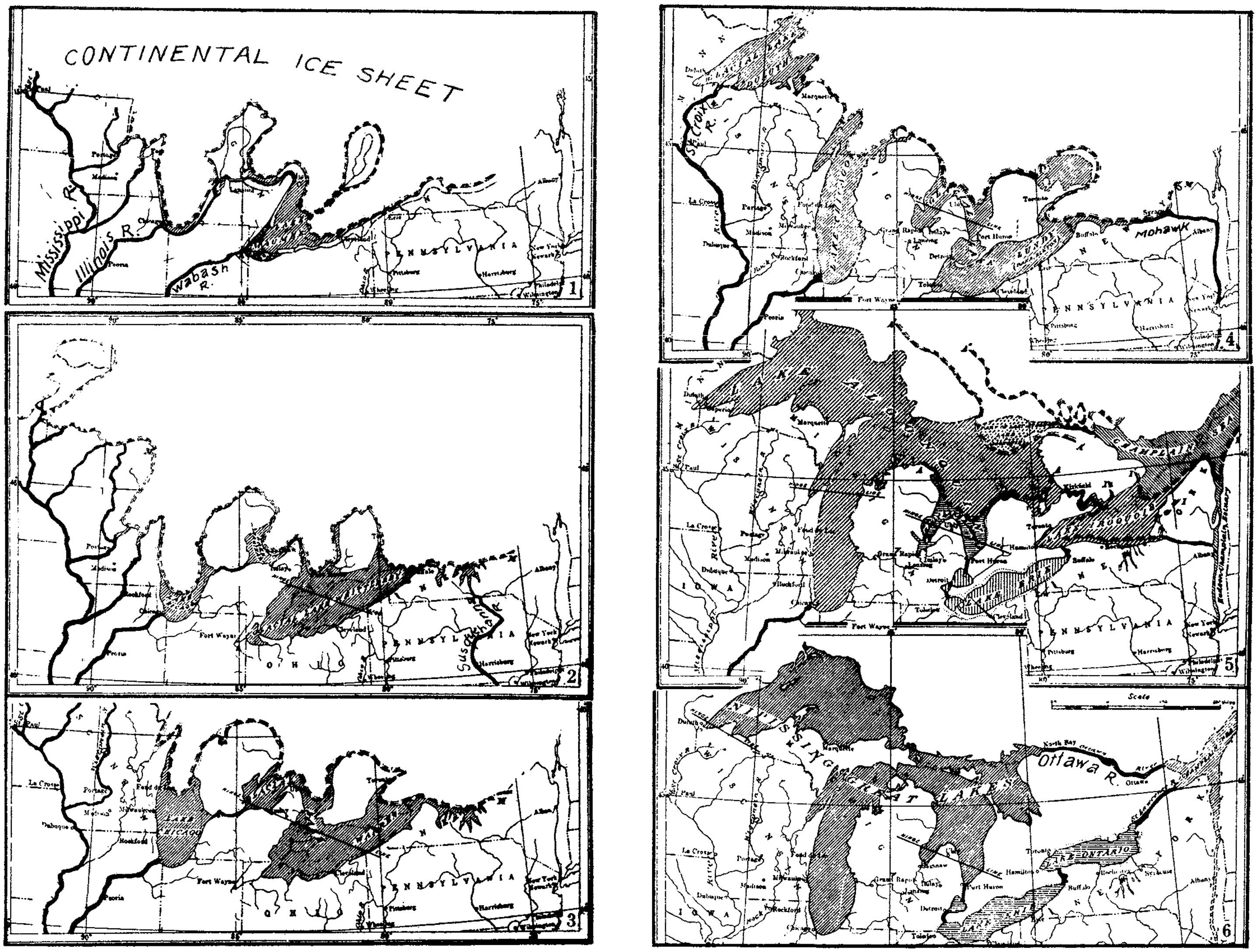


A. MAP SHOWING AREAS COVERED DURING SUCCESSIVE STAGES OF QUATERNARY GLACIATION. (AFTER CHAMBERLIN AND MACCLINTOCK, FROM MANY SOURCES)

1. Show by heavy or colored line the limit of Wisconsin glaciation. Label the "Driftless Area, and explain it.
2. Point out one region where the Illinoian drift covers the Kansan. What two large rivers flow almost along the margin of the drift-covered area? Explain the more southerly extent of glaciation in the eastern United States.



B. SIX STAGES IN THE GLACIAL HISTORY OF THE GREAT LAKES. (FROM MARTIN, AFTER LEVERETT AND TAYLOR)

1. Through what rivers in the central United States did the Great Lakes first discharge? What four eastern rivers later became outlets? Why do the upper Great Lakes no longer discharge through Ottawa River, as shown in the 6th stage? In what stage did Niagara Falls appear? What is meant by the "HINGE LINE" shown on several of the maps? Is it possible that the lakes may again discharge southward?

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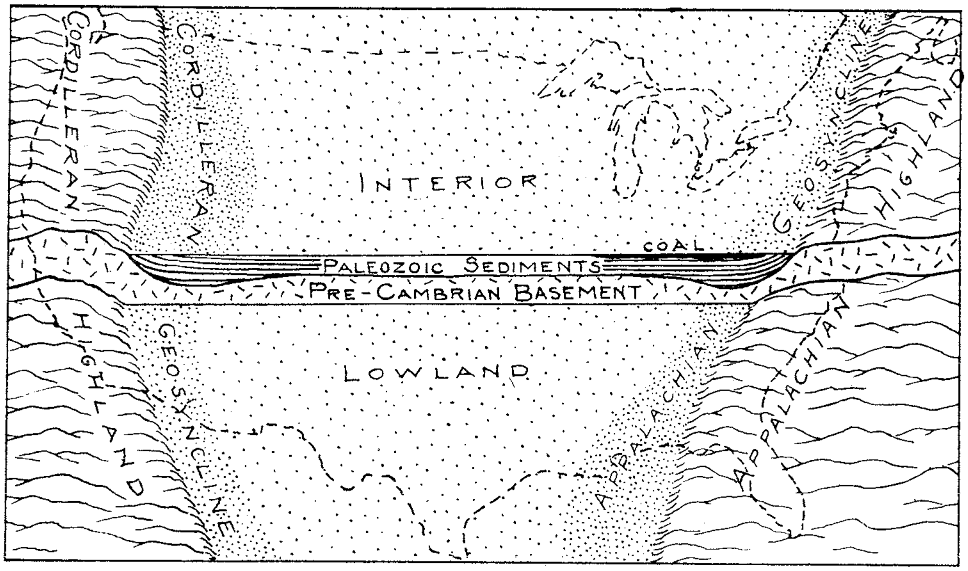
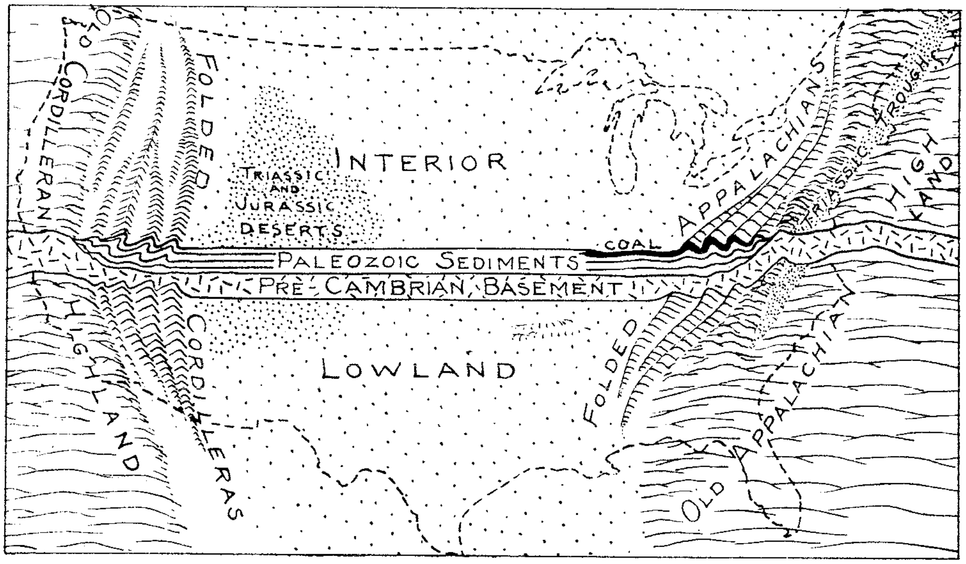
SIX STAGES IN THE GEOLOGICAL HISTORY OF THE UNITED STATES.



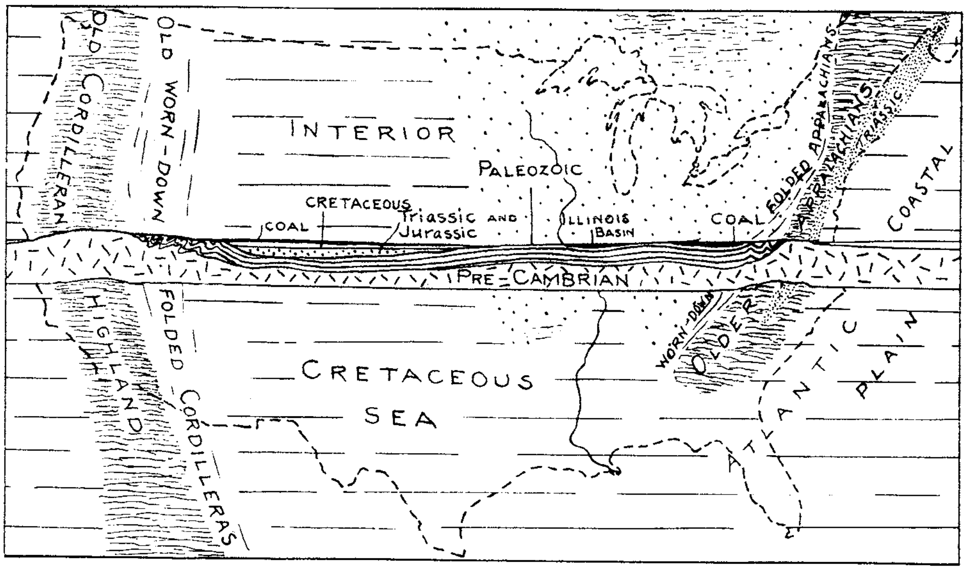
A. PALEOZOIC DEPOSITION.
The North American continent with its two bordering highlands and great interior basin covered intermittently by shallow seas. Excessive sedimentation, largely continental in character, in two great geosynclines bordering the highlands. Formation of coal, presumably in marshes, at end of Paleozoic.

1. What is the relative thickness of the Paleozoic deposits in the central and eastern United States?
2. Are conglomerates to be expected in the central states?
3. Does the formation of coal indicate a gradual emergence of the continent?



B. THE APPALACHIAN REVOLUTION
Caused by pressure from the two sides of the continent, and resulting in slightly overturned folds in the Folded Appalachians and Folded Cordilleras; followed by deposition of Mesozoic sediments in deserts and basins in both the eastern and western United States and resulting in the conspicuous "RED BEDS" of Triassic and Jurassic time.

1. What kind of sediments predominate in the Triassic and Jurassic? Why are they red?
2. Do you see anything in the fact that this was a time of great land animals?
3. In the western United States are the Mesozoic beds probably conformable upon the Paleozoic or is there a marked unconformity?



C. CRETACEOUS DEPOSITION
MARINE MESOZOIC
Formed largely in a great interior sea, and on the Atlantic Coastal Plain. Accompanied by profound wearing down of the mountain areas on the two sides of the continent, resulting in the Cretaceous peneplain of the Appalachian region.

1. If the Cretaceous sea advanced from the south into the interior of the continent where is it likely that the thickest Cretaceous limestones will occur?
2. Account for coal and lignite in the Upper Cretaceous.
3. Why are there several different coal fields in the interior of the United States?
4. Are the Cretaceous beds probably unconformable upon the Paleozoic?

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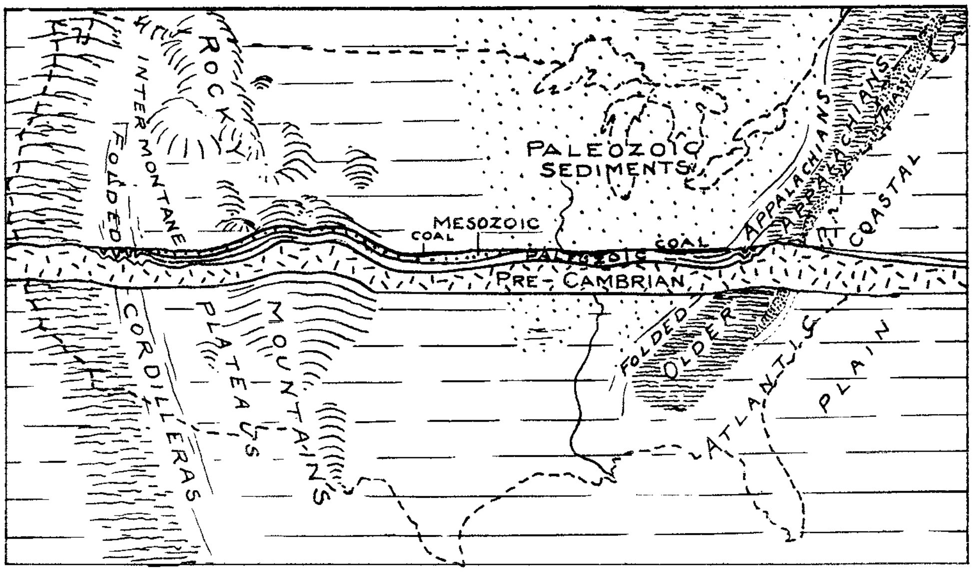
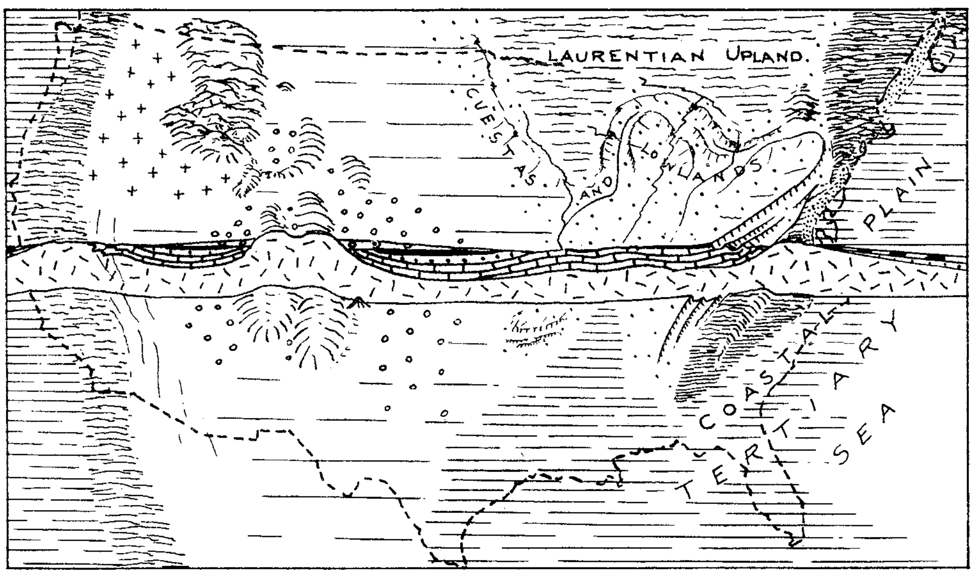


STAGES IN THE GEOLOGICAL HISTORY OF THE UNITED STATES, CONT.

D. THE LARAMIDE REVOLUTION AT END OF MESOIC.

The Rocky Mountains formed by strong local up-arching and faulting. In the east, a slight regional uplift.

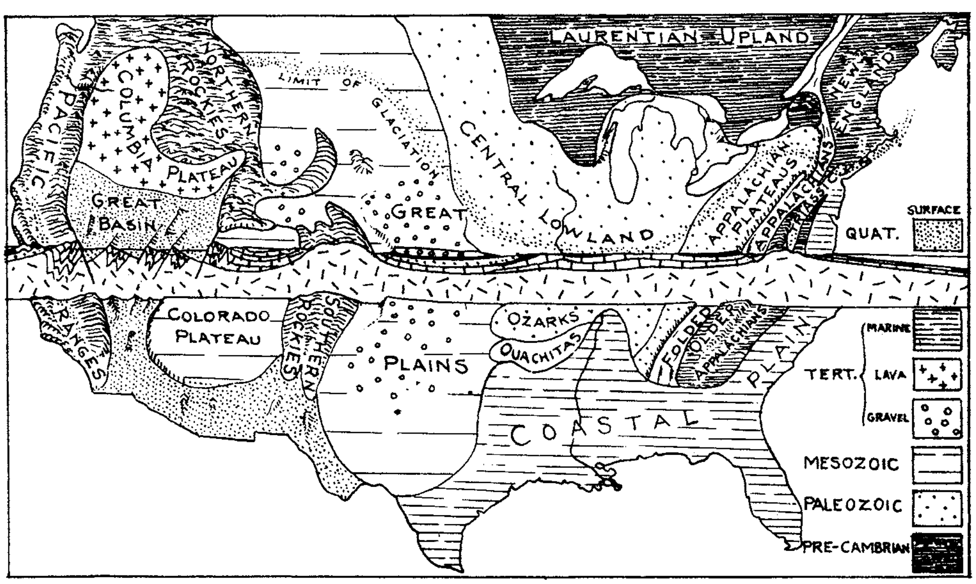
1. Why is this called the "Laramide" Revolution? Name some of the ranges of the Rocky Mountains which were raised at this time.
2. Why is the Rocky Mountain region characterized by so many basins and parks?
3. What was the effect of the uplift of the Cretaceous peneplain in the eastern United States?
4. What great events closed the Paleozoic and Mesozoic eras?



E. TERTIARY DEPOSITION AND EROSION.

Continental deposits (Tertiary gravels) deposited in the Great Plains area, and in the numerous basins of the Rocky Mtn. region, often across the eroded edges of the Mesozoic beds. Lava flows in the Columbia Plateau region. Marine deposits on Atlantic Coastal Plain. Continuous erosion in the interior, forming the present topographic features.

1. What features were produced at this time in the Great Lakes region?
2. What three distinctly different types of deposits were made in Tertiary time?
3. Do the Tertiary deposits in most places rest unconformably upon the underlying rocks?



F. CASCADIAN REVOLUTION AT END OF TERTIARY.

Uplift of the Cascades and Sierra Nevada. Great Basin formed by faulting in the Cordilleran belt. Regional uplift of the continent, with continued erosion. Quaternary glaciation.

1. What part of the continent has suffered least from mountain-making disturbances?
2. Classify the 17 physiographic provinces named on the map in accordance with the age and character of the rocks composing them.
3. As erosion proceeds, which of these provinces will increase in area and which will decrease?
4. Which of these provinces are simple geological units and which are made up of a variety of rocks and structures?

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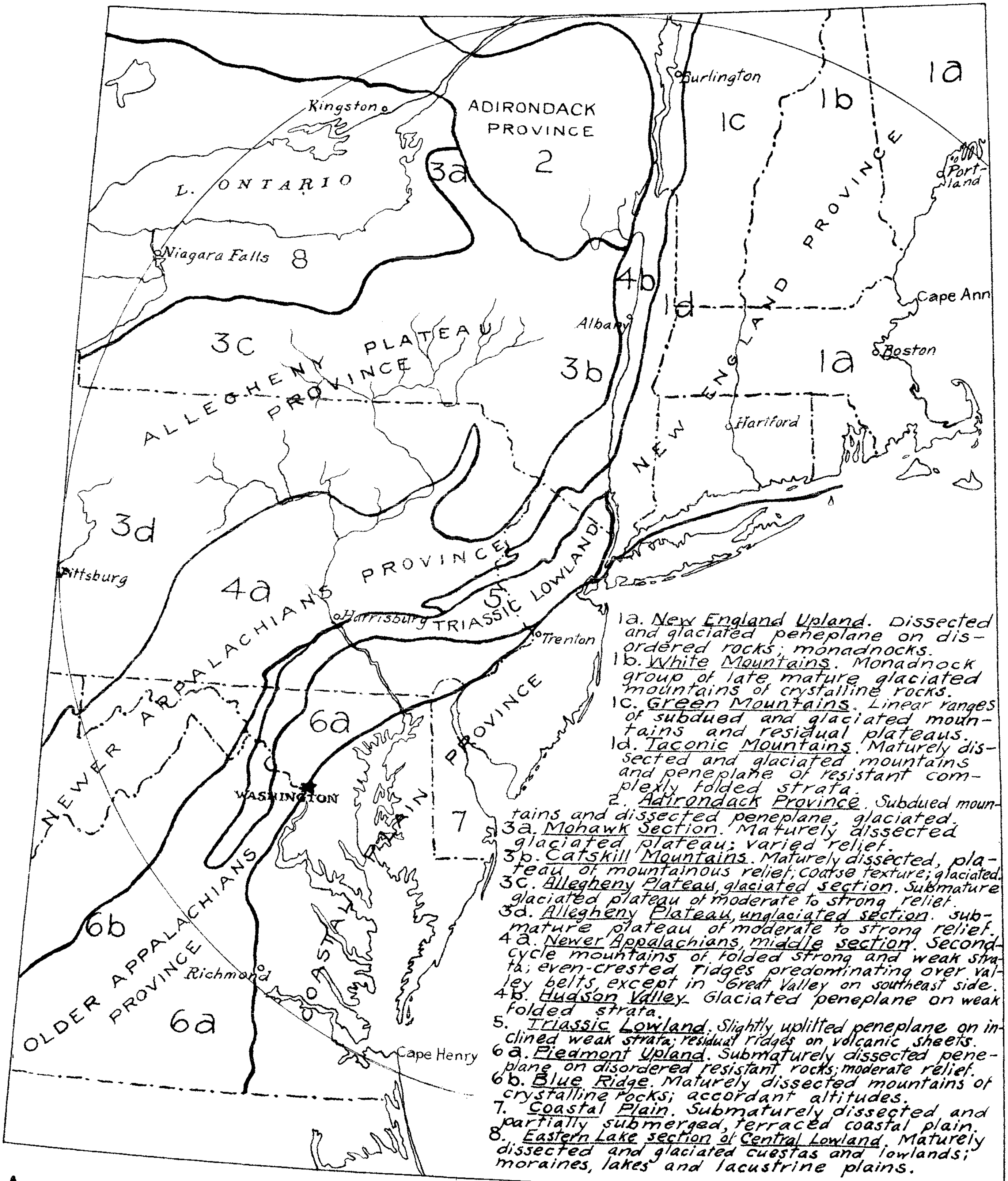

A. THE PHYSIOGRAPHIC PROVINCES OF THE EASTERN UNITED STATES.

1. Label the Reading Prong and the Manhattan Prong of New England.
2. Label the Carlisle Prong and the Trenton Prong of the Older Appalachians.
3. What is the age of the rocks in the Allegheny Plateau of New York? in Pennsylvania?
4. Label the Wyoming Valley; the Fall Line; the Tug Hill Plateau.
5. Do any Triassic rocks occur outside of the Triassic Lowland?

(N.Y. Acad. Sci.)

