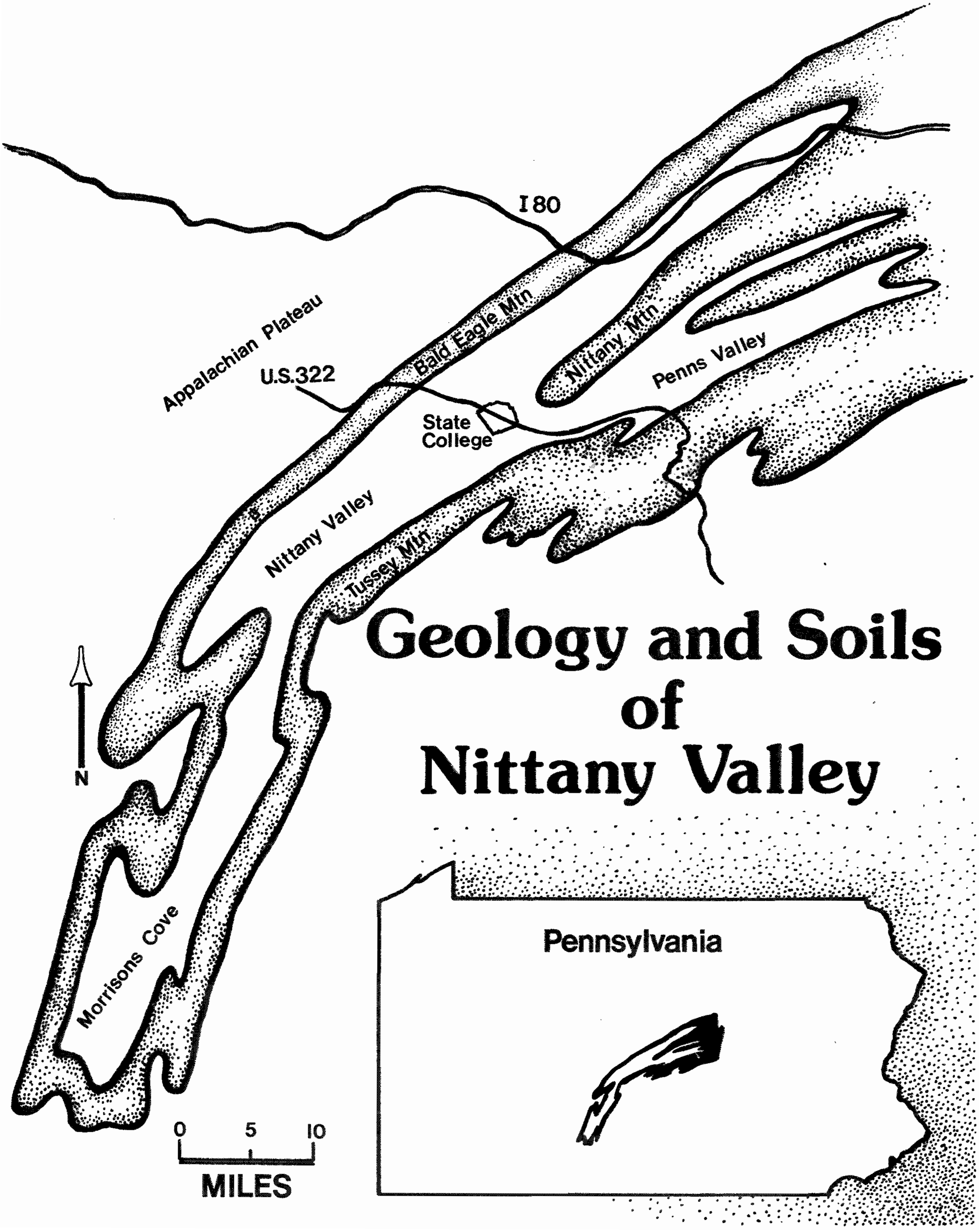
Edward J. Ciolkosz



Geology and Soils of Nittany Valley

Geology and Soils of Nittany Valley

by

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CONTENTS

CHAPTER 1

Introduction

Nittany Valley is located in central Pennsylvania (see illustration on the cover). In Pennsylvania it is the first Northwestern valley of the Ridge and Valley Physiographic Providence (see Fig. 2.1, 2.2, and 2.3). It is also with the exception of the Great Valley (see Fig. 2.3), the largest valley in the Ridge and Valley area of the Eastern United States. The valley starts just south of Lock Haven and extends southwestward for 75 miles to a point east of Altoona (Fenneman, 1938). The valley varies from 1 or 2 to 10 miles in width. Penns Valley and Brush Valley are extensions to the northeast. To the southwest, Nittany Valley splits on Brush Mountain east of Altoona with the southwestern fork extending and ending in Sinking Valley and the southeast fork merging with Morrisons cove south of Hollidaysburg. If Morrisons cove is included as an extension of Nittany Valley, the valley extends for 90 miles.