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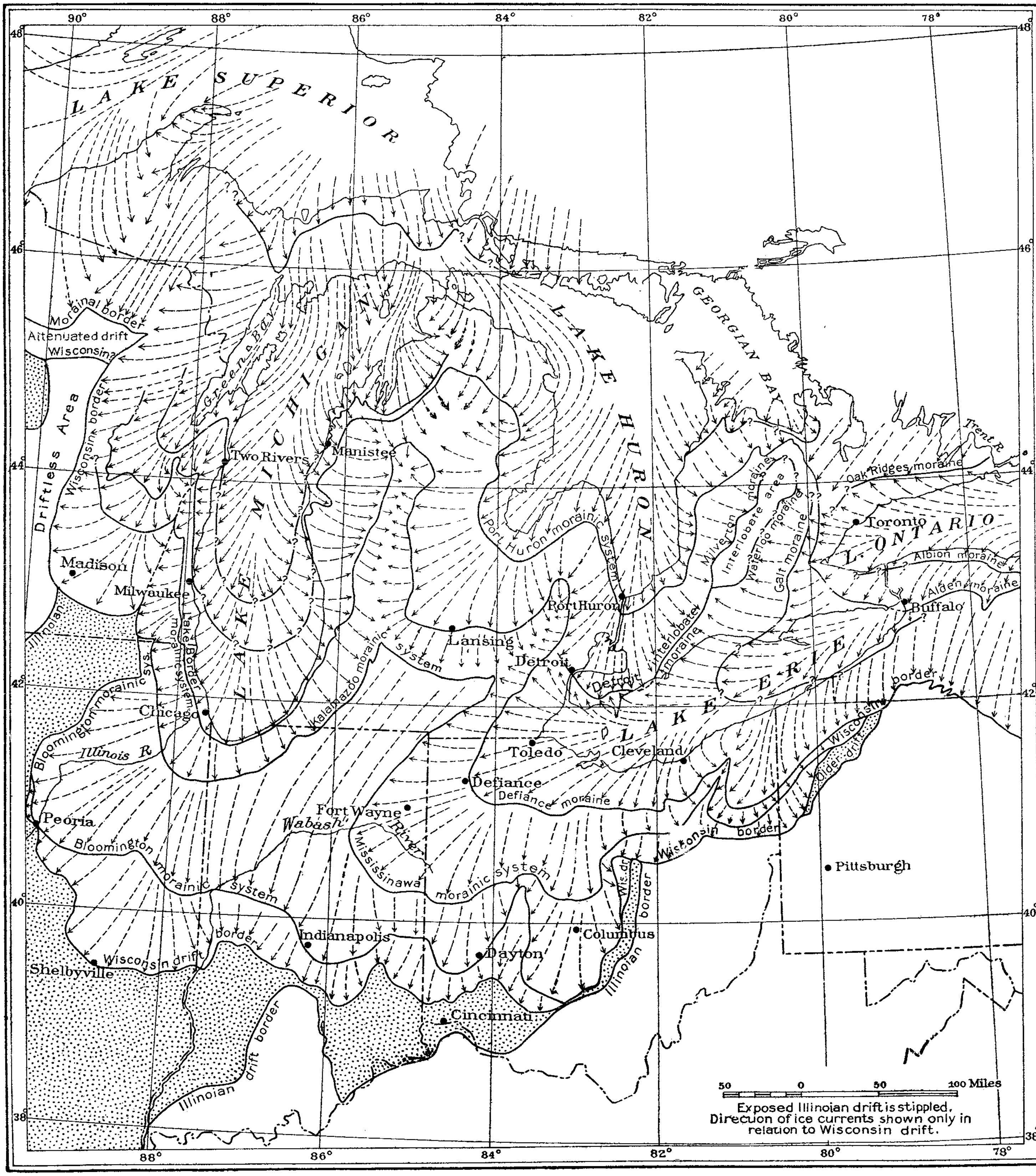
THE INTERIOR LOWLANDS.



DIAGRAMMATIC REPRESENTATION OF THE OUTLINE OF THE ICE BORDER AT SEVERAL SUCCESSIVE POSITIONS AND THE DIRECTION OF ICE MOVEMENT IN CONNECTION WITH EACH POSITION.

1 What caused the ice border to be so irregular in this region? Were the Great Lakes there before the ice came? Do these facts explain the Driftless Area?
2. What is an Interlobate Moraine? Name the different lobes. What is Attenuated Drift?
3. What does the stippled area represent? Explain the intersection of moraines.

From U.S.G.S. MONOGRAPH No. 53.

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THE INTERIOR LOWLANDS.

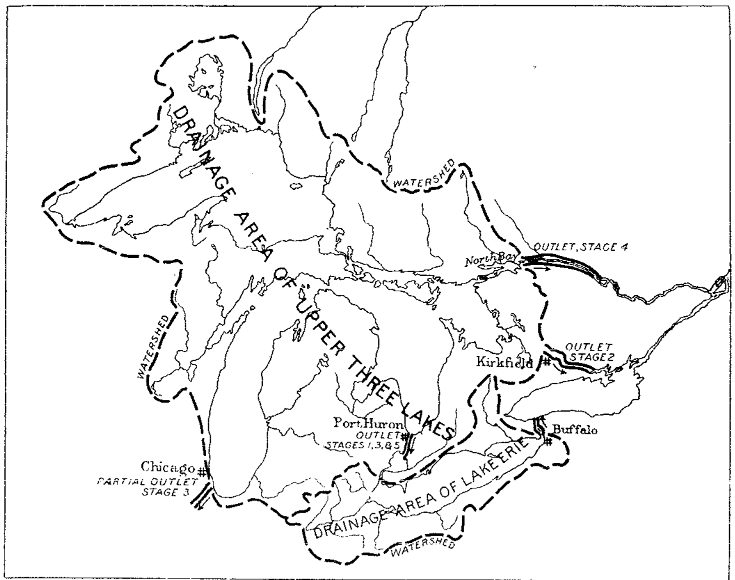


FIGURE 12.—Sketch map showing drainage areas tributary to Niagara River, the volume of discharge through the river during five lake stages, and the various outlets of the upper three Great Lakes during these stages.

Stage 1.—Early Lake Algonquin. Large volume of discharge divided between Niagara River and four other spillways over Niagara escarpment.

Stage 2.—Kirkfield stage of Lake Algonquin. Small volume through Niagara River; large discharge through outlet at Kirkfield.

Stage 3.—Port Huron-Chicago stage of Lake Algonquin. Large volume through Niagara River; small discharge through outlet at Chicago.

Stage 4.—Nipissing Great Lakes. Small volume through Niagara River; large discharge through outlet at North Bay.

Stage 5.—Present Great Lakes. Full discharge of the upper four lakes through Niagara River.

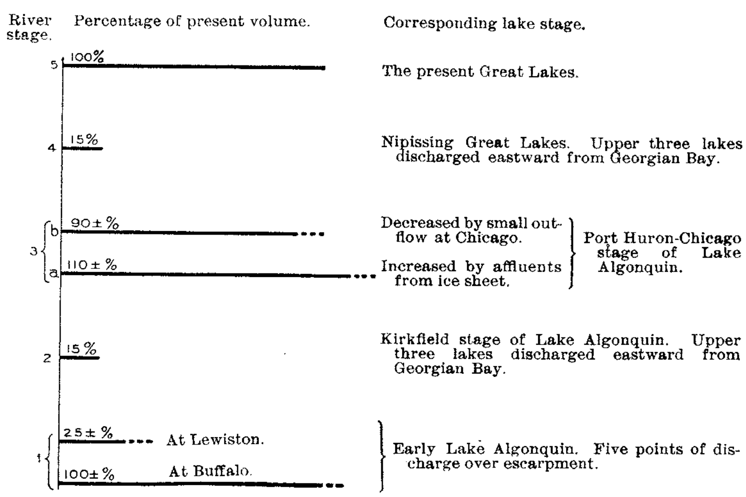


FIGURE 13.—Diagram showing variation in volume of Niagara River during the five lake stages sketched in figure 12.

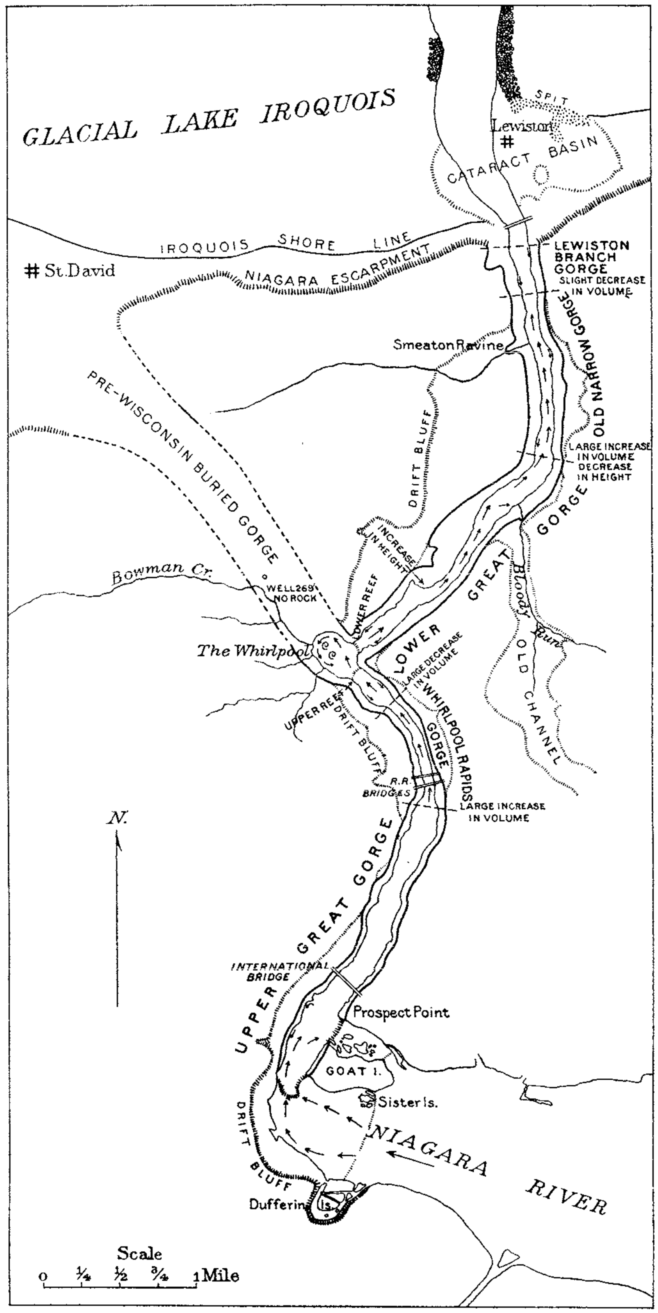


FIGURE 14.—Sketch map of Niagara gorge showing the five named divisions of the gorge and changes in volume of the river and height of falls corresponding to the five lake stages shown in figure 12, which determined their character.

Lewiston Branch gorge, cut during the first lake stage; small volume. Old Narrow gorge, second lake stage; small volume. Lower Great gorge, third lake stage; large volume. Whirlpool Rapids gorge, fourth lake stage; small volume. Upper Great gorge, fifth lake stage; full volume of upper four lakes.

THE DEVELOPMENT OF THE NIAGARA GORGE. (From U.S.G.S. Niagara Folio, No. 190.)

1. During which two stages did Lake Erie alone discharge over Niagara Falls?
2. As regards place of discharge how did Stage 1 differ from Stages 3 and 5?
3. Which three sections of the Gorge are narrow and represent small volume of discharge?
4. Which two divisions are wide and represent large volume of discharge?
5. Why did the Great Lakes change their outlet in the manner indicated?
6. Indicate on Fig. 14 the "Horseshoe Falls" and the "American Falls". Which one is retreating most rapidly? How far have the Falls retreated since their beginning? If rate of retreat was 4 feet per year during the two large-volume stages, and ½ foot per year during the three small-volume stages, what is the age of the Falls, since retreat of the Ice Sheet? Explain The Whirlpool.

OUTLINE OF NIAGARA FALLS AND GORGE

I. Development of Gorge.

A. Lewiston branch gorge.
   1. 2,000 feet southward from its mouth.
   2. 1300 feet wide and 500 feet to bottom of river.
   3. Formed during existance of Lake Tonawanda and during early stage of Lake Algonquin.
      a. Lake Tonawanda had 5 spillways - Shores and cliffs of old lake lead into Niagara Falls.
      b. Part of the original channel is on west side of the gorge from Clifton House to Hubbard Point.

B. Old narrow gorge
   1. Extends from first section to Niagara University.
   2. 1200 feet wide and 400 feet to bottom of river.
   3. Cut during Kirkfield stage of Lake Algonquin.
   4. Volume of cataract about 1/4 of present capacity.
   5. Weathering carried on to a greater degree.
      a. Lockport dolomite 35 feet thick.

C. Lower Great gorge
   1. From University to the upper end of the Eddy Basin but not including the whirlpool - 2 miles in length.
   2. Formed during Port Huron stage of the Algonquin.
   3. Made just after disappearance of ice from Great Lakes region.
   4. Kirkfield Outlet was closed, thus increasing the volume of Niagara Falls.
      a. One of reasons why gorge is shallow at this point.

D. The whirlpool (not of the gorge)
   1. Rock basin of whirlpool is older than the gorge - pre-Wisconsin.
   2. The gorge, above, below, and two sides of the whirlpool are walled in by rock.
   3. Whirlpool was formed by digging out of glacial drift (sand and gravel) by the action of the water. Will not dig further due to the fact that large boulders cover up the sand below the water.
   4. At the whirlpool the old gorge is 1875 feet wide at the top and 1200 feet at the water line. Extends 2 miles northwest.
   5. Bowman Creek arises 2 miles away.
   6. Reef formed by the breaking away of the east wall of the old gorge.

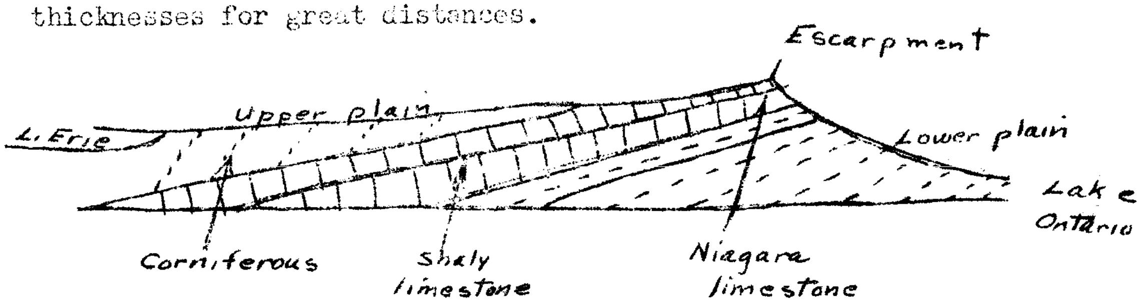
E. Whirlpool rapids gorge
   1. From south side of Eddy Basin to expansion just above railroad bridge - 3/4 mile long.
   2. Width is 760 feet at the top and water is 35 feet deep.
   3. Cut during the time of the Nipissing Great Lakes.
   4. Speed of water is 22 m.p.h.
   5. On west side is a drift bluff.

F. Upper great gorge.
   1. From place of widening up to the Horseshoe Falls - 1/24 mile.
   2. This section has been cut during the present lake stage.

II. The falls
   A. 158 feet high - dolomite on top and softer shales beneath.
   B. Greatest change has occurred in the middle of the Horseshoe curve — 220 feet of limestone bed have been carried away. Gorge becoming longer $4\frac{1}{2}$ feet per year.
   C. Soft shale is worn away and limestone falls due to its own weight.
   D. Pool below falls probably 200 feet thick.
      1. Deepened by the cutting of the limestone which has fallen down.
   E. Falls divided unequally be Goat Island
      1. HorseshoeFalls
         a. 95% of water
         b. Total length of crest 2500 feet.
         c. 158 feet
      2. American Falls
         a. 5% of water.

ADDITIONAL FACTS OF NIAGARA RIVER

I. St. Lawrence Drainage system.
   A. A group of basins sloping toward some central point.
      1. Lakes Superior and Michigan to Lake Huron, Lake Erie through Niagara River and on to Lake Ontario.
      2. Water in river is free from pebbles — little cutting power.
   B. Upper and broader plain has a gently undulating surface toward the escarpment.
   C. The rocks strata are flat, resting one upon another of nearly uniform thicknesses for great distances.

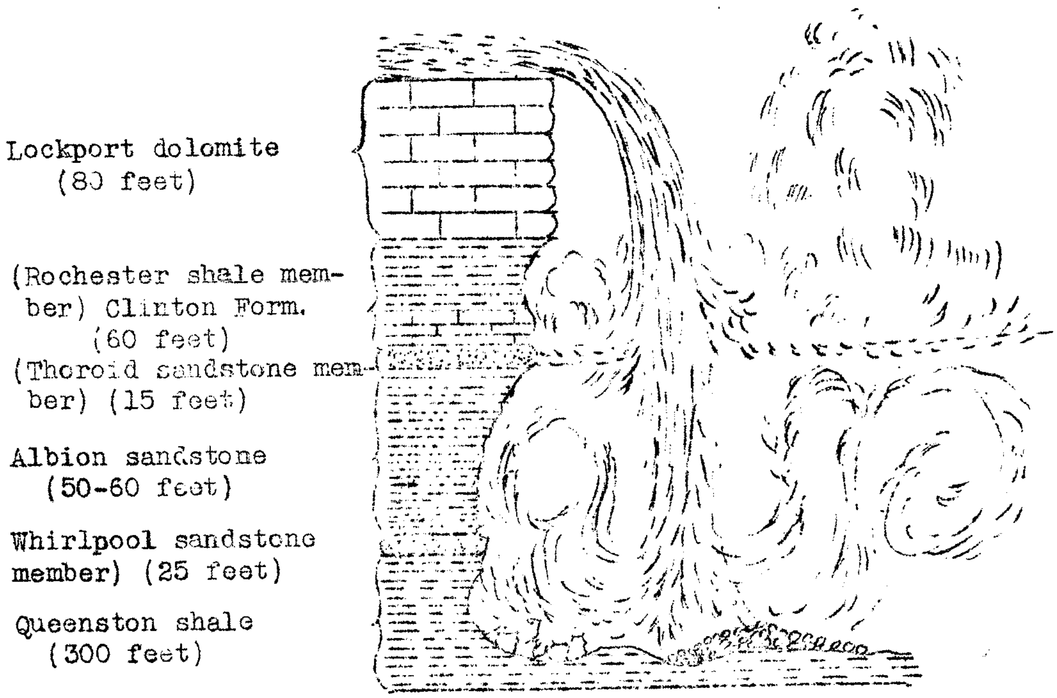


      1. Corniferous limestone makes a low ridge along the north shore of Lake Erie and dips below lake.
      2. Salina shales in middle part of upper plain dip beneath the Corniferous limestone.
      3. Niagara limestone stops at the escarpment -- full thickness 140 feet.
      4. Below this is a series of mud shales 1000 feet thick, occupying the lower part of the escarpment and the whole of the lower plain.
      5. Glacial drift 30-40 feet thick overlies all of this.

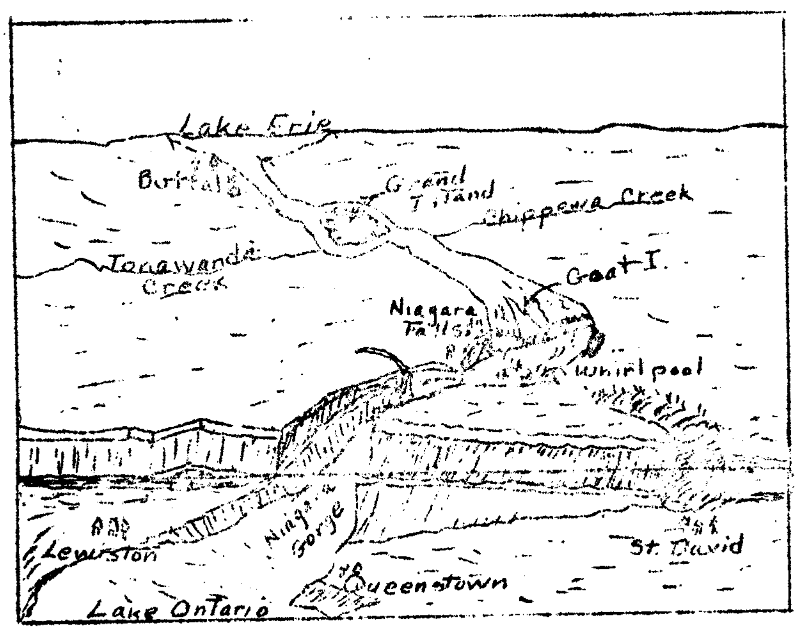
II. Formation of Niagara
   A. Retreating of the ice exposing Lakes Iroquois, Erie and Huron.
      1. As Lake Iroquois lowered, a stream was started between the two lakes - tilting of the land toward the south.
   B. The first work of the river was the digging of the gorge. Before this, the glaciers were responsible for the work.
   C. During Lake Lundy, the predecessor of Niagara Falls was established.
   D. Further retreat of ice resulted in draining of Lake Lundy.
      1. Remnant of Lake Lundy was Lake Tonawanda.
         a. A discharge of Lake Tonawanda divided and four cataracts were formed, but Niagara took the greater volume of water.

Bibliography: Niagara Folio.

Ed. McAllister



Section of brink of Niagara Falls showing the arrangement of hard and soft strata and illustrating the process of erosion.
Scale, 1 inch = 135 feet.



Bird's-eye view of the Niagara River.

THE LAKE ONTARIO SHORE FEATURES

Estending from the Niagara Escarpment on the south to the Laurentian plateau and Georgian Bay on the north is the broad, level expanse of the Ontario plain. During the Pleistocene Period when the region was glaciated, the land was, for a time, under the waters of Lake Iroquois, a glacial lake which was held back by an ice barrier across the St. Lawrence Valley. Its outlet was at Rome, N.Y., through the Mohawk Valley to a marine estuary in the Valley of the Hudson River. The shore line feature to be studied are associated with this lake. The beach, which is one of the developed old shorelines in the Great Lakes region, takes the form of a low but well-marked ridge from 10 to 30 feet above the general surface. It runs along the inner margin of the Ontario plain, in some places close to the Niagara Escarpment, in others more than four miles from it. This marks one of the higher levels of Lake Iroquois, of which Lake Ontario is a temnant. In many places, the beach takes the form of a wave-cut shorecliff; in others it is a wave-built sand or gravel bar; in still others, it is cut into the side of morainic features.

The ridge varies considerably in height, the crest being at Lewiston (375' above sea level) In general, the eastern end is higher and more heavily built than the western portion. Usually, it is about 15 to 20 feet above the old lake bottom about 150 or 200 yards out from shore. At Lockport, the spits froming the east and west sides of the old bay there stand 40 feet above the adjacent streams. The beach varies in width from 300 to 500 feet.

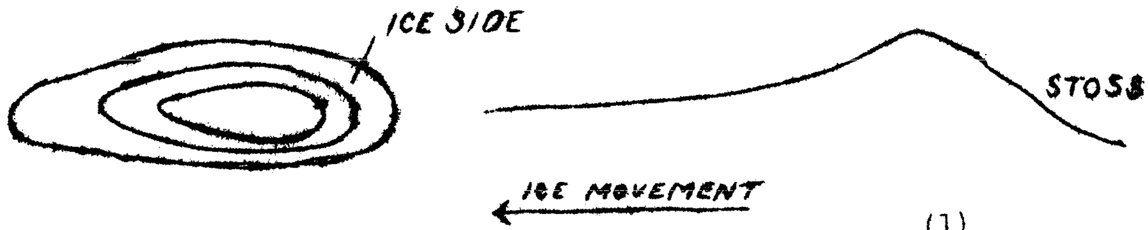
The sandy gravel of the shoreline is characterized by dark-red, well-rounded pebbles composed of hard Oswego (?) sandstone.

Material from:

U.S.G.S. Geological Atlas, No. 190
The Niagara Folio

DRUMLINS OF WESTERN CENTRAL NEW YORK

A drumlin is a type of ground moraine formed during a readvance of retreating glacial ice. They are only the most emphatic of a variety of forms produced by the rubbing of ground-contact ice under thrust motion. Glacial material is thus plastered onto obstructions to form the typical elongated oval shape of the drumlin. They are elongated in the ice direction with the steeper or stoss side on the ice side and gradually levelling off on the other side.



There are three major drumlin areas in the United States:[1]

1. New England Area
2. Michigan Area
3. New York Area

The New York Area includes a belt 35 miles wide bordering the south side of Lake Ontario, and about 140 miles long from the Niagara River to Syracuse, New York. This area is estimated to contain 10,000 drumlins, with 5 to a square mile not uncommon. Most of the drumlins cover an area of low, level plains, the Ontario Plains. They are spread out over the greatest thicknesses of the Salina shale where the drift is clayey and plastic. Most of the drumlins are cleared and are productive of farm crops. Many of the drumlins of New York are cored in shale.

The size of the drumlins varies. The maximum height seems to be 200 feet, and the maximum length about 2 miles. The width is generally 1/5 of the length.

Some prominent drumlins we will probably see are:

1. Morman Hill- - - - -4 mi. s. of Palmyra - - - height - 100'
2. Zurich Hill- - - - -5 " " " Sodus - - - - " - 200'
3. Triangular Station -2 " " " Weedsport - - " - 140'

Reference:
(1) "Drumlins of Western Central New York", Fairchild, H. L. 507
Bulletin N.Y. State Museum No. 111, 1907. N567Mb.

P. S. Baumgras.

FINGER LAKES

The basins of the Finger Lakes were first generally explained as the result of ice erosion, a kind of glacial overdeepening, but with the action confined to a single glacial period. Later and more detailed studies have shown that the forces which produced these basins are complex in their nature and relations. Glacial erosion is indeed the most important element of the explanation, as the steepened sides of the basins, the hanging tributary valleys, and the presence of lateral and terminal moraines at the valley heads testify. The last-named feature is clearly shown on the map, and proves that the valleys were highways of more active glacial motion.

The most important facts pointing to complexity of origin relate to the hanging valleys tributary to the Finger Lakes. On the steepened slopes of the main valley sides a series of buried gorges has been found. The gorges are occupied by drift deposits of the last (Wisconsin) ice invasion, which indicates that they were formed before that invasion.

From the known facts it is concluded that before the glacial period there was a system of mature drainage with main valleys along the axes of Cayuga and Seneca lakes and with tributaries entering them at grade. With the overspreading of the region by glacial ice there was begun a process of exceptional deepening in the main valleys because they served as lines of most rapid glacial flow. At the end of the first ice invasion the valleys had been broadened and deepened, the amout of the deepening being about 500 feet. Lakes may have formed in these overdeepened valleys after the ice had been melted away. At any rate the discordance of level between tributary and master valleys was pronounced and the tributaries began to cut down their valleys to the level of the main valleys, making gorges of notable breadth and depth before the second glacial invasion filled them with drift, reexcavated and deepened the main valleys, increased the discordance between tributaries and master streams, and so altered the topography in detail that the postglacial streams do not flow everywhere in the interglacial courses. Wherever a postglacial stream enters one of these buried gorges with its easily eroded drift in contrast to the hard rocks of the rest of the valley there the valley broadens suddenly; where the stream leaves the buried valley the valley contracts. It is these features, together with the irregular as well as regular jointing of the bedded rock--shales and sandstones--that give to the gorges so much of their surprising variation from place to place and to the beautiful waterfalls and cascades of the many glens their wild, picturesque quality.

The lower portions of the valleys of the tributaries to each of the Finger Lake basins are for the most part more or less completely drift-filled gorges, so that the rock floor is in many cases far below the drift floor of the valley, a condition brought about not by over-deepening of the main trough but the clogging of the tributary valley with drift. There are, however, perfect examples of hanging valleys with rock floors in the Cayuga and Seneca troughs and in the Tioughnioga and Cayuta valleys.

The abrupt descents of the valley slopes in the Finger Lake region is illustrated by the change at the 900-foot contour just of Watkins in the Cayuga trough. The slope from the 900-foot contour to the valley bottom, which has an elevation of 477 feet, takes place in a distance of a little over a half mile, while west of the 900-foot contour the valley side rises only 700 feet in a distance of 5 miles.

REPORT ON WATKINS GLEN

Location and Area:

Lies near the center of the southern tiers of counties of New York State. Northernmost boundary is approximately 4 miles north of Ithaca and southern boundary is the New York-Pennsylvania line. It includes portions of 5 counties and has an area of 885 square miles.

Geographic and Geologic Relationships:

Lies entirely within area of Alleghany plateau. Consolidated rocks are all Paleozoic sediments deposited in the sea which lay to the east of the old Appalachia land. Were brought to surface when Appalachians were re-elevated. Minor folds are seen but the formations are still approximately horizontal. Latter events of glaciation were the invasions of continental glaciers, the late one being the Wisconsin. Rocks underlying surface cover are of Devonian age.

The majority of the valleys are very deep and have exceptionally steep banks. Valleys in this area have two drainage systems; first, the St. Lawrence; second, the Susquehanna. Although numerous valleys can be seen, it is known that there were many more which have been drifted full of sediment.

Drainage:

Because of rugged features, the drainage is good. Swamps occur only in few places and these where isolated lakes stood. The lakes stand at the lowest of the valley levels and the two largest lakes are Cayuga and Seneca, these having depths of 618 feet and 435 feet respectively.

Descriptive Geology:

Three classes of surface rocks.

a. Argillaceous shale, thin bedded sandstones, impure limestone (belongs to Devonian system).
b. A few small dikes of igneous rocks (no metamorphism)
c. Deposits of river sand, gravel, and glacial till.

Devonian System:

Formation	Member	Description
Catskill		280+ feet. (Sandstone and chocolate-colored shale.)
Chemung	Wellsburgh	600 to 700 feet. (Sandstone)
	Cayuta	600 feet. (Shale)
Portage	Enfield	1200-1300 feet. (Shale)
	Ithaca	80--480 feet. (Shale)
	Sherburne	180 feet. (Sandstone, flagstone)
Genesee		(Shale). About 100 feet thick, much in a calcareous horizon near top.

Total thickness is about one mile of Devonian system. 102 species of fossils are found here.

Igneous Rocks:

25 small dikes of mica peridotite appear in the vicinity of Ithaca. Intrusive rocks outcrop in the area of the Portage formation. Basic rocks studied were found to be olivine, serpentine, calcite, mica, iron oxide and a little apatite.

Glacial Action:

Wisconsin sheet covered this section and even extended down into Pennsylvania some 50 miles. The striae are weak, short, and irregular, indicating weak ice movement. The ice sheet apparently was rather thin.

This sheet was very effective in spreading the till around and filling some of the valleys. Drumlin-like hills occur in broad valleys although there would have been more if the melting of the ice had not been so rapid.

Moraines in the upland are few and no definite system has been worked out; however, morainic terraces occur along Cayuta valley, and Chemung. Morainic loops appear at Latty Brook and in one of the larger valleys.

Many marginal lakes were formed and all types are represented. Clay is the most abundant material found in the glacial drift.

Kames are found in abundance and every gradation is found. Eskers are also found and the Jackson Creek esker is almost perfect, because the ice stood still here and did not molest the serpentine winding.

Outwash gravel plains:

a. Post Creek
b. Pony Hollow
c. In many through valleys
d. Chemung
e. Susquehanna

Hanging deltas are found along Seneca and Cayuta valleys, indicating the presence of former small marginal lakes.

Hanging Valleys:

Truncation of steep sided hills and valleys leaves a hanging valley. Valleys are abundant, best examples being along Cayuga and Seneca Lakes. Have heights of 800-850 feet.

Approximate Locations of Outcrops of the Various Formations:

Portage Formation:

a. Sherburne Flagstone member -- in the quarries of Trumanburg, Seneca Lake, Salt point, and at foot of Fall Creek Gorge.

b. Ithaca Shale Member -- head of Cayuga Lake, at Forest Home, and Marathon.

c. Enfield Shale Member -- near Ithaca, and along Tioughnioga valley.

Chemung Formation:

a. Cayuta Member -- west Danby section on east side of Quadrangle.

b. Wellsburg -- Martin Hill and Quackenbush Hill, Quarry at Rosstown, in Chemung river and Chemung narrows, Ashland Hill near Elmira.

Catskill Formation:

On the high hill west of Tracy Creek. Shows in few places in this Quad., but appears more in Catatonk Quad.

Genesee shale outcrops in the extreme northeast corner of Watkins Glen Quad.

---K. W. Ellison

GENESIS OF THE EASTERN PROVINCES

Pre-Cambrian rock basement.

Paleozoic.

1. Early Cambrian - eastern margin was warped up to form old Appalachia to the west - a trough warped down to make the Appalachian trough.
   Rocks of Appalachia eroded.
   Sediments transported and loaded into the trough.
   Isostatic adjustments during interval of Sedimentation.

2. Paleozoic - Sedimentation.
   In each of the periods of the Paleozoic - the Appalachian Trough was depressed below sea level and flooded.
   At the same time Appalachia was elevated.
   Streams were rejuvinated.
   Sediments from highlands transported to flooded lowlands.
   Cambrian, Ordovician, Silurian, Devonian, Mississipian, Pennsylvanian - thick layers of sediments.
   In Pensylvania - total thickness of Paleozoic deposits -- 30,000 feet.

3. Silurian period.
   Appalachia was raised before the trough was depressed.
   Coarse detritus carried down was deposited on lowland above sea level.
   Lowland had an arid climate - large saline lakes developed.
   These lakes were especially large in Western New York, Ohio and Michigan.
   As they became desiccated - arid climate.
   Salt was deposited in beds - 10-250 feet thick.
   Intercalated with gypsum and shale.

   a. Clinton iron ores.
      Later in Silurian - when sea had flooded Appalachian trough - quantities of iron were brought in solution into the inland sea, precipitated by bacterial action, thus making layers of hematite extending from New York to Alabama.
      In the North thickness of deposits 1-2 feet increases to the South. In Alabama - 10 feet thick.
      Iron in water injurious to animal life of sea.
      All fossils from this formation are dwarfs.

   b. Petroleum.
      Devonian deposits are especially thick in Pennsylvania.
      Abundance of life in sea.
      Petroleum - bacterial action.
      Microscopic globules of oil deposited with sediments.

c. Coal.

Latter part of Pennsylvanian period - trough was a lowland just above sea level.

Great swamps developed on the lowland from Pennsylvania to Alabama, and westward to Illinois and Missouri.

Peat developed in the swamps.

Land depressed - sea spread over peaty deposits.

Deposits of clay over peat.

Coalification --

With each slight elevation the swamps were reelevated only to be buried again.

Repeated time after time.

In Pennsylvania - 29 separate beds of coal covered by a layer of marine sediments were developed.

4. Pennsylvania - Permian

Appalachian Revolution

By end of Pennsylvanian Period sediments had accumulated in trough to a depth of 6,000 to 8,000 feet in Georgia and 30,000 feet in Pennsylvania, lesser amounts westward 8,000 to 10,000 feet in Michigan

Appalachian deformation - Sediments thrown into a series of N. S. folds.

In south - folding was accompanied by both normal and overthrust faulting.

Crustal shortening due to folding and faulting amounted to 15 miles.

According to Chamberlin the original 81 miles was reduced to 66 miles.

During the folding (orogeny) the whole eastern half of America as far west as Minnesota and Missouri was raised.

Mesozoic.

1. Triassic Basins.

During Permian and early Triassic erosion reduced the whole of eastern North America to a lowland -- if not to a complete peneplain.

Middle of Triassic - great faults developed especially over section that had been Appalachia .

Connecticut Valley basin.

Bay of Fundy.

Triassic Lowland - Hudson River and extending across Maryland into Virginia.

In these faults, blocks on northwest rose.
block on southeast sank.

Gravels and sands were worn from W. block and filled in depressions to the southeast.

Lava flows - Palisades of Hudson (traps).

In Pennsylvania - total thickness of Triassic deposits - 20,000 feet.

2. Jurassic.
   Another period of faulting.
      Deposits broken into smaller blocks and tilted slightly.

3. Cretaceous - Fall Line Peneplain (Middle Cretaceous)
   After Jurassic area became more stable
      Erosion again reduced surface to a peneplain.
   Then the area was so warped that all of the eastern portion was depressed below the sea.
      Covered by marine marls and clays.
   Whole region was raised in a low arch on which consequent drainage was developed.
      Streams were later let down and became superimposed on strong rocks of Cretaceous.

Schooley Peneplain (Late Cretaceous) Early Eocene

Middle Cretaceous arching rejuvenated the streams.
   Erosion became more active.
   Late Cretaceous - great Schooley peneplain developed in both strong granites and metam rocks of Appalachia and weaker Sandstones and shales of the Mts.

Uplift in early Eocene.
   Province raised in a low Anticline the axis of which extended from Middle Vermont to Central New Brunswick.

By end of Eocene, erosion had again leveled the surface except for scattered Monadnocks such as Mt. Monadnock, Mt. Greylock and the Peaks of the Green and White Mountains.

This leveled surface is called the Schooley Peneplain and has a wide extent not only over New England but southward to Alabama and Westward to the Mississippi River.

Most of the upland surfaces of New England reach the peneplain level - nearly level skyline.

....

Schooley peneplain developed both on strong granites and metamorphic rocks of Appalachia and on the weaker sandstones of the mountains and of the plains.

Lowland Peneplain

After the Schooley Peneplain was some 90 per cent complete, it in turn was raised in a low anticline with its axis extending from Vermont to New Brunswick.

Erosion again started to make new lowlands wherever the rocks were weak.

By the time about one tenth of the country had been reduced to these new lowlands (lowlands of the present), erosion was interrupted by Pliocene uplift. In southern New England the lowlands are but 200 to 300 feet below the Schooley peneplain but in central Vermont and Maine the interval between the two surfaces increases to 1200 or more feet.

It was at this time (early Eocene) that the Coastal Plain; Piedmont, Blue Ridge, Valley and Ridge Province became differentiated.

Eastern part of Schooley Peneplain, originally a part of old land Appalachia was warped downward and covered by marine deposits

FORMATIONS OF SOUTHERN PENNSYLVANIA AND MARYLAND

	AGE	NAME	GENERAL CHARACTER
Triassic	Upper.	Gettysburg shale------------ New Oxford formation------- Unconformity	Red shale and sandstone Arkosic sandstone and red shale.
Carboniferous	Pennsyl-vanian.	Monongahela formation----- Conemaugh formation-------- Allegheny formation-------- Pottsville conglomerate----	Coal-bearing shale and sandstone. Do Do Hard sandstone and conglomerate.
	Mississip-pian.	Mauch Chunk shale---------- Pocono sandstone-----------	Red sandstone and shale. Thick sandstone.
Devonian	Upper	Catskill formation--------- Chemung formation---------- Portage shale-------------- Genesee shale--------------	Red sandstone and shale. Shale and sandstone. Gray shale and platy sandstone. Black fissile shale.
	Middle	Hamilton shale------------- Marcellus shale (with representative of Onondaga limestone at base).	Black, highly fossiliferous shale and sandstone. Black fossiliferous shale.
	Lower	Oriskany sandstone--------- Helderberg limestone-------	Coarse sandstone Blue limestone and chert.
Silurian		Cayuga formation----------- Clinton formation---------- Tuscarora sandstone--------	Shaly limestone, shale, and Bloomsburg red shale. Shale, sandstone, and fossiliferous red hematite. Hard ridge-making sandstone.
Ordovician		Juniata shale (a)----------- -Unconformity in east ______ Martinsburg shale---------- -Unconformity in east______ Chambersburg limestone----	Red shale and sandstone (absent east of Harrisburg). Gray shale. Fossiliferous limestone (absent east of Harrisburg).

(a) Believed to be Silurian by the authors.

-continued-

Ordovician		Stones River limestone----	Very pure limestone (absent south of Harrisburg).
		Beekmantown limestone-----	Thick-bedded limestone and dolomite.
Cambrian	UPPER.	Conococheague limestone---	Limestone and dolomite (Ozarkian of Ulrich).
	MIDDLE.	Elbrook limestone---------	Thin earthy limestone.
		Waynesboro shale (absent in this area)	Red shale, sandstone, and limestone.
	LOWER.	Ledger dolomite-----------	Pure dolomite and limestone
		Kinzers formation---------	Shale and mottled limestone.
		Vintage dolomite----------	Blue knotty dolomite.
		Antietam quartizite-------	Rusty-weathering quartzite.
		Harpers phyllite----------	Phyllite and schist.
		Chickies quartzite--------	Thick white quartzite containing Scolithus tubes
		Hellam conglomerate member.	Coarse conglomerate and slate.
		Unconformity	
Pre-Cambrian (b)		Greenstone----------------	Metabasalt.
		Aporhyolite---------------	Acidic lava.

(b). In the Hellam Hills.

CHYSTALLINE ROCKS IN THE SOUTHERN PART OF PENNSYLVANIA AND MARYLAND

AGE	NAME	GENERAL CHARACTER
Late Paleozoic?	Woodstock allenite granite and associated pegmatite.	Intursive. Shows little cataclastic deformation.
	Aplite Port Deposit granite (granodiorite) Relay quartz diorite Gunpowder granite Serpentine, peridoitite, pyroxenite Hypersthene gabbro	Instusives of post-Glenarm age. Show cataclastic deformation accompanied by partial or complete recrystallization.
Glenarm series (late pre-Cambrian.)	Wissahickon formation	Oligoclase-mica schist and albite-chlorite schist fecies, both containing quartzite beds.
	Metabasalt	Lava flows.
	Cockeysville marble	Coarse phlogopitic dolomitic and calcic marble.
	Setters formation	Mica gneiss, quartzite, and mica schist.
	Unconformity	
Early pre-Cambrian.	Hartley augen gneiss (intrusive	Sedimentary gneiss of granite aspect, intruded by gabbro.

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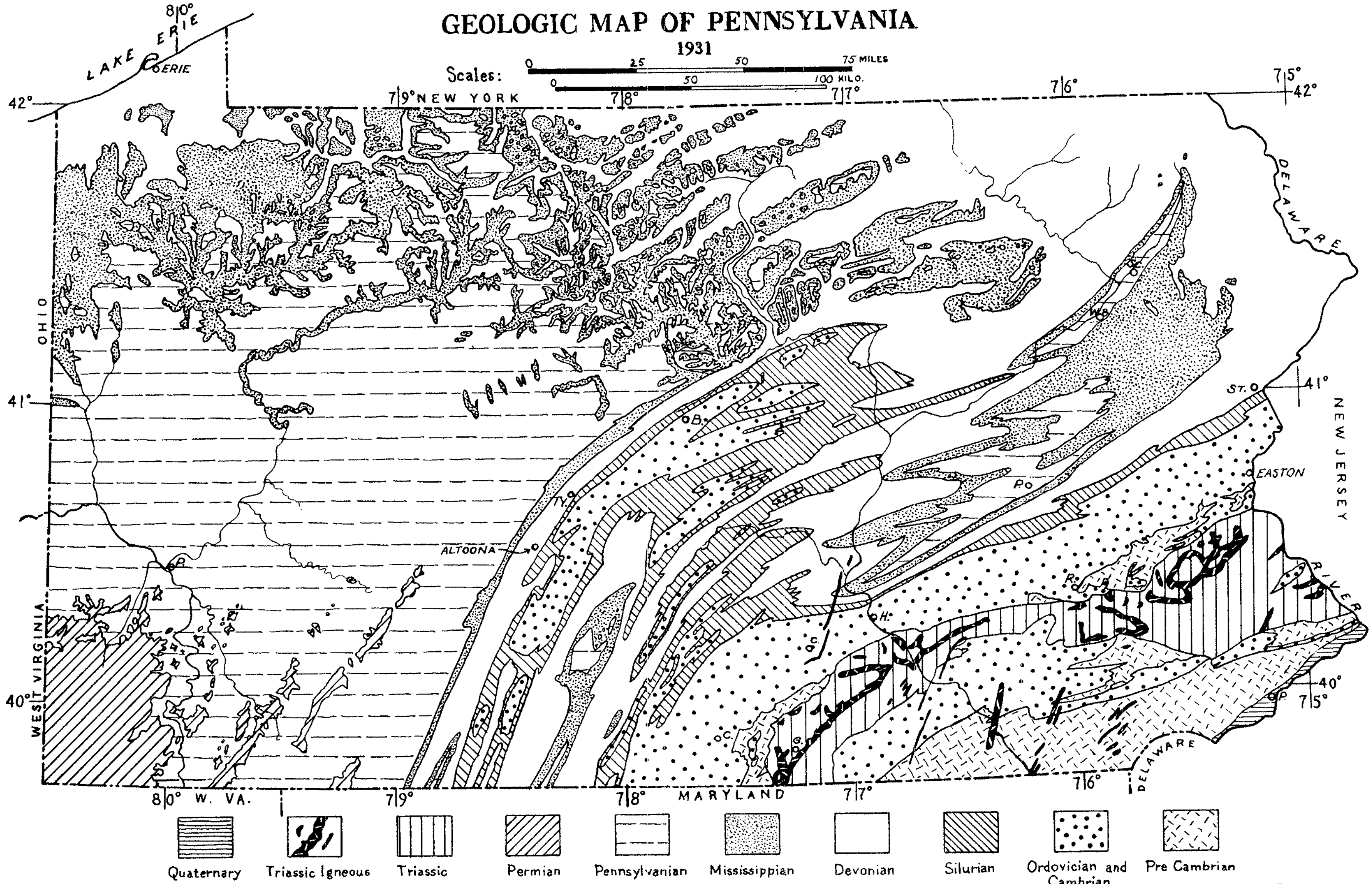
THE FOLDED APPALACHIANS.



Drawn by F.S.S.Sharpe, from Penn. Geol. Surv.

A. 1. How do you explain the persistent N.E.-S.W. orientation of the outcrops of the Mississippian in the north central part of the state and of the Permian in the S.W. corner?

2. In what physiographic province does each of the 16 cities shown on this map lie?

3. Construct a structure section from the Alleghany Plateau west of Altoona, to the Great Valley at Carlisle using a horizontal scale four times that of this map.

4. Construct a structure section from Harrisburg N.18° E. for 40 miles. Where in this section would you be most likely to find coal? What kind? Where else in the state is such coal found?

5. Where might the Susquehanna River have obtained the coal now found in its bed near Harrisburg?

6. What is the regional dip of the rocks of the Alleghany Plateau; of the Great Valley; of the Triassic Lowland?

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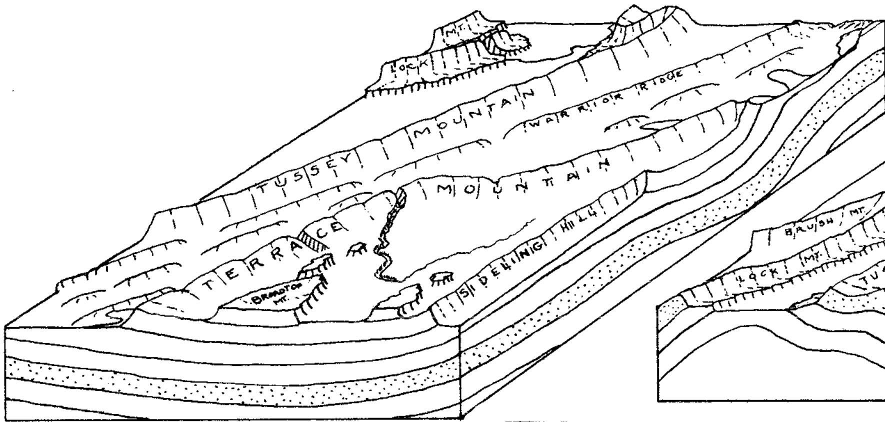
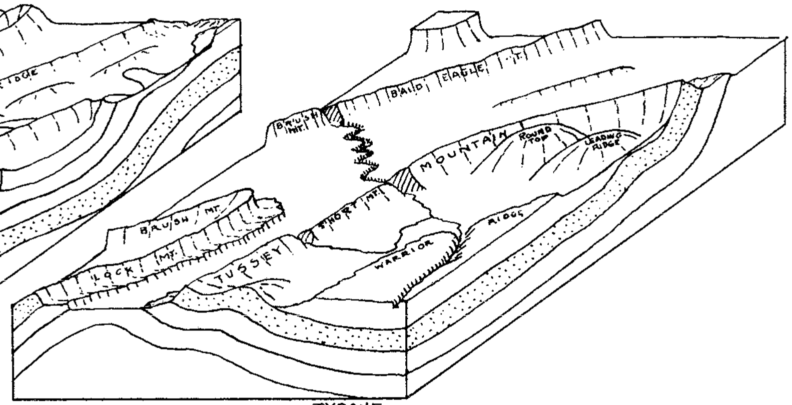
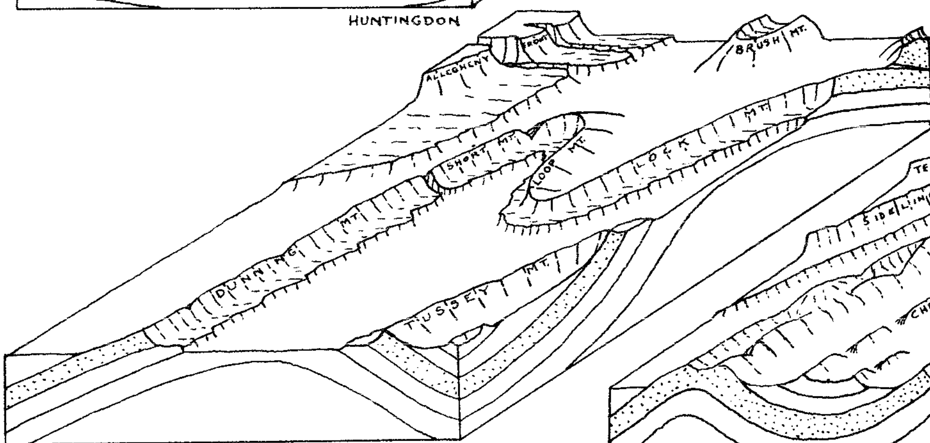


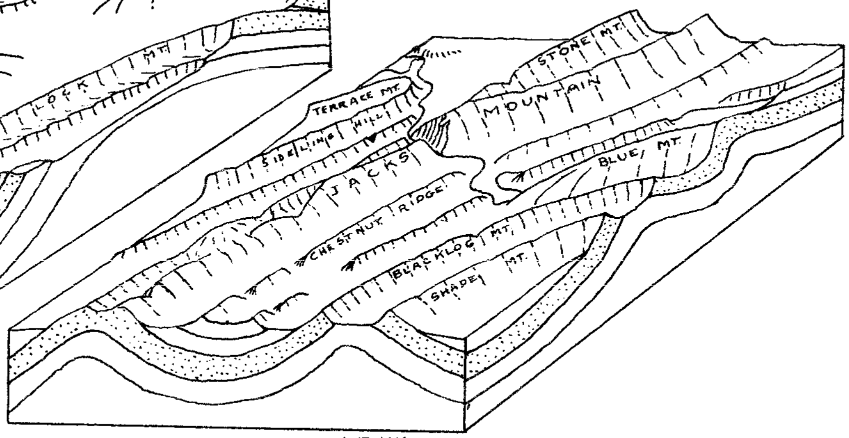
HUNTINGDON



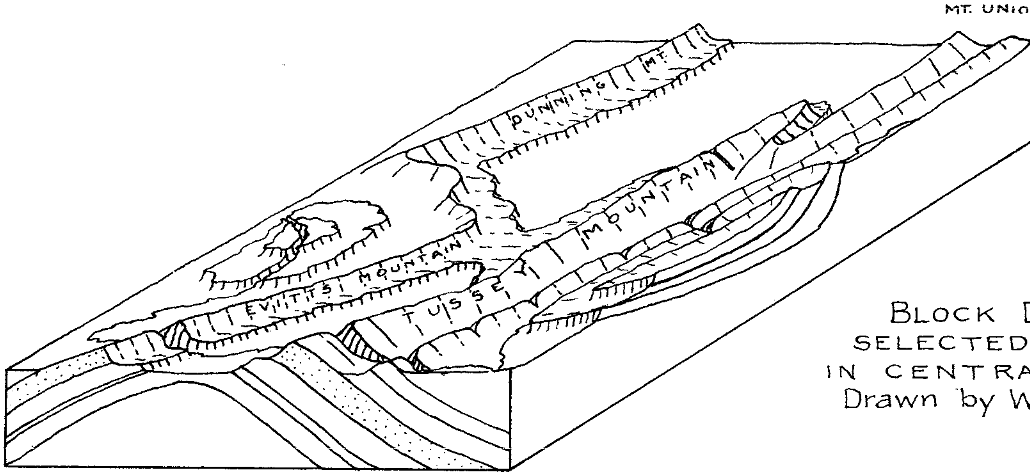
TYRONE



HOLIDAYSBURG



MT. UNION



EVERETT

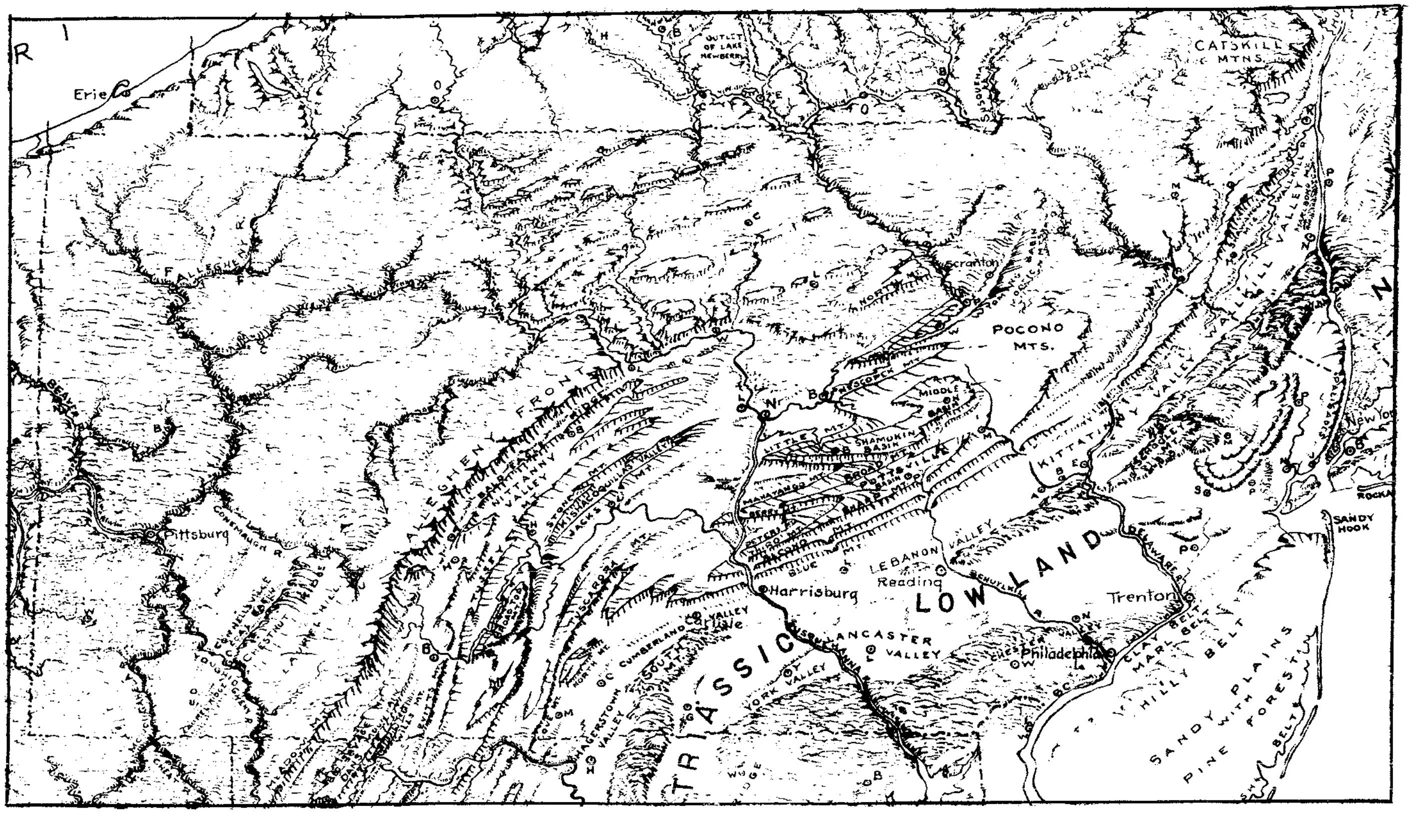
BLOCK DIAGRAMS OF SELECTED QUADRANGLES IN CENTRAL PENNSYLVANIA
Drawn by Wilfrid Webster, 1929.

1. These five diagrams, when cut apart and properly arranged with relation to each other, form a continuous unit. They should then be pasted upon a larger sheet of paper. Add one more block showing what you conceive the topography to be on the map next north of the Holidaysburg Quadrangle. Explain the ZIGZAG in the center of the Holidaysburg block. Where in this entire area are the youngest formations found? Does this explain the presence of coal there?

2. Where in this region are the oldest formations found? What are they?

3. Locate and label an ANTICLINAL MOUNTAIN, a SYNCLINAL MOUNTAIN, a MONOCLINAL MOUNTAIN, and also a valley of each type. To what formation are the large ridges due?

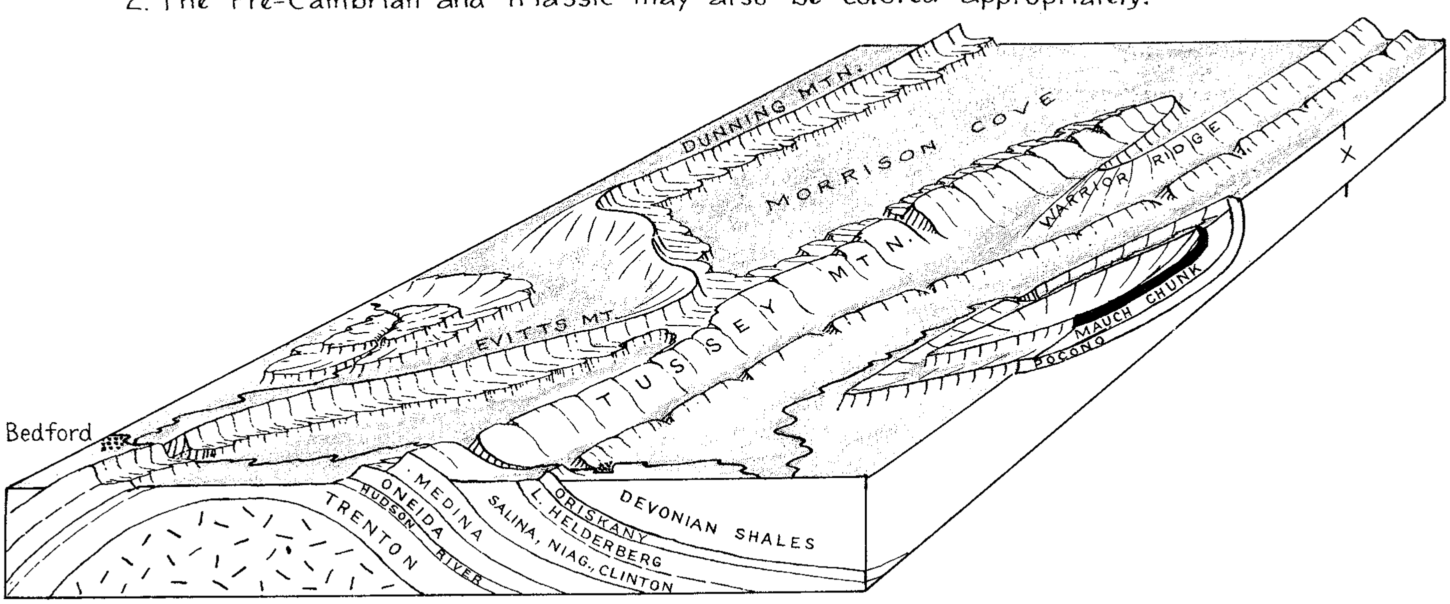
THE FOLDED APPALACHIANS



A. PHYSIOGRAPHIC DIAGRAM OF PENNSYLVANIA AND NEW JERSEY. (From Diag. of U.S., Nystrom)

1. Consult the Geological Map of Pennsylvania and color the diagram as follows:
Early Paleozoic (Camb. and Ord.) .... BLUE, mostly in Great Valley, Nittany and similar valleys.
Middle Paleozoic (Sil. and Dev.) ..... PURPLE, making up the folded ridges, and the Catskills.
Late Paleozoic (Carb., i.e. Miss. and Penn.) .... GRAY, the Allegheny Plateau and anthracite region.

2. The Pre-Cambrian and Triassic may also be colored appropriately.



B. BLOCK DIAGRAM OF EVERETT QUADRANGLE, PENNSYLVANIA. (Lobeck: Block Diagrams, Wiley)

1. Color this drawing to show surface geology. Where in this region do the oldest rocks outcrop? the youngest? Draw an East-West section across the entire region, passing through X. Explain the terrace or bench on Dunning Mtn.

2. Locate this area on the diagram above. Label on Figure B the Broad Top Coal Basin.

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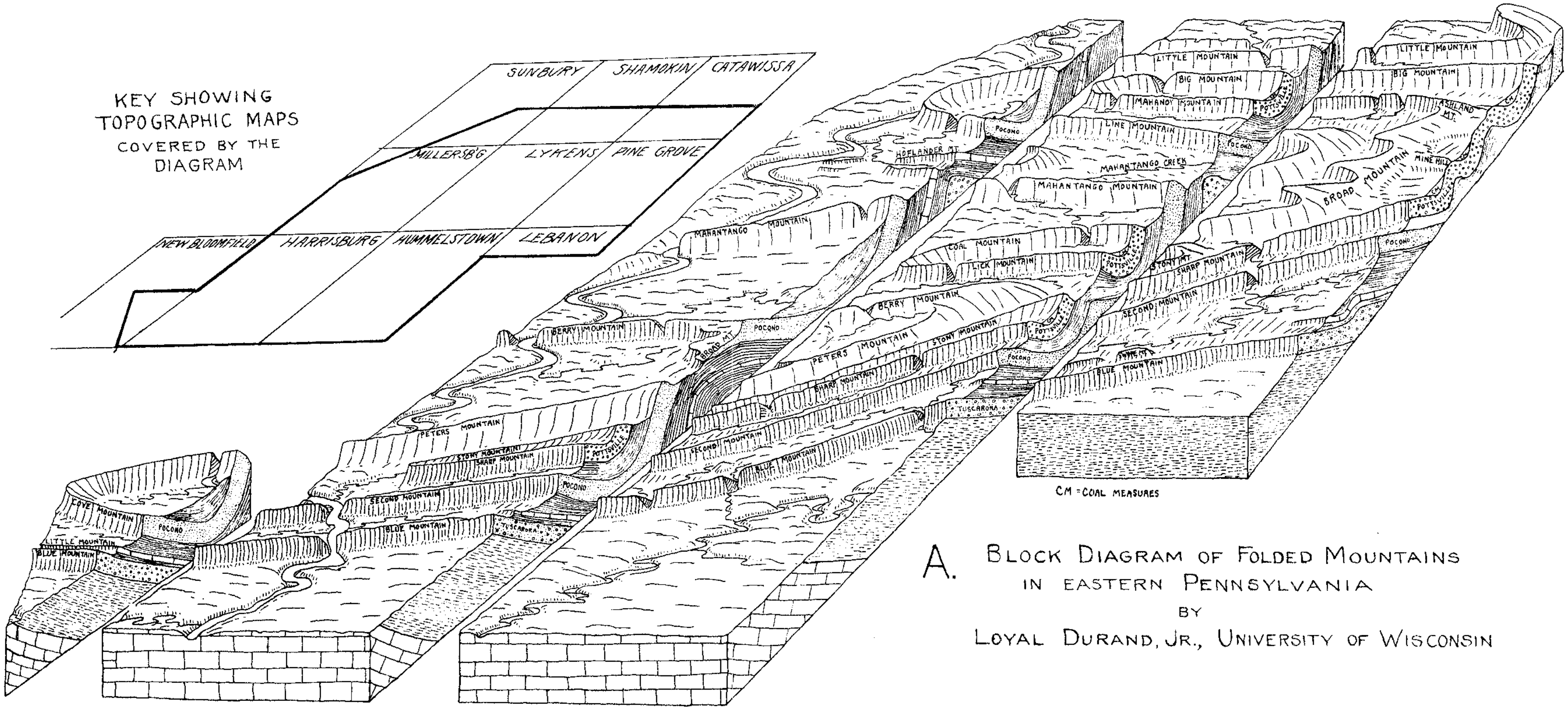
Sheet No. 34

THE FOLDED APPALACHIANS.

KEY SHOWING TOPOGRAPHIC MAPS COVERED BY THE DIAGRAM



A. BLOCK DIAGRAM OF FOLDED MOUNTAINS IN EASTERN PENNSYLVANIA
BY
LOYAL DURAND, JR., UNIVERSITY OF WISCONSIN

1. The diagram should first be colored, lightly on the surface, more deeply on the cross-sections, to show geological formations. Append a legend. What three resistant formations account for the ridges?

2. Extend the diagram westward to show what probably becomes of Berry and Mahantango Mts.

3. In which direction do most of the synclines pitch? the anticlines? How can the nose of a pitching syncline be distinguished from the nose of a pitching anticline?

4. Prepare a sketch map of the entire region, like the maps below, and show on it the topography by hachures, geology by colors, as well as frequent dips and pitches by arrows.

B. SKETCH MAPS OF ZIGZAGS FOR PROBLEMS.

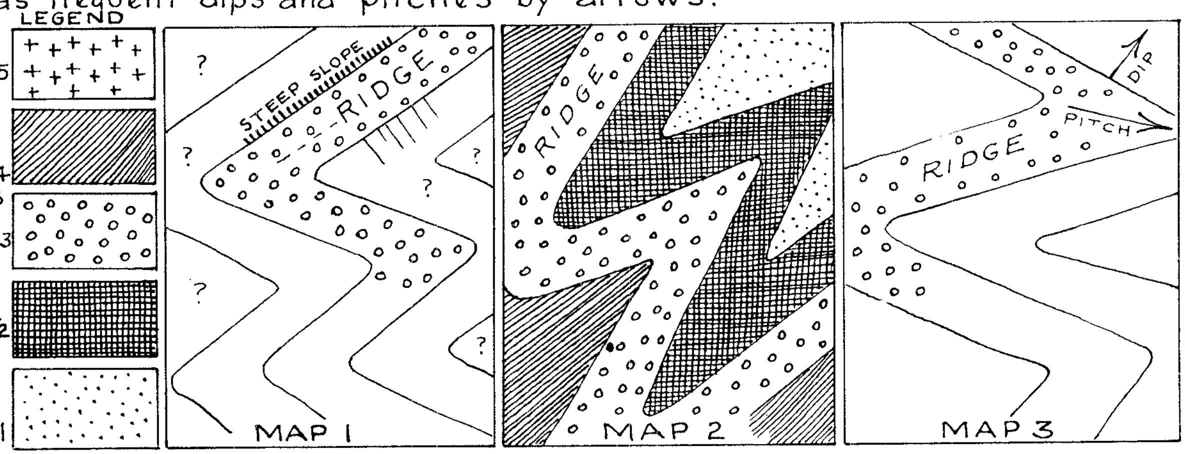
1. Each map shows a ridge, made up of Formation #3, but the dip and pitch vary in the different cases.

MAP 1 suggests the topography. To this should be added the geology and dips.

MAP 2 gives only the geology. Add the topography by hachures and show dip and pitch in several places by arrows.

MAP 3 shows dip and pitch. Add the geology and topography.

2. Draw a cross-section in each case transverse to the structure.



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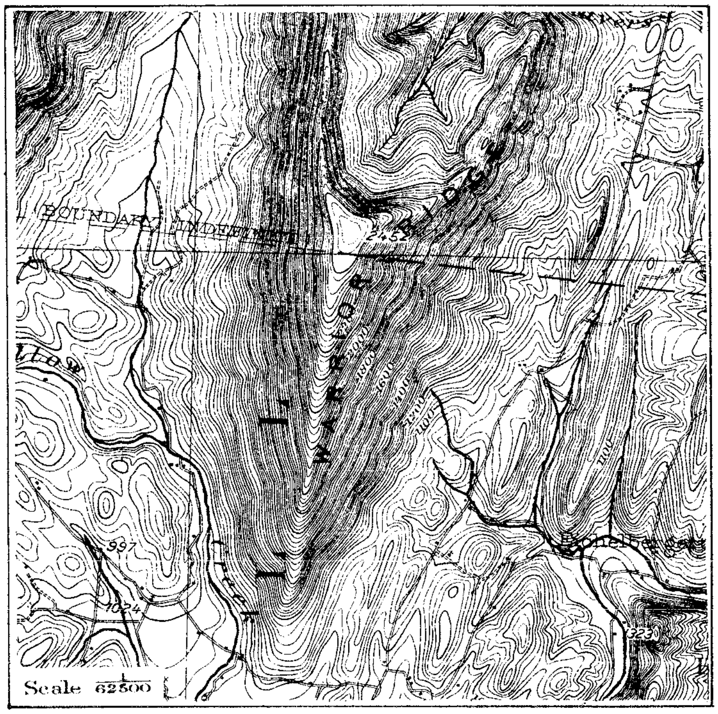
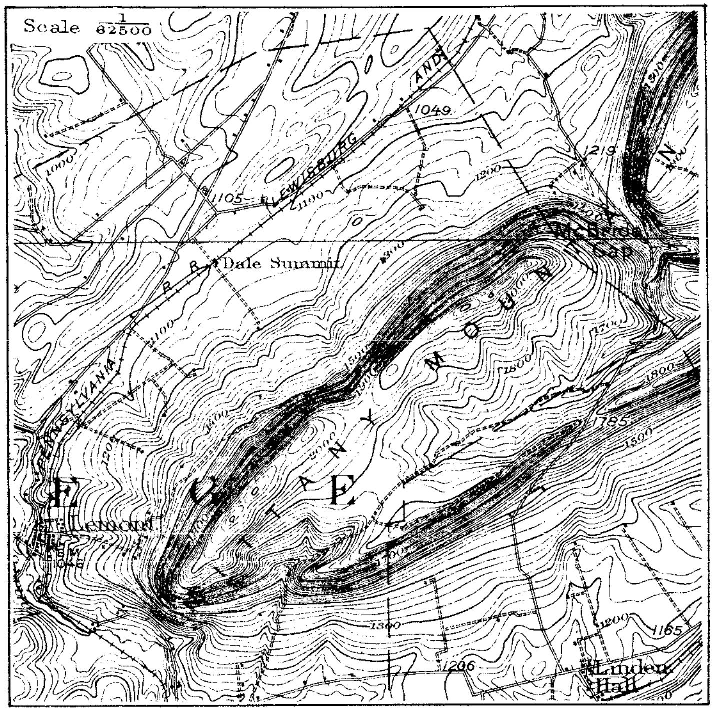
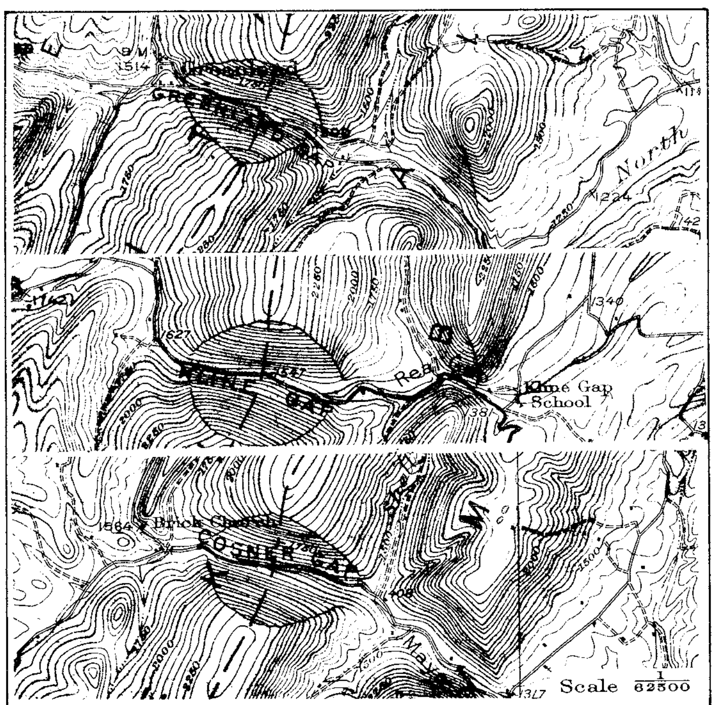


A. A PITCHING ANTICLINE (Everett, Pa.)
1. In what part of this region do the oldest rocks, and where do the youngest rocks of the area occur? Draw profile and section along the line marked "BOUNDARY INDEFINITE".

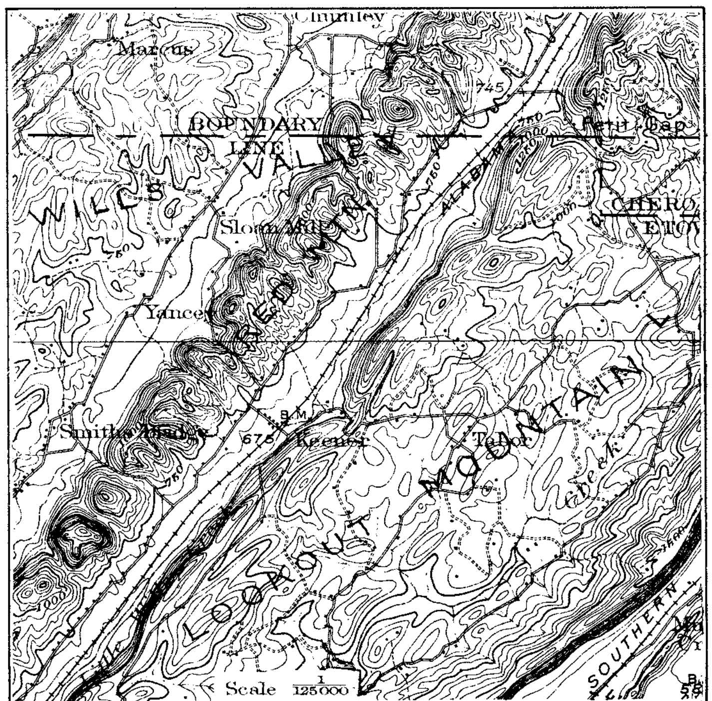


B. A PITCHING SYNCLINE. (Bellefonte, Pa. map)
1. How do the contours on this map show that this is a pitching syncline?
2. How does the form of McBride Gap indicate which way the rocks dip?



Greenland Gap, W.Va.

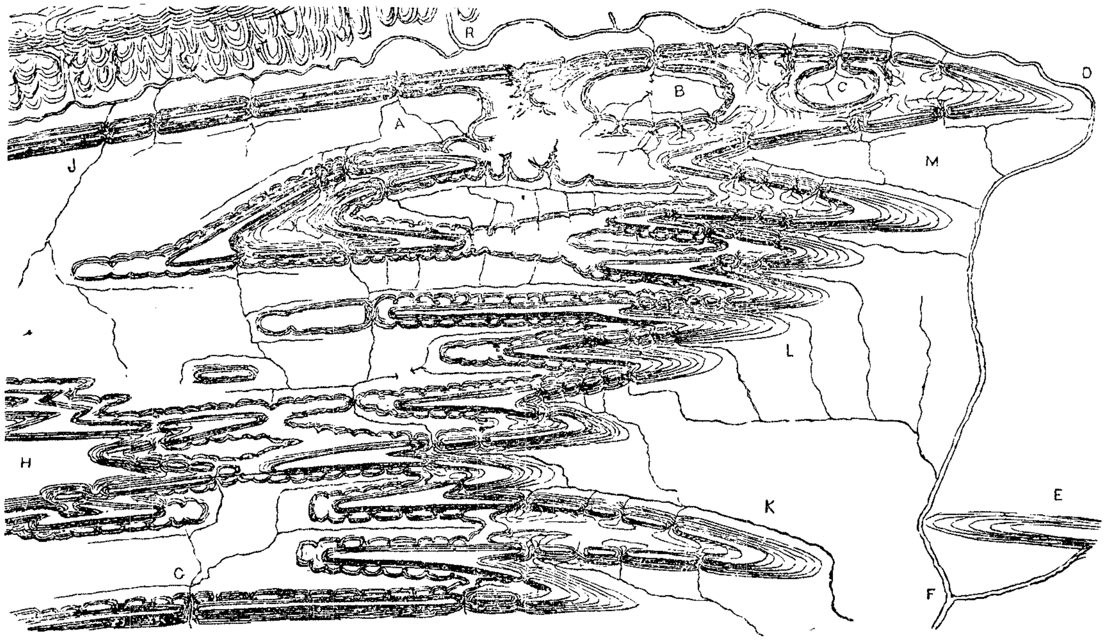
C. THREE GAPS IN AN ANTICLINAL RIDGE.
1. Redraw on a very much larger scale the contours in Greenland Gap. Show by a red line exactly the path taken by the 1750' contour.
2. Explain the straight contour line in Real Gap.



Fort Payne, Ala.

D. FOLDED STRUCTURES IN ALABAMA.
1. Draw a geological section from Northwest to Southeast corner of map. Why is there no pronounced ridge corresponding to Red Mt. on the northern side of Wills Valley?

THE FOLDED APPALACHIANS



It represents the Buffalo Mountains, L of Union County, Pennsylvania; Jack's Mountain, K; the anticlinal Kishicoquillas Valley (Logan the Indian lived at G); the upper end of the synclinal Standing Stone Valley H, and the Seven Mountains back of it; the Bald Eagle Mountain sweeping from Bellefonte J, to Muncy D, on the Susquehanna West Branch; the Nittany Valley A, with its anticlinal limestones appearing again in the Nippenose or Oval Valley B and the smaller Oval valley C; the Nittany synclinal mountains south of it with their small included anticlinal vales; and finally the simple anticlinal Montour's Ridge E apart from all the rest.

A. CONTOUR MAP SHOWING ZIG-ZAG RIDGES IN CENTRAL PENNSYLVANIA. (From Lesley: Manual of Coal.)

1. This map may be very effectively colored, using three tints — one to show the resistant ridge-forming rocks; one to show the weak rocks lying beneath them; and the third to show the younger weak rocks lying above the hard layer.
2. In what part of the Folded Belt does this region lie?
3. Draw a North-South section through the western part of the area. Label on map all anticlines and synclines.
4. What evidence is there on the map to suggest that the resistant series consists of two hard layers?
5. Draw a section (N.E.-S.W. through C) to include as many as possible of the pitching anticlines. Indicate on map.

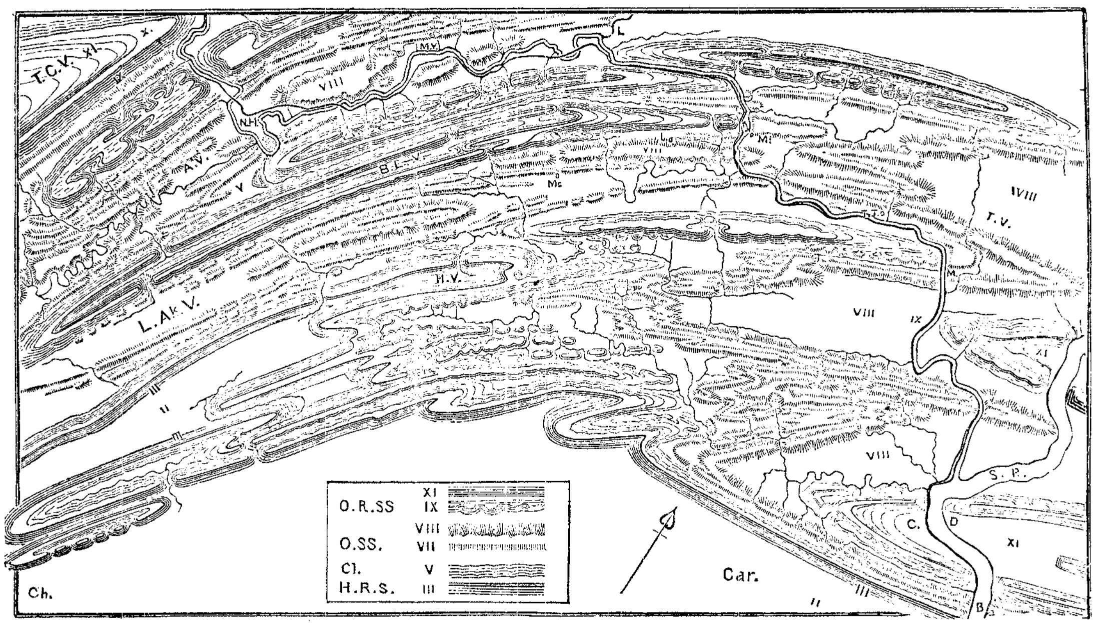
Description.—The letters on the map read as follows:—

T. C. V. Trough Creek Valley.

N. H. Newton Hamilton,	J.	A. V. Awkwick Valley.	
M. V. McVeytown,	M. E.	L. Ak. V. Little " "	
L. Lewistown,	Upon the Juniata.	H. V. Horse Valley.	
Mf. Mifflintown,	Ch. Chambersburg.	B. L. V. Black Log "	
T. V. Thompsontown.	Car. Carlisle.	T. V.	

C. the Cove; D. Dauphin; B. The Penna. R. R. Bridge over the Susquehanna.

In the square, the letters read O. R. Old Red Sandstone; O. S. S. Oriskany Sandstone; Cl. Clinton Group; H. R. S. Hudson River Slates.



B. THE RIDGES IN CENTRAL PENNSYLVANIA.

1. This map should be colored to show more clearly the six different formations represented in the legend. Which is oldest?
2. Label the Susquehanna and Juniata rivers.
3. Draw several sections through the area to explain adequately the geological structure.
4. Point out examples of pitching anticlines and synclines and indicate clearly by an enlarged drawing the difference in the contours.
5. Label examples of Subsequent, Obsequent and Resequent streams. Also of Superposed rivers, if any.
6. Does coal occur in this part of Pennsylvania? Why? Does the Great Valley appear on this map?

ZIG ZAG RIDGES OF THE NEWER APPALACHIANS

Essential facts:

(a) Appalachian type of structure prevails throughout the region, that is to say, a series of rather regularly folded strata, the folds being in the form of more or less regular anticlines and synclines; (b) these folds have been base-leveled or peneplained, so that by the end of the Cretaceous cycle of erosion the surface of the country had been worn down nearly to a plane surface; (c) the fact of base-leveling of these folds means, further, that hard and soft rocks were at one time exposed in belts but with only the faintest topographic expression; and (d) naturally all the rock strata would be exposed almost in the same plane, for the topographic cycle was long enough not only quickly to bring down the soft rocks to base level but also finally to reduce even the most stubborn members almost to the general level.

(e) Uplift then occurred in the region and opportunity was afforded for the rejuvenation of the streams, the beds of soft rock were worn quickly down approximately to the new base level, while the harder rock belts stood out as ridges whose summits now present to our belated sight the ancient level of the Cretaceous peneplain. The ridges are eventopped because they were all worn even by the end of the earliest erosion cycle, and time enough has not lapsed since the uplift of the region and the development of extensive lowlands by differential erosion for the ridges to be much affected by erosion. The material composing them is the most resistant conglomerate (Pottsville) and a stubborn sandstone (Medina and Pocono), and when compared with the soft coal measures and the shales (Hudson R.) and shale (Mauch Chunk) these offer incomparably greater resistance.

A sixth and last fact must be observed: (f) the axes of the folds are not horizontal for any distance, but pitch below the level of the peneplain, now at steep angles, now at gentle angles. Upon this feature depends the degree of divergence of the ridges. If the axes of the fold pitch at a steep angle the more strongly divergent will the ridges be formed; and conversely, the gentler the pitch the more narrow the angle between the ridges, the limit being parallelism, which would appear only when the folds became actually horizontal. Accordingly as the original folds were broad and gently pitching, or narrow and steeply pitching, the zig zags are long and wide or short and narrow.

Extra facts:

The topographic features of the region have been likened to a canoe, because of the gentle inner slopes and steep outer slopes, the resemblance is more striking when it is recognized that the end of a synclinal mountain where it often meets in a rather sharp V is doubly resistant and usually stands out as a not quite reduced portion of the mountain region, a terminal knob suggesting the high prow of a canoe. In the case of anticlinal mountains the strata dip outward, and the unroofing of the anticline by peneplanation and the subsequent valley excavation in the belts of softer rock has produced a group of mountain forms in sharp contrast to the forms of synclinal mountains. The steep slopes are here on the inside of the fold and the gentle ones on the outside. Fundamentally the law is the same in both synclines and anticlines, for in both cases the gentle slopes are down the dip of the strata and the steep slopes are those formed across the strata. It is the difference of direction and dip in the two cases that has produced the slope contrasts. Were the strata arched across the gap in the heart of the folds the resulting form would roughly resemble a cigar tapering down at one or both ends, so this type of mountain is described as cigar shaped variation of form and degree of contrast of opposite slopes depend, as in the case of synclinal mountains, upon the degree of dip of the strata. And like the synclinal mountain the meeting of the two ridge markers at the terminal point of the mountain doubles the resistance at that point and produces a terminal knob which in many cases exists as a residual or monadnock upon the surface of the peneplain.

A region may exhibit either or both synclinal and anticlinal mountains. The actu conditions at a given place will depend upon the relation of the plane of base-leveling to the hard and soft strata. In the Appalachian region the plane of base-leveling appears to have cut through the strata in such a manner as to form a larger number of anticlinal than synclinal mountains though the latter type are numerous.

The most striking features of the valleys of the zig-zag ridges, whether of one structure or another, are their linear extent and shut-in or cove-like structure. The sharp contrast between the linear extent and the width of the valleys is a direct result of the attitude of the strata, giving broader valleys where the strata are gently inclined and narrower valleys where steeply inclined.

Variations upon the simple scheme outlined above are not hard to understand. If each anticline and each syncline has several hard ridge markers, several parallel ridges will come into existance, as is the actual condition of the region north of Harrisburg. The number of ridges that will occur in a given place will depend upon the size of the folds and the number of alternations of hard and soft strata. A mass of strata may be so thick that it can not be compressed in such a manner as to form folds exposing the entire section in the form of regular anticlines and synclines. The limit is about 50,000 feet. If the hard layers are separated by a very thin soft layer the valleys between the ridge makers will not be deep unless the dip of the strata is unusually great. The two sides of a given ridge maker are also apt not to be so sharply contrasted as where sufficient space occurs between ridges for the formation of a large valley.

<u>Drainage Features of the Region</u>

The master streams flow roughly at right angles to the trends of the ridges and cut across them through water gaps of notable depth and often of pronounced beauty. Where they cross the ridges in the gorge-like water gaps the main streams are swift, often descending short rapids, while across the intervening valleys they often flow lazily and in regularly meandering courses.

The chief cause for the wholesale modification of the drainage of a region such as above is the warping or bowing of the surface that commonly takes place after or during the last stages of peneplanation and inaugurates a new cycle of erosion or forms one of the late substages of the first cycle. The effect of such warping or bowing is to cause a migration of the divides toward the main axis of uplift and away from the area of subsidence. The antecedent drainage tends to become adjusted to the warped condition, streams come to occupy axes of depression, and divides finally become located on the axes of elevation. The Appalachian region was bowed or warped up along a southwestward-tending axis located in western Pennsylvania. Not all master streams have divides on this axis, but most do.

As intrenchment progresses after uplift and other erosive agencies are set into operation differential erosion will follow, hard rock will be exposed in patterns sympathetic with respect to structure, and there will be brought about a most unsympathetic relation between the topography and the drainage, precisely the sort of drainage that now exists between the main streams and the main lines of relief within the central district. The weaker tributary streams wibl for a time flow across the harder ridges, but the steady development of subsequent streams along belts of weak rock will in time effect an almost complete adjustment of tributary streams to structure. The gradual headward growth will be accompanied by progressive capture of streams af the disadvantage of crossing the harder ridges to reach the main streams. The old water gaps will become wind gaps and a diminished river will flow in the channel of the beheaded stream. Here and there a larger tributary or one with exceptional advantages will persist like its master stream.

—Weinburgh

REJUVENATION OF STREAMS IN THE HARRISBURG AREA

After the uplift of the Schooley peneplain a period of erosion took place during which the Harrisburg peneplain was formed. This peneplain; which, along with some others put forth by a number of authors and often referred to collectively as the Lowland peneplain; did not bevel the resistant ridges, as had the older Schooley surface, but only succeeded in plaining the weaken rocks between the ridges.

It was upon this Harrisburg peneplain surface between the ridges that many streams reched the mature development of old age, characterized by broad swinging meanders and very low gradient. Near the site of the present city of Harrisburg, these streams all flowed into the larger antecedent river; the Susquehanna, which at this time occurred at a higher level with respect to the Harrisburg surface than it does at present.

At this stage in the development another uplift of the land or lowering of the ocean took place increasing the gradient of the eastern watershed. The powerful Susquehanna river responded to this by cutting down its channel. This automatically lowered the base levels of its tributaries and thus increased their eroding powers. The down cutting which occurred in the old meandering stream channels of the Harrisburg peneplain caused a deep entrenchment that reached a magnitude of 150 feet at some points.

The best example of these entrenched meanders is illustrated by Conodoguinet Creek, which empties into the Susquehanna approximately opposite Harrisburg.

OUTLINE

I. Uplift of Schooley peneplain.
    1. Erosion period.

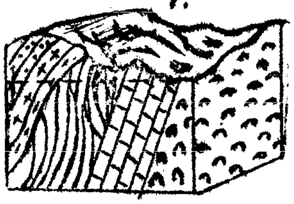
II. Formation of Harrisburg peneplain on the weaken rock of the Schooley.
    1. Hard rocks formed ridges.
    2. Streams developed to maturity.

III. Uplift of Harrisburg peneplain.
    1. Entrenchment of mature streams.
        a. Depths of 150 feet.

PENEPLANES AROUND HARRISBURG

In Cretaceous time, arbitrarily called late Jura-Trias-Cretaceous, peneplanation occurred throughout the Appalachians. This period of peneplanation is developed the Fall Zone peneplane. It is characterized at the present time by falls and rapids in streams passing from the old land mass of the Appalachians into the coastal plain provinces. If this old peneplane was projected westward over the mountains, it would go well above them. Diagrams 1 and 2 illustrate the process of erosion during this period and figure 3 shows later inundation of the peneplane. During the Cretaceous period of inundation, sediments were deposited. Later broad uparching took place, and initiated a new drainage pattern. This was followed by subsequent peneplanation into the so-called Schooley-Kittatinny, or just the Schooley peneplane during the Tertiary period. Figures 4 and 5 illustrate the characteristics during this period. Many superposed streams held their courses during this long erosion period, although it is believed that much adjustment to structure took place.

1.



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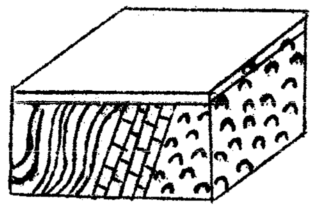

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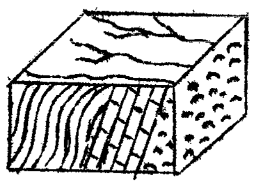

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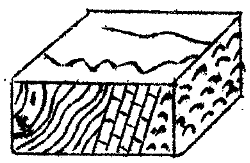
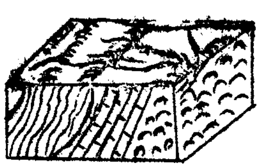


Uparching of the Schooley peneplane, fig. 6, permitted rejuvenation of the drainage system, and the development of the Harrisburg peneplane on weak rock formations (fig. 7). Further moderate uplift allowed incision of streams in the Harrisburg level, and development of the Somerville peneplane. The weaker beds (x) of figure 8, formed this peneplane. Renewed uplift accounts for the rejuvenation of streams below the Somerville level (fig. 9).

This short synopsis of the peneplane cycles is of course simplified. It is quite possible that other inundations took place besides the one shown on figure 3, and it is also quite possible that intermediate peneplanes were formed, though evidences appear to be lacking, and the principal peneplanes are more important to us as we will have opportunity to observe them on the course of our trip.

6.

7.



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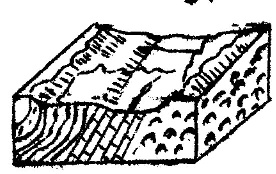
9.



R. A. Gavan

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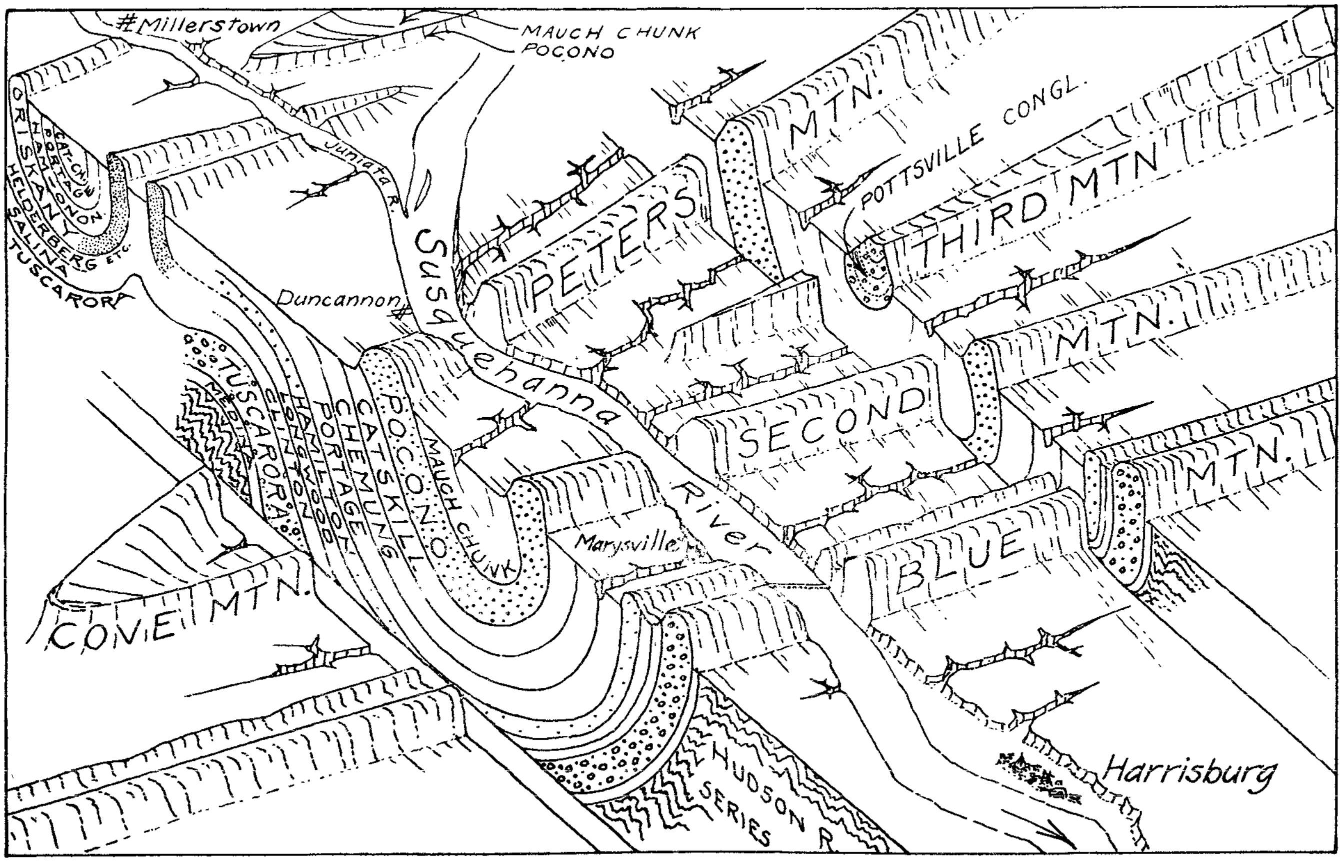
THE FOLDED APPALACHIANS

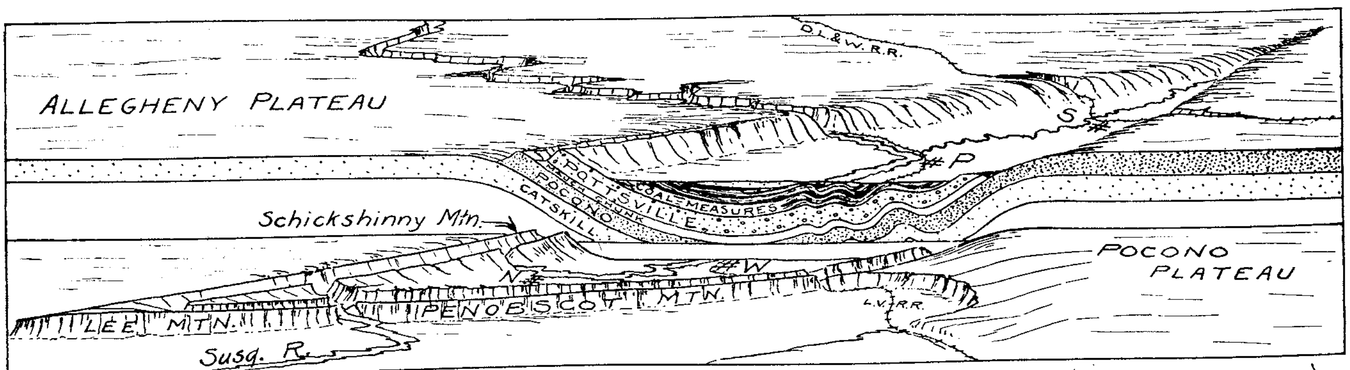


A. DIAGRAM SHOWING STRUCTURE OF THE FOLDED APPALACHIANS AT HARRISBURG. (N.Y. Acad.)

1. What is the essential structure of this region and in which direction does it pitch? What other feature on the map resembles Cove Mtn. in form and structure?

2. The coal beds occur immediately above the Pottsville Conglomerate. Where in this region, therefore would you expect to find coal?

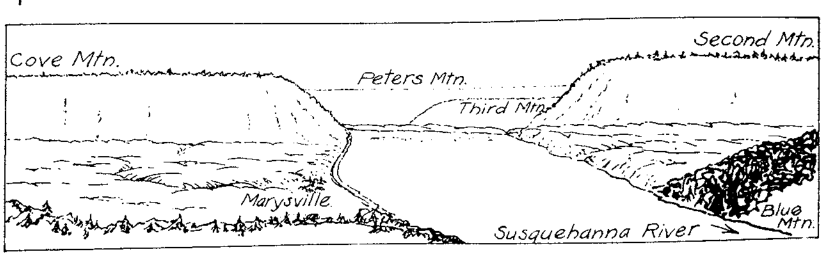
3. Note a pitching anticline. Note also the three cycles of erosion represented here.



B. DIAGRAM SHOWING STRUCTURE OF THE WYOMING COAL BASIN. (N.Y. Acad. Sci.)

1. What is the structure of this basin? What cities lie in this basin?

2. Which of the formations represented here are resistant? Do they correspond with any in the Harrisburg region?



C. THE WATER GAPS ABOVE HARRISBURG.

1. Color this picture, as well as the Harrisburg map above, in order to show the different geological formations, using the same colors in each.

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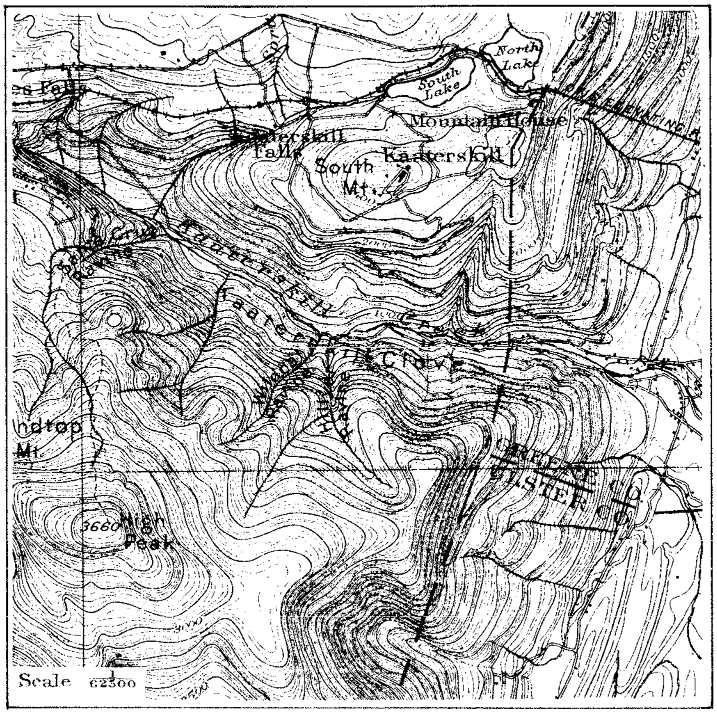
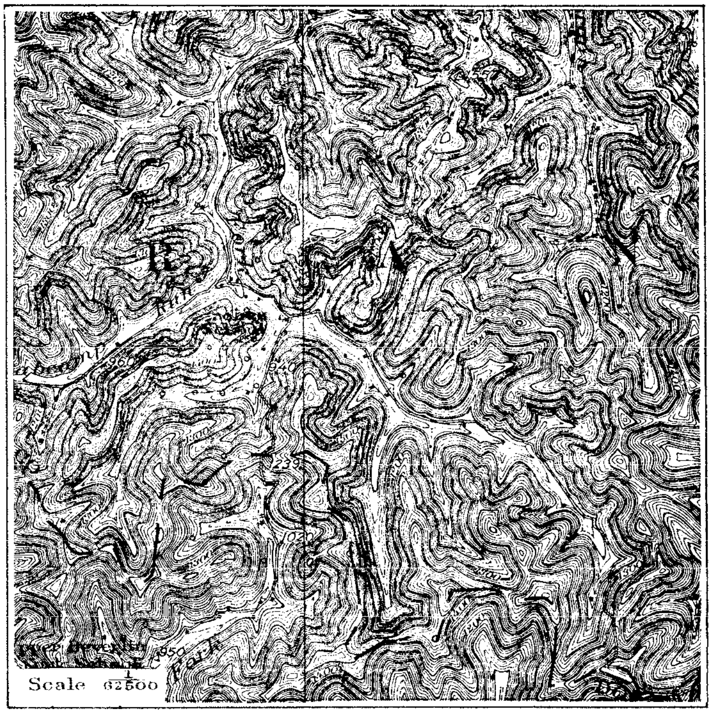
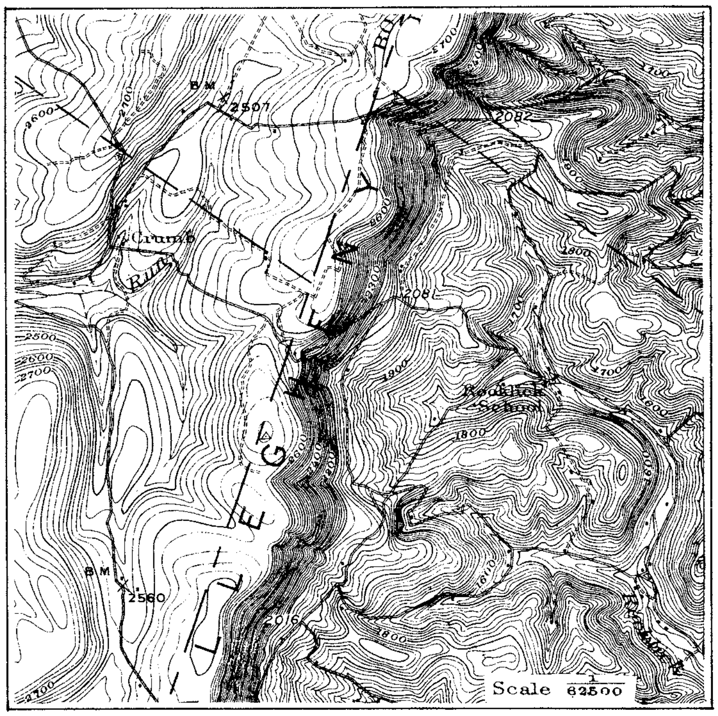
THE APPALACHIAN PLATEAUS.



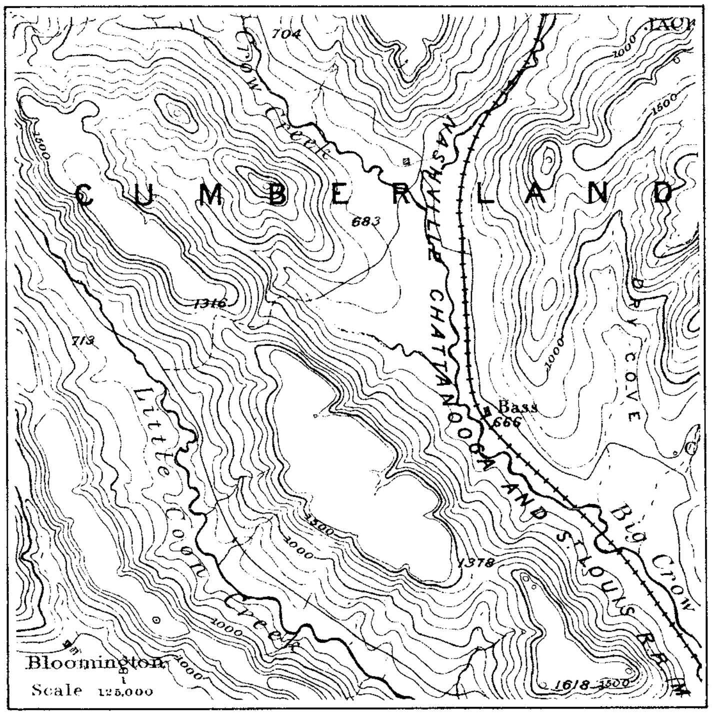
A. THE CATSKILL MOUNTAINS.
1. What evidence is there that the rock structure here is horizontal? Why is the topography so bold and coarse-textured?
2. Explain Kaaterskill Falls. (KAATERSKILL SHEET)



B. APPALACHIAN PLATEAU IN WEST VIRGINIA.
1. What is the texture of the topography?
2. In what stage of development is it?
3. Show streams in all the valleys.
(CENTERPOINT SHEET)



C. THE ALLEGHENY FRONT IN PENNSYLVANIA.
1. What suggestion is there of horizontal structure? Or of a westward dip?
2. Why are there no folded ridges east of the Allegheny Front? (BEDFORD SHEET)



D. THE CUMBERLAND PLATEAU IN ALABAMA.
1. What is the difference between this topography and that on the other maps?
2. How does the area of this map compare with that of the other maps? (STEVENSON SHEET)

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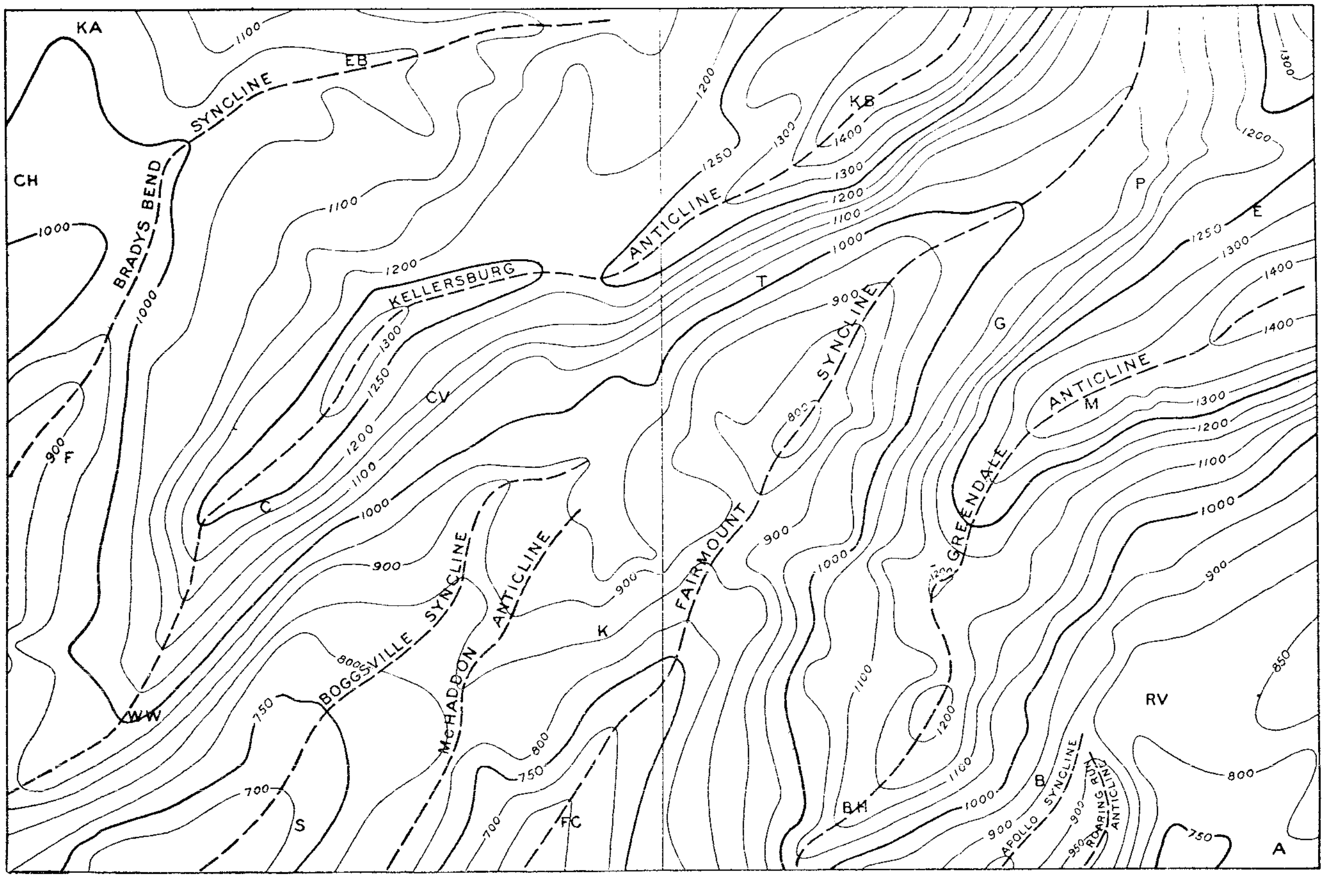
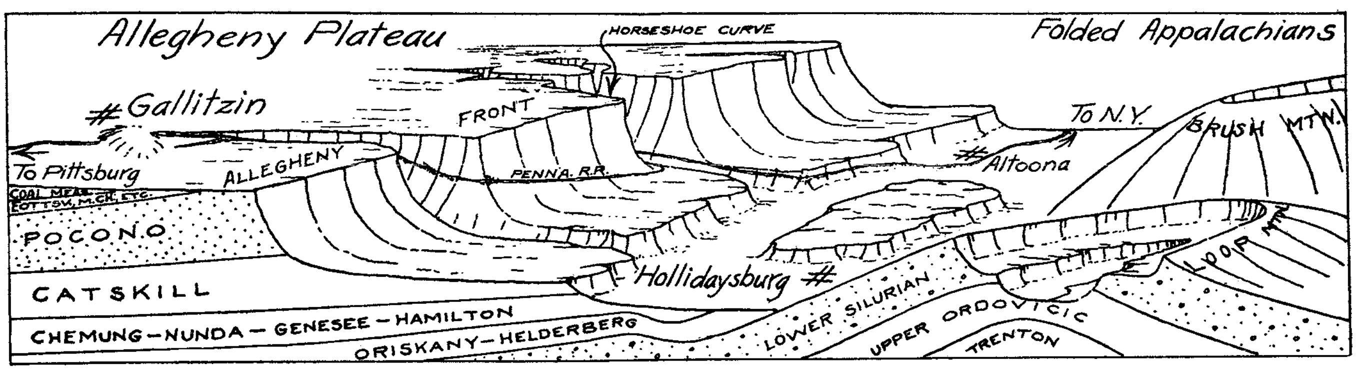
THE APPALACHIAN PLATEAUS.



A. PART OF ALLEGHENY PLATEAU IN PENNSYLVANIA, showing geologic structure by means of STRUCTURAL CONTOURS drawn on top of the VANPORT LIMESTONE. Surface topography is not represented. 1 Mile = 1/4 inch. (U.S.G.S. Folio 115)

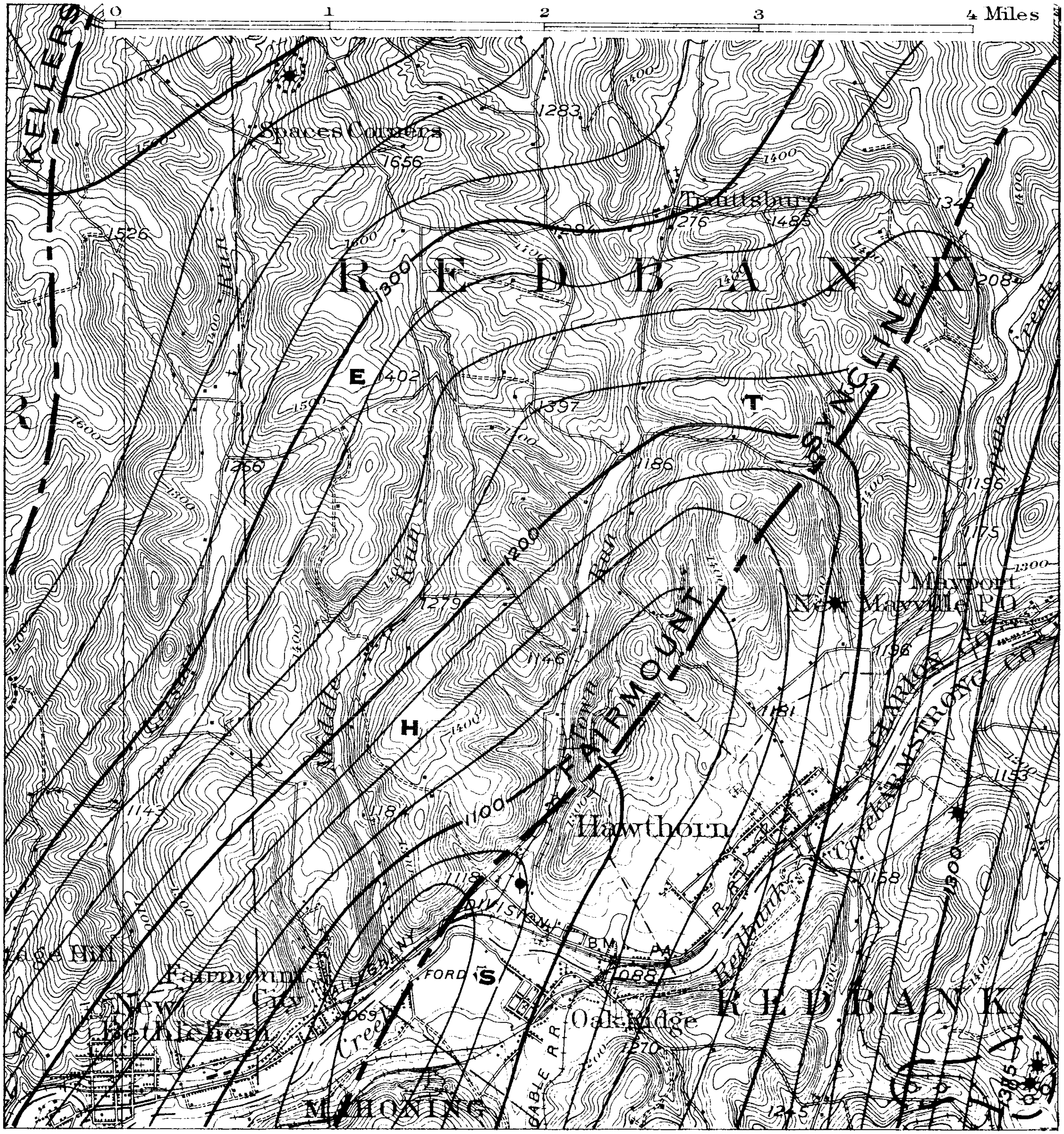
1. If this is a plateau why is it so folded? What is the steepest dip, in feet per mile that you note on the map? How many degrees is this?
2. Draw a profile along the southern margin of the map, using a vertical scale of 1 INCH = 1000 FEET. What is the vertical exaggeration in this case?
3. Suppose the top of the plateau were level and stood at an elevation of 1000 feet, where would the Vanport Limestone outcrop? How deep would it be beneath the surface at the Point K? at CV? at RV? at KB?



B. THE ALLEGHENY FRONT AT ALTOONA, PENNSYLVANIA. (N.Y. Acad. Sci.)

1. In what direction do the formations dip along the Allegheny Front?
2. Explain the Horseshoe Curve on the Pennsylvania Railroad.
3. Why is coal not found in the Folded Appalachians near Altoona?
4. What structural features characterize this part of the Folded Appalachians?
5. Draw a simple CONTOUR MAP of the region shown above.
6. Then color the map to show geological formations.

THE APPALACHIAN PLATEAUS.



A. Topographic Map of part of Allegheny Plateau with Structure Contours showing depth to Vanport Limestone Formation. (From U.S.G.S. Folio 178, Clarion sheet)

1. Note first the different contour intervals used in the two groups of contours.
2. Then determine outcrops of Vanport Limestone, by noting all points where similar contours of each set cross. Shade or tint lightly all areas underlain by Vanport Limestone.
3. Draw a cross-section along bottom edge of map, showing both topography and structure. Use a vertical of One Inch = 400 Feet. Determine, in feet per mile, dip of Vanport Limestone.
4. How far beneath the surface is the Vanport Limestone at the points E, T, H, and S?

ITINERARY - HARRISBURG, PA. TO WASHINGTON, D.C.

Harrisburg to York

At Harrisburg the Susquehanna River runs in a rock-cut channel 10 to 15 feet deep. Local deeps or rock cut channels are filled with gravel to a depth of 45 feet. The business part of Harrisburg lies on a gravel terrace 340 feet above sea level, the gravel 20 or more feet deep lying on an irregular rock floor 10 to 15 feet above the river. The capitol buildings stand on a gravel capped rock hill, 60 feet above the lower river terrace or 360 feet above sea level. The eastern part of the city lies on a gravel and silt covered terrace at 120 feet above the river or 420 feet above sea level, which is correlated with glacial deposits of Illinoisan age. The railroads run in an old channel of the river, still flooded at very high water.

From Harrisburg to Cumberland the road crosses a broad valley underlain by the Beekmantown limestone (lower Ordovician).

At Lemoyne (Riverton)(station 1) pure Stones River limestones of Chazy (Lower Ordovician) and a thin representative of the fossiliferous Chambersburg limestone, of Black River (Middle Ordovician, crop out between the Beekmantown limestone and the Martinsburg shale (Ordovician) that forms the hills at the bridge entrance and in the city of Harrisburg. These fossiliferous limestones (Stones River and Chambersburg) are absent at the Martinsburg shale contact at the south side of the Beekmantown area, near New Cumberland.

New Cumberland lies in an abandoned bed of the Susquehanna River floored with river gravel deposited in late glacial times (Illinoisan or Wisconsin). The present river channel is 60 feet lower. There is here a belt of Martinsburg shale, or Trenton and younger age, which forms the line of hills west of New Cumberland (See map).

At Newberrytown, 4.5 miles north of Yorkhaven, (Main highway U.S. 111) the sandstone and conglomerate are intruded by a thick crosscutting body of diabase. Just southeast of Kartman Hill (6.2 miles north of Yorkhaven), a small diabase sill shows in the road cut, with black metamorphosed shale at the lower contact.

In the lower ground to the north the red shale and soft red sandstone of the Gettysburg formation (Upper Triassic) are exposed. Harder gray sandstone and coarse conglomerate interbedded with red shale dip northwest above the softer red shale and form the upper part of the Gettysburg shale. A diabase mass which intrudes these upper beds, has altered them into hard baked sandstone.

The upper conglomerate bed extends to the north edge of the Triassic belt where they are terminated by a normal fault, (see map) by which the Triassic block has been depressed along its north edge and the beds tilted northward. Although the block to the north was uplifted, the limestone exposed by the uplift has been dissected into a lowland, as may be seen from the edge of the escarpment (station 2). The fault which crosses the road 0.7 of a mile north of the foot of the hill, is deeply covered with terrace gravel.

The road crosses hard gray sandstone and some coarse conglomerate beds interbedded with red shale, the lower part of the Gettysburg formation (Upper Triassic). This conglomerate forms the Conewaygo Hills to the southwest. The dip of the beds is uniformly northwest, 15° to 35°. The Triassic in this area has a calculated aggregate thickness of 25,000 feet.

On the hill southwest of Yorkhaven (locality 3) are some interesting basic and acidic differentiates of the diabase, as well as altered and mineralized shale, in thin roof remnants of the sheet.

At Yorkhaven the road turns south after passing southeastward more directly across the strike of the beds. For 2 miles the road has passed over a thick sheet of Triassic diabase.

The Triassic diabase is well exposed in a large quarry (locality 4), in the river bluff (Susquehanna) and the shales at the contact are baked to hard black porcelanite banded with white. Large residual boulders (round) of diabase abound in the fields.

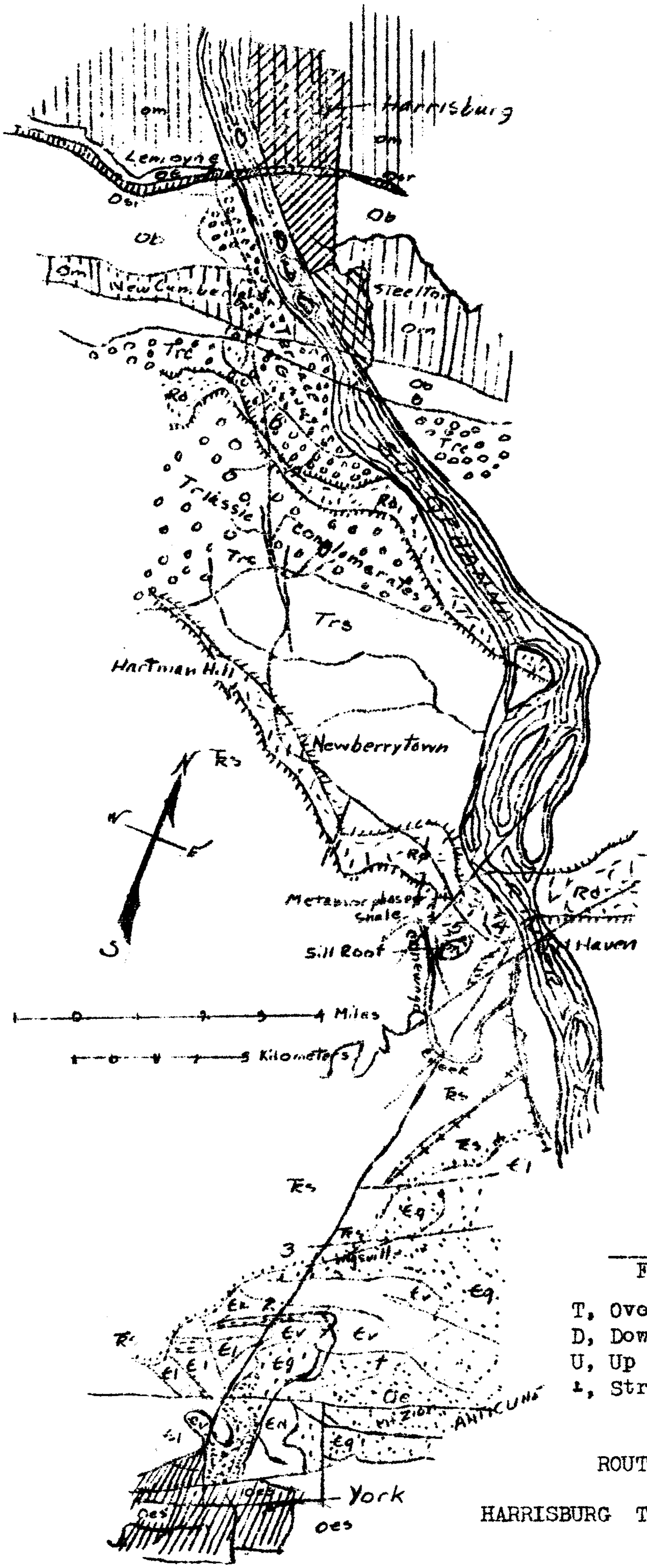
At 8 miles north of York the road crosses Conewaygo Creek (290 feet below the peneplain level. The intricate meanders (entrenched) of this stream as those of the Conodoquinet Creek (near Harrisburg), are believed to have been acquired on the Harrisburg peneplain. Most of the hilltops at about 520 feet above sea level close to the Susquehanna River, have scattered water worn pebbles or cobbles in the soil. Gravel and cobble (scattered) also occur on flat tops hills or benches at several levels below this plane. They are remnants of deposits left by the river in deepening its valley.

At 5.8 miles north of York the road is on a remnant of the Harrisburg peneplain, here 520 feet above sea level (probably Pliocene).

Between Yorkhaven and Emigsville the road passes diagonally over the northwest-ward-dipping yellowish arkosic sandstone and interbedded red sandstone of the Upper Triassic New Oxford formation, the lowest formation of the Triassic.

At Emigsville (locality 5,) in the railroad cut just south of the highway bridge, the Triassic red sandstone unconformably overlies the Antietem quartzite, with a small mass of Cambrian limestone unfolded or infaulted at the contact. There is a noticeable discordance of dips (Triassic, 58° N.W; Antietem, 30° S.E.) The Antietem contains rust covered molds of Lower Cambrian trilobites and shells.

Southward the route passes over another hill (location 6) composed of Kinzer's formation to a valley underlain in part by Sedger dolomite (upper part of Lower Cambrian). The beds here are overturned and dip 15° S.E., so that the fossiliferous limestones of the upper part of the Kinzers formation on the north side of the shale hill dip under the shale and are thrust northwestward over Vintage dolomite on a low angle fault of considerable throw. The Vintage dolomite continues to Emigsville, where the rise of the Strata brings up the Antietem quartzite (lower Cambrian).



LEGEND

Triassic

Symbol	Description
Trd	Intrusive Diabase & Metamorphosed Shale at Contact
Trs	Red Shale and Sandstone (Gettysburg & New Oxford)
Trc	Conglomerates

ORDOVICIAN

Symbol	Description
Om	Martinsburg Shale (Trenton, Eden & Maysville)
Oce	Conestoga Limestone
Oc	Chambersburg Limestone (Black River)
Osr	Stones River Limestone (Chazy)
Ob	Beekmantown Limestone

LOWER CAMBRIAN

Symbol	Description
Єl	Ledger Dolomite
Єk	Kinzers Formation
Єv	Vintage Dolomite
Єq	Quartzites and Slates (Antietam, Harpers & Chickies)
Єc	Basal Conglomerate (Hellam)

Fault

T, Overthrust side
D, Down
U, Up
⊥, Strike and dip of bedding

ROUTE MAP

HARRISBURG TO YORK

A mile to the north of York, on the hill (locality 7 on route map), is an outcrop of the shale of the Kinzers formation, at the plunging end of the Mount Zion anticline. The shale is cut off by a normal cross fault from the Antietem quartzite (lower Cambrian) in the plunging nose of the anticline, which makes the hill to the east, and the narrow valley east of the road at this point contains the intervening Vintage dolomite (lower Cambrian), which is normally about 100 feet thick but is largely cut out by faulting.

Just north of York the highway crosses lower Cambrian limestones that overlie older arenaceous Cambrian rocks (Chickies and Harpers), exposed to the northeast in the Hellam Hills. These strata are broken by many normal faults that offset and repeat the beds.

In the northern part of the city the road crosses a shale hill of the Kinzers formation (lower Cambrian) which carries a rich trilobite fauna. The shale is well shown in the cut on the west side of the road.

The city of York lies in a limestone valley at the nose of the southwestward plunging Hellam anticlinorium which forms low hills to the northeast.

York, Pennsylvania to Baltimore, Maryland (U.S. - 111)

South of York - Cambrian phyllite and quartzite (the Chickies formation and Harpers schist) are thrust on a flat fault plane northwestward over Conestoga limestone.

Thence southward may be seen the Wissachickon formation - foliated biotite - muscovite - oligoclase schist, gneiss and quartzite (late pre-Cambrian).

Cross the Tucquan anticline at Bentley.

From a point 2 miles north of Cockeysville to and beyond Monkton- Phoenix anticline in the gorge of Gunpowder Falls (river) exposes the Baltimore gneiss (early pre-Cambrian) and overlying Setters quartzite (late pre-Cambrian).

Through the broad valley of Cockeysville marble through Cockeysville, the type locality.

Many quarries in this white marble (coarse) from which the rock used in the lower part of the Washington Monument at Washington was obtained.

The hills west of the valley - mica schist and mica gneiss of the Wissahickon formation (late pre-Cambrian)

From Rider to Mount Washington - the road skirts the west side of the Glenarm - Towson anticline which has a thrust westward along a north-south fault over Cockeysville marble.

Gabbro extends south from a point north of Mount Washington.

Farther on - many coarse pegmatite dikes make prominent ledges across Jones Falls.

North of Baltimore - E. side of R. R. is a large quarry in the Baltimore gneiss.

Baltimore, Md. to Annapolis, Md., (Route 27)

Annapolis, Md. to Washington, D. C. (U.S. - 50)

The cities of Washington, D. C., and Baltimore, Md., lie at the junction of two geomorphic provinces, The Piedmont, on the west and the Coastal Plain, on the east. In the Piedmont Plateau the rocks are crystalline, the soils, residual, the stream courses flow in narrow gorges in which rapids and falls are numerous. The surface features reflect the character of the underlying rock and the streams are largely under rock control.

Approaching Washington, via U.S. - 50 the route traverses the gentle outward slope of the lowland area which merges into great estuaries or drowned river mouths. Chesapeake Bay, the drowned river valley of the Susquehanna River, is the largest. The Potomac River, also drowned, is navigable to the city of Washington. Numerous tidal tributaries of these waterways penetrate southern Maryland.

The Coastal Plain is made up of sediments which range in age from Cretaceous to Recent.

They comprise a series of unconsolidated strata, the lowest of which are composed of arkosic sands and clays derived from a deep mantle of distintegrated gneiss and phyllite such as now form a part of the Piedmont Plateau. Higher in the section the strata consist of variegated clays and coarse, irregularly bedded sands. Then follow sands and clays in alternation with but slight variation in character. The surface soils are derived from clay, sand and gravel deposits. The rivers flow sluggishly in shallow valleys produced by streams born upon plains newly uplifted from the sea, and discharge into broad tidal estuaries or coastal swamps.

The waters of Chesapeake Bay are very shallow rarely exceeding 18 feet and averaging only 10 feet. Twenty five feet of elevation would cause it to become a low coastal terrace.

Leaving the outward slope the route crosses the inner lowlands finally coming upon the Piedmont cuesta at Washington.

Baltimore, Md. to Washington D. C. (U.S. - 1)

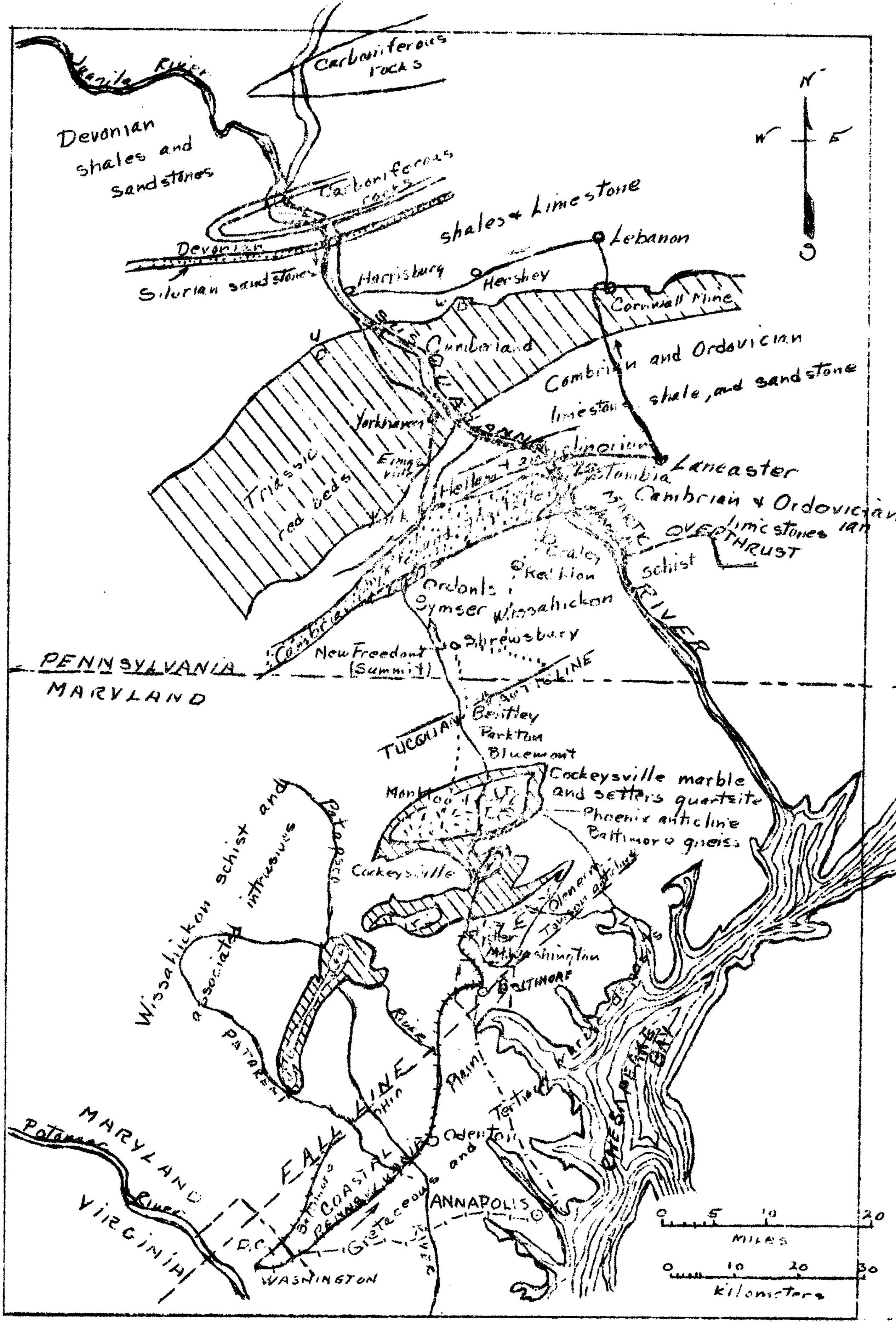
Near Baltimore leave the pre-Cambrian gneiss exposure and come upon the Coastal Plain.

In the higher land around Odenton, the overlying Raritan formation (basal formation of the Upper Cretaceous) of inter-bedded sand and clay, is crossed.

At Patuxent River - large rounded masses of pre-Cambrian gabbro are exposed in stream bed beneath the Cretaceous.

In the cuts -- R. R. Variegated clay. Patapsco formation (uppermost formation of Potomac Group).

Unconsolidated rocks at Lower Cretaceous age (Potomac Group).



U, D, Upthrown and downthrown sides of normal fault; T, over thrust side of Thrust fault; ⊥, strike and dip of bedding; ⊥, strike and dip of schistosity.

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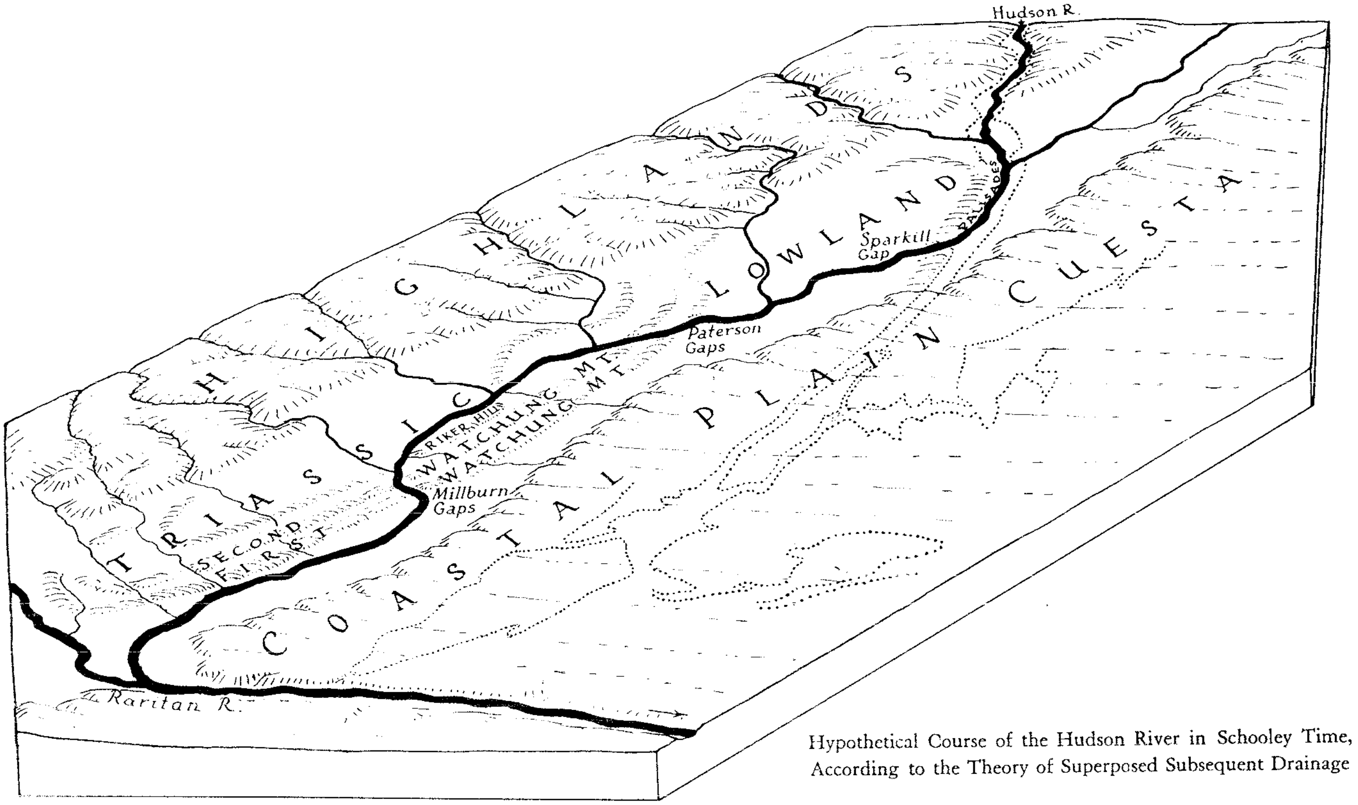
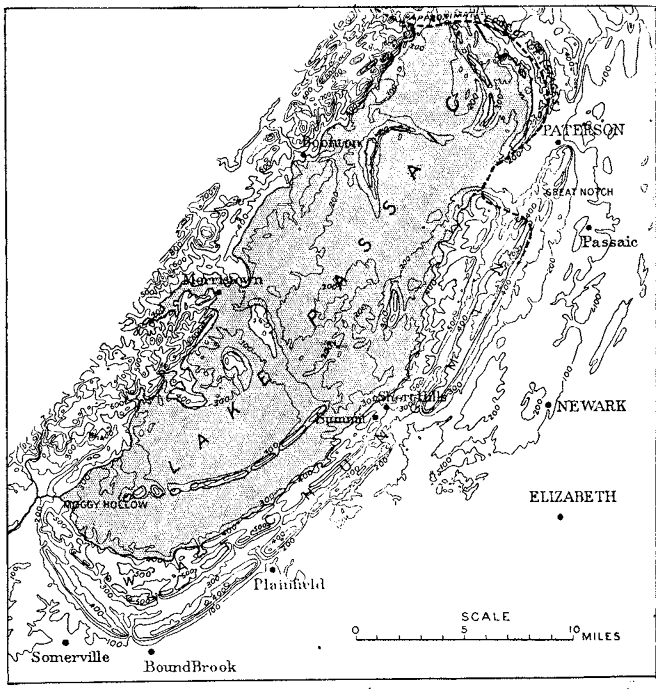
THE TRIASSIC LOWLAND



Hypothetical Course of the Hudson River in Schooley Time, According to the Theory of Superposed Subsequent Drainage

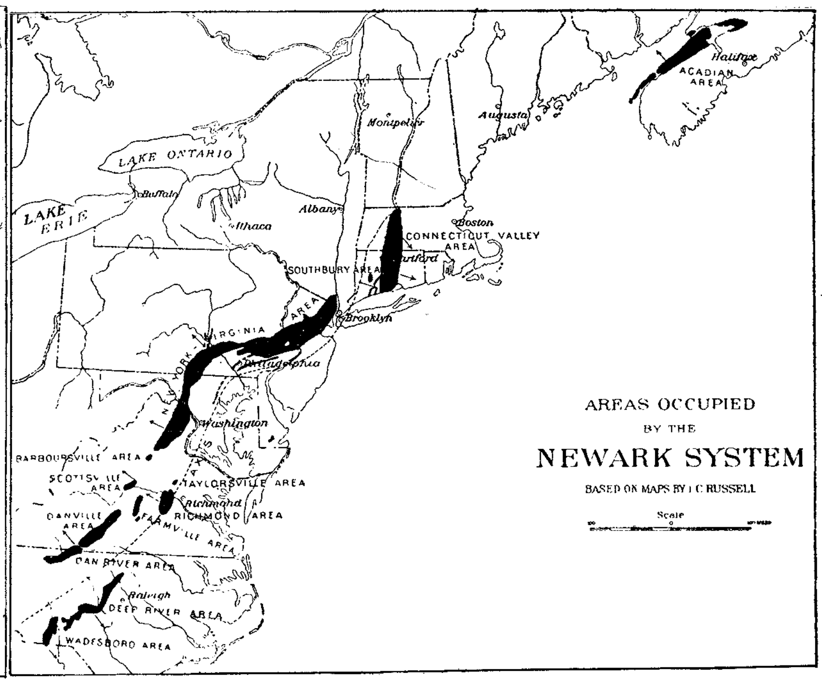
A. DIAGRAM TO ILLUSTRATE Professor Johnson's THEORY FOR THE ORIGIN OF THE GAPS IN THE WATCHUNG RIDGES. (Drawn by E. J. Raisz for Johnson: Atl. Slope)

1. Where is the Coastal Plain Cuesta at the present time?
2. Is the Triassic Lowland the same as the Inner Lowland? Explain.
3. Does this theory also explain the Hudson River Gorge through the Highlands?
4. What should be the relative depths of the different gaps if this theory is correct?



B. LAKE PASSAIC (U.S.G.S. Folio 157)

1. What caused Lake Passaic and why does it no longer exist?
2. Where was its outlet during its maximum stage? Why not through the gap at Short Hills?



C. THE TRIASSIC AREAS OF THE EASTERN U.S. (From Hobbs: Newark System, Bull. G.S.A. 13)

1. Do the Triassic rocks everywhere dip in the same direction? What is a possible explanation for this? Which one of these areas is known as the Triassic Lowland?

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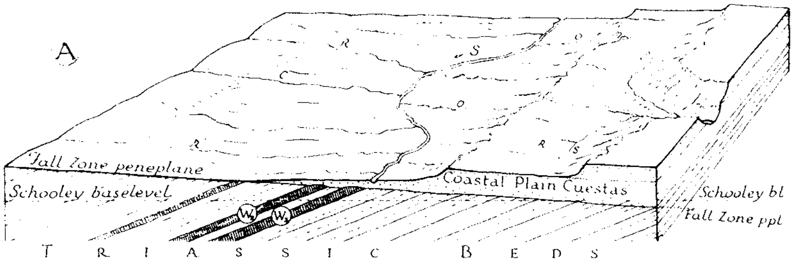
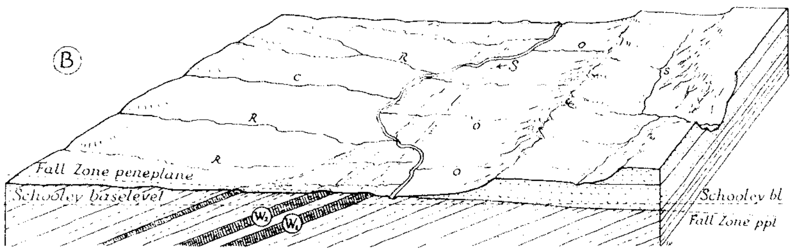
THE TRIASSIC LOWLAND

A

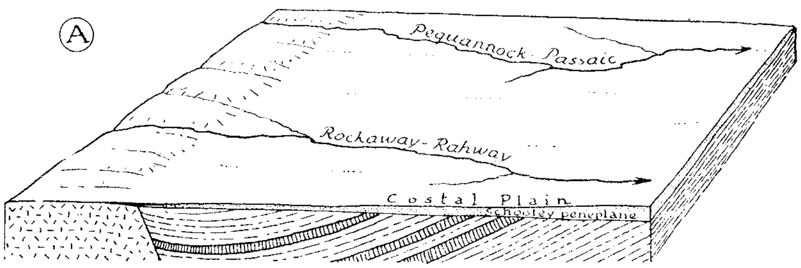


(B)

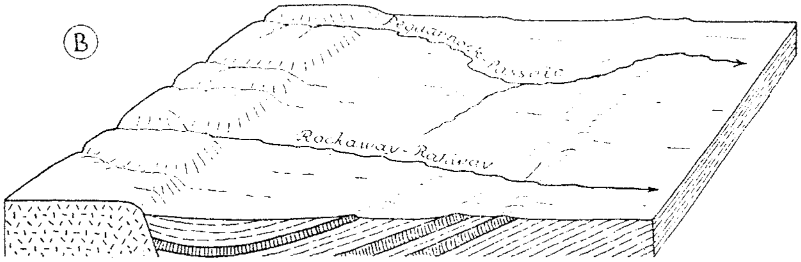


A. EXPLANATION OFFERED BY Prof. Johnson for the GAPS IN THE WATCHUNG RIDGES AT PATERSON AND MILLBURN. (Johnson: Atlantic Slope. Col. Univ. Pr.)
1. Label the two sets of gaps. (Paterson is at S.)
2. The letters stand for Consequent, Subsequent, Resequent and Obsequent.
3. If this explanation is correct which of these gaps would be deepest and which the shallowest?

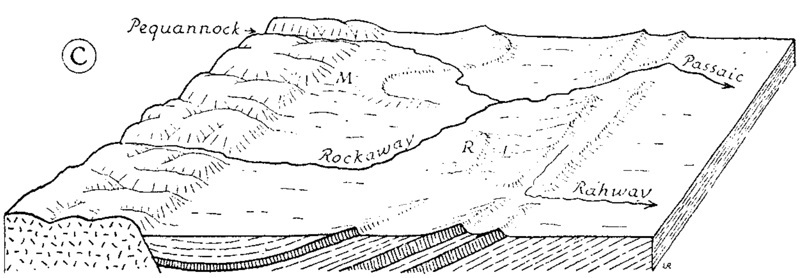
(A)

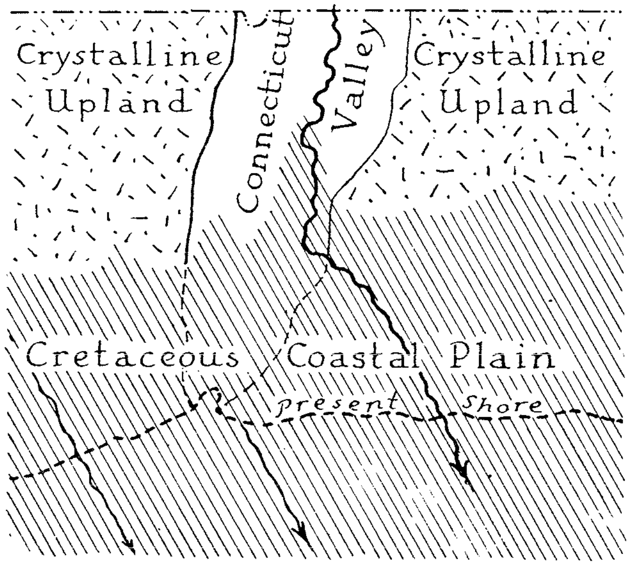


(B)



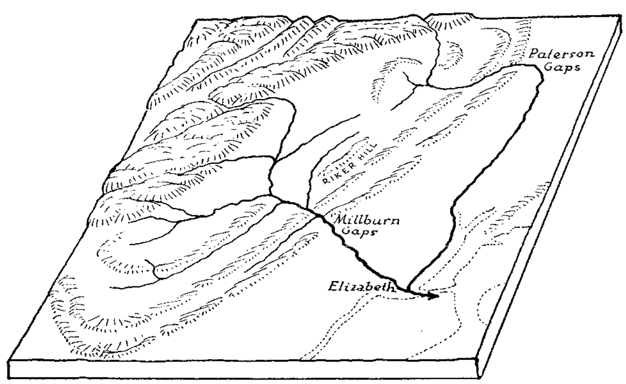
(C)





B. FORMER EXTENT OF THE COASTAL PLAIN IN CONNECTICUT. (Johnson)
1. What type of stream is the lower Connecticut? Is there any evidence that the coastal plain ever extended this far inland? How does this explain the Connecticut gorge? Label the gorge.

C. EXPLANATION OFFERED BY Professor Davis for the GAPS IN THE WATCHUNG RIDGES. (From Johnson: Atlantic Slope)
1. In what respect are Johnson's and Davis' explanations alike and in what respect different?
2. If Davis is correct what would be true about the relative depths of the different gaps? Why is it so difficult to determine which one of these explanations is correct?



D. MAP TO ILLUSTRATE THE THEORY ADVANCED BY Professor Salisbury.
1. Salisbury thought the Pre-glacial rivers were as shown above. If so, how did the ice sheet change the drainage? Where, for instance, is the Terminal Moraine?

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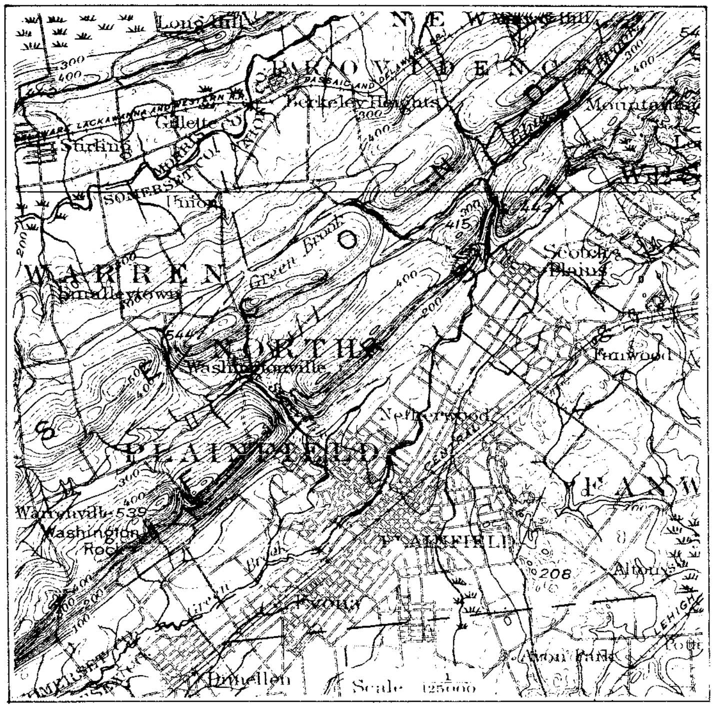
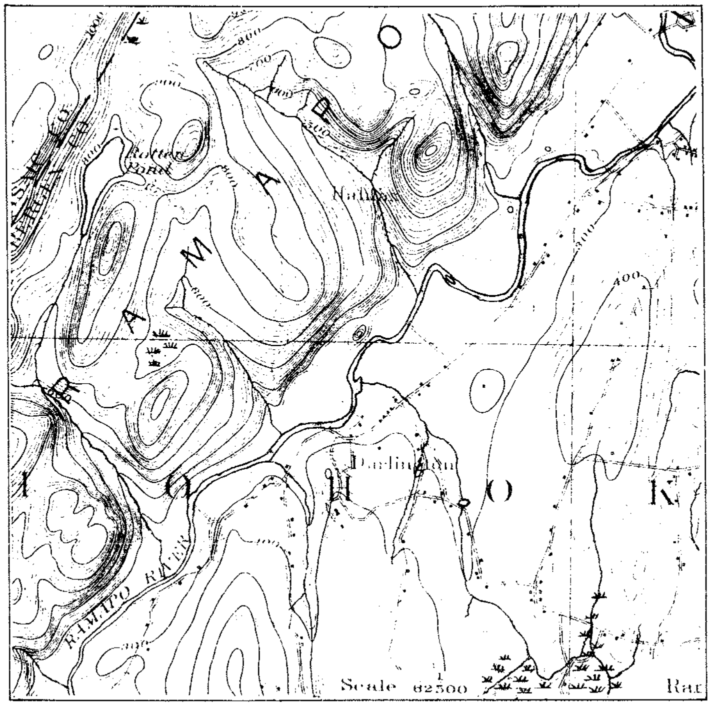
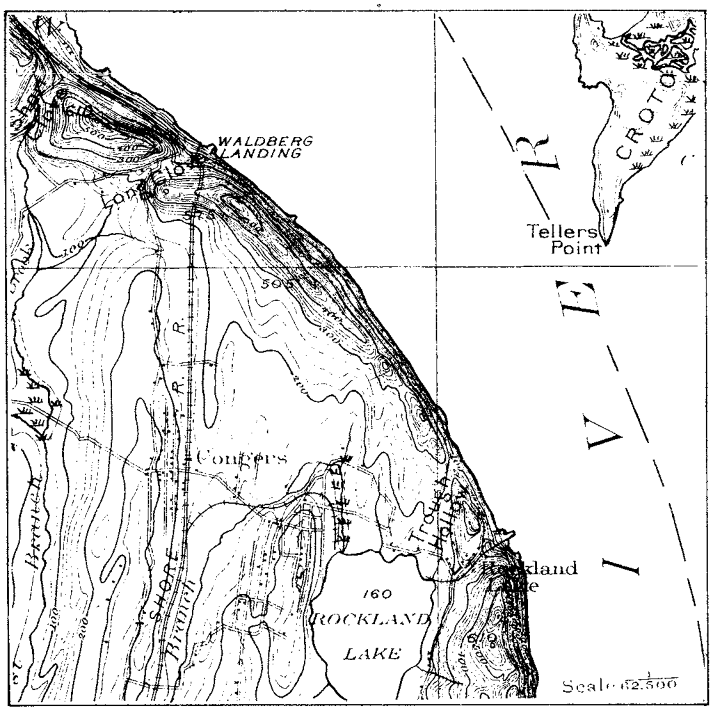
THE TRIASSIC LOWLAND



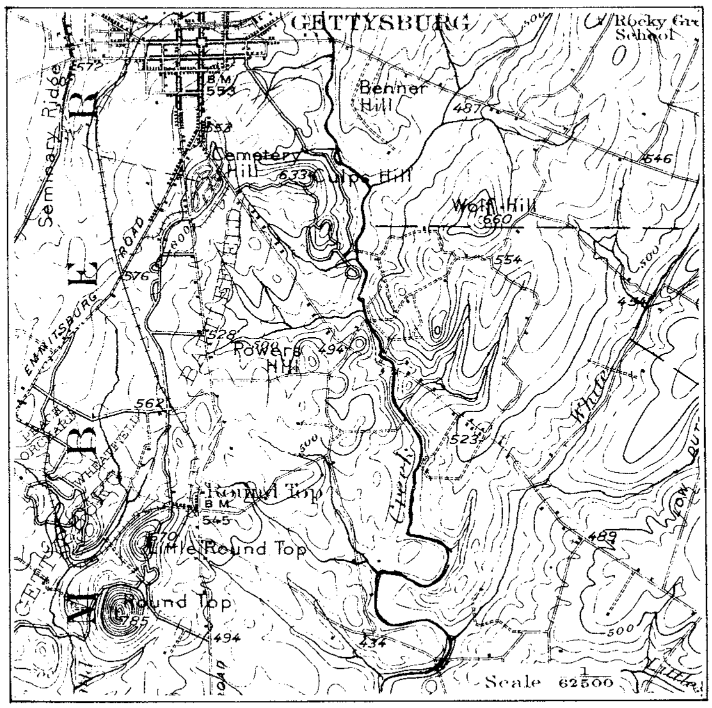
A. THE WATCHUNG RIDGES (Passaic, N. J. sheet)
1. In which direction do these formations dip?
2. Explain the belt of hills in the eastern part.
3. Account for the plain upon which Plainfield stands.
4. Color this map to distinguish sandstone and trap.



B. THE FAULT LINE SCARP ALONG WESTERN SIDE OF TRIASSIC LOWLAND (Ramapo, N.J. sheet)
1. Why is this called a "Fault Line" rather than a Fault scarp? What is the direction of strike of the Triassic beds? the direction of dip?



C. THE UPPER PALISADES (Tarrytown, N.Y. sheet)
1. What is the direction of strike of the Triassic beds back of the Palisades? Account for the fact that the Palisades cuts across them.
2. What is Croton Point across the river?



D. THE GETTYSBURG BATTLEFIELD showing hills of diabase rising above Triassic Lowland.
1. What is the direction of strike of the Triassic rocks in this region? their dip? Are these hills volcanic necks? (Gettysburg, Pa, sheet)

THE ATLANTIC COASTAL PLAIN

I. Lowlands.
   A. Ages - Cretaceous and Tertiary
   B. Character of strata - dip gently seaward
   C. Types of material
      1. soft sands, silts and clays
      2. derived from - clay, sand and gravel deposits
   D. Physiographic features
      1. represent work of streams born upon plains newly uplifted from sea.
      2. reflect the general attitude of the lowland.

II. The Fall Line - the dividing line between the lowlands, or coastal plain area, and the Piedmont Plateau.

III. The Piedmont Plateau
   A. Materials - residual soils underlain by crystalline rocks.
   B. Position - north-easterly to south-westerly direction, a few miles (varying) inland from the Atlantic shore-line.
   C. Physiographic feature - stream courses flow in narrow gorges with cataracts and rapids.

IV. New Jersey-Maryland Section
   A. Character
      1. Surface resembles gently undulating sea floor, broad and even.
      2. Coasts are great peninsulas formed by drowning of major valleys.
      3. Waterways discharge through reedy swamps, or shore inlets into land-locked bays.

V. The Chesapeake and Delaware Bays.
   A. Secondary reentrants fronted by small banks and bars.
   B. Low cliffs formed at ends of finger-like extensions of land between bays.
      1. Formerly stood at higher level, and faintly sculptured by draining streams.
      2. Later, depression submerged the lower ends of valleys, where bays now exist.
      3. Bays preserve characteristic dendritic plan of Coastal Plain drainage.
      4. Though submergence affects a large extent of Coastal Plain, actual amount of depression slight.
      5. Often, miles to shore from a given point in bay greater than number of feet to bottom of bay. (average - 10 feet, though sometimes as high as 18 feet).

VI. The Southern Portion (Maryland)
   A. Characteristics
      1. Outer shore - long, narrow reefs, caused by shore drift and wave action.
      2. Inward - shallow lagoons of variable widths (fraction of a mile to four or five miles).
         a. Eastern portion formed by shallow marshes along the western edge of sand reef.
         b. West shore, by half submerged topography of mainland.
         c. Floods of lagoons very shallow, flat, and composed of:
            1) sand blown over from beach dunes
            2) mud deposited by rivers and tides
            3) matted roots of marine vegetation

VII. Eastern Maryland
   A. Surface
      1. Broad and even
      2. Resembles gently undulating sea floor.

B. Long interstream stretches of plane surface of considerable breadth.
C. Inequalities of outer border produced during submergence. (Pleistocene)
  1. Streams and lakes not drained.
    a. Plain raised so recently above sea.
    b. Plain raised to very small height.
  2. Swamps disposed chiefly along main divides (as though dissection had not yet progressed to headward sections of streams).

VIII. Following is a diagram showing the formations and erosion intervals which go to make up the Atlantic Coastal Plain in the vicinity of Washington, D. C. :

Formations and erosion intervals	Nature of formations and of erosion intervals	
Post Columbian	Alluvium (mainly below tide) marsh, talus and debris on slopes	Rec.Pleistocene
Erosion interval	Disection of later Columbian terraces and development of present topography	" Later Pleistocene
Later Columb.	Gravels and loams on lower terraces: maximum thickness - 25 feet.	Early Pleistocene
Erosion interval	Trenching of earlier Columbia terraces.	"
Earlier Columb.	gravels and loams on high terraces; thickness 20 feet.	"
Erosion interval	Trenching of Layfayette plain; development of present topography	"
Layfayette	Gravels, sands, and loams on extensive plain; thickness 20-30 feet.	Pliocene (?)
Erosion Interval	Widespread and relatively complete planing on Coastal Plain and Piedmont region.	Pliocene
Chesapeake	Fine buff sands, clays, and diatomaceous deposits. Thickness 0-80 feet.	Miocene
Erosion interval	Planing of surface of preceding formations	Eocene
Pamunkey	Glauconitic sands and marls; thickness 0-120 feet	Early Eocene
Erosion interval	Planing of surface of preceding formations	Later Cretaceous
Monmouth	Brown sands; thickness, 0-25 feet	" "2
Matawan	Black Argillaceous carbonaceous sands - thickness 2-30 feet.	" "
Erosion interval	Planing of surface of preceding formations with deposition of Magothy formation to the northeast	Middle Cretaceous
Potomac	clays and sands, thickness 0-650 feet	Early Cretaceous
Great erosion interval		

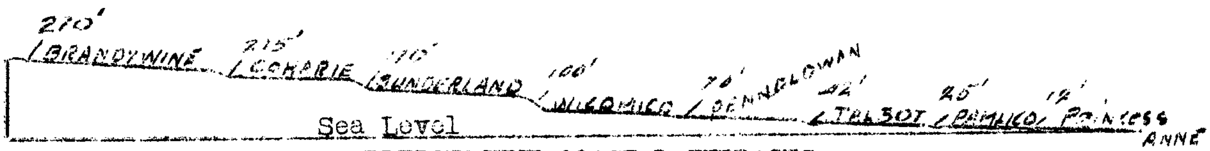
Material for this report was taken from Bowman's Forest Physiography, and Folio #70, Geologic Atlas of the United States.

Frances Atkinson

The valleys now occupied by Chesapeake Bay, the Potomac River and probably also the Patuxent River appear to have been formed during late Tertiary time, when the land in the vicinity stood considerably higher than now. At the end of Pliocene time a tilting or warping of the continent submerged the Coastal Plain of the Middle and North Atlantic States beneath the sea and slightly raised the Coastal Plain in the Southeastern States. The valleys in the north were deeply drowned well into the Piedmont, but the streams in the south extended their courses across the newly emerged part of the continental shelf. The mouths of even these southern streams are slightly drowned now, but this drowning is much more recent and seems to be due to a world wide rise of sea level.

In spite of this late Pleistocene or recent rise of sea level, the coast of Maryland is now much less deeply drowned than it was at the beginning of the Pleistocene for the sea appears to have stood then about 272 feet higher than the present level. That is indicated by a series of scarps, supposed to mark an ancient shore line, which level across the tilted Pliocene surface at that altitude.

Between the 270 foot shore line and the present beach there are seven other shore lines, also horizontal, which indicate successively lower stages of the sea. There is good evidence that the retreat of the sea from the highest to the present did not take place by simple intermittent lowering from one level to the next but that it occurred by repeated oscillations from high to low and part way back. These fluctuations of sea level have been attributed to alternating accumulation and melting of the continental ice sheets during glacial and interglacial stages, but part of the lowering may have been due to crustal movements beneath distant oceans, for it is hardly likely that the existing ice caps contain enough water to raise the sea to its former height of 270 feet if they were completely melted.



PLEISTOCENE COASTAL TERRACES.

Each of these shore lines marks the landward limit of a terrace. The shore lines of the Pleistocene terraces of the eastern United States are horizontal and stand approximately at the following altitudes above mean sea level.

Brandywine terrace	270 feet	(Soldier's Home)
Coharie Terrace	215 "	
Sunderland terrace	170 "	
Wicomico terrace	100 "	(Above Penna. Avenue)
Penholoway terrace	70 "	
Talbot terrace	42 "	(Lincoln Memorial)
Pamlico terrace	25 "	
Princess Anne terrace	12 "	

In southern Maryland the terraces below the Sunderland are entirely estuarine. They form comparatively narrow fringes along the shores of the Potomac, Patuxent and Patapsco Rivers, Chesapeake Bay and their tributaries. The Sunderland terrace originally occupied more than half of southern Maryland, but it is now greatly dissected. While it was being formed the seashore seems to have lain 10 or 12 miles west of the present shore of Chesapeake Bay (all of the land east of the Bay was submerged).

The Coastal Plain, of which Maryland forms a part, has never been subjected to violent movements of the earth. The deposits of which it is composed retain very nearly their original position, although those older then the Pleistocene have been very gently tilted or warped. The regional dip is southeastward, toward the Atlantic Ocean. The dip rarely exceeds 40 feet to the mile and at most places in southern Maryland it is much less.