The following chapters summarize some of the geology and soils information about Nittany Valley. The presence of The Pennsylvania State University in State College in the central part of Nittany Valley and the expertise and willingness of the University's faculty has contributed greatly to the development of this presentation. The comments and data presented in the following chapters are centered on the central part of Nittany Valley.

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CHAPTER 2

Geologic and Geomorphic Evolution of Pennsylvania

The general form of the surface of the United States is the result of dynamic processes of crustal rising and erosion or the wearing down of the crustal material. The form of the earth's surface at any one time can be organized into earthform or physiographic regions. Fig. 2.1-A and 2.1-B give the physiographic regions of the United States. Fig. 2.2 and Fig. 2.3 give more detailed information on the landforms and physiographic provinces of Pennsylvania.

In order to understand the present landforms of Pennsylvania, a look at the geologic past is necessary. In Pennsylvania, the bulk of the geologic record started in the Paleozoic (Table 2.1). Although the Precambrian preceded the Paleozoic, very little is known of it in Pennsylvania and only a small area of Precambrian rocks are exposed in the southeastern part of the state (Fig. 2.4). At the beginning of the Paleozoic, the land sea relations were similar to that of today (Fig. 2.5-B and 2.8-A), following the splitting of the North American plate from the African plate in the late Precambrian time (Fig. 2.5-A). In the middle Ordovician, the Taconic Orogeny (period of mountain building) occurred when the proto-Atlantic began to close and a land mass called Appalachia was formed with a geosynclinal basin between Appalachia and the continental land mass (Fig 2.5-C and 2.8-B). During the Devonian, the proto-Atlantic continued to close and the Acadian Orogeny occurred (Fig. 2.5-D and 2.8-C). During the Paleozoic, various types of sediments accumulated in the geosyncline. Of particular interest were the sandy and gravelly deposits which formed what would later be called the ridge forming formations of Pennsylvania (Bald Eagle, Tuscarora, Pocono, and Pottsville--Table 2.1). During the middle and late Paleozoic sea level and land level in the geosyncline were at about the same elevation and much of Pennsylvania was a broad coastal plain sometimes slightly above and sometimes slightly below sea level. During this period, organic deposits accumulated in swamps which were buried and later transformed into the coal measures of Pennsylvania.

At the end of the Paleozoic, the proto-Atlantic closed completely as Africa smashed into North America (Fig. 2.5-E and 2.6-2). The collision called the Appalachian or Allegheny Orogeny forced the sediments in the geosyncline to be folded and in some places to be overturned. The crustal shortening during the folding was in the order of 15-60 miles. At the time of folding, 5,000 feet of sediments had accumulated in the geosyncline at the Pennsylvania-Ohio line, while in the State College area, 20,000 feet had accumulated, and in the Harrisburg area, > 30,000 feet had accumulated. The pressure was exerted from the southeast and its effect decreased to the north and west. To the north of Williamsport and west of Altoona, the effect of the folding was minimal, causing only some gentle folds in the sediments. It is believed that the folding of the sediments took place in a few million years. This is a realistic estimate in light of present day rates of deformation of 1-5 feet/100 years. From reconstructions of the folds of these mountains, it has been estimated that some of the mountains were > 20,000 feet high.

When the pressure from the southeast was released in the Triassic time by splitting of the welded North American and African plates (Fig. 2.5-F), large areas collapsed and formed elongated troughs parallel to the new coastal line (Fig. 2.11). Into these troughs washed sediments from the newly raised Appalachian Mountains (Fig. 2.12). In the latter part of the Triassic, dark colored basic rock (basalt composition) was intruded into the sediments that had accumulated in the trough areas.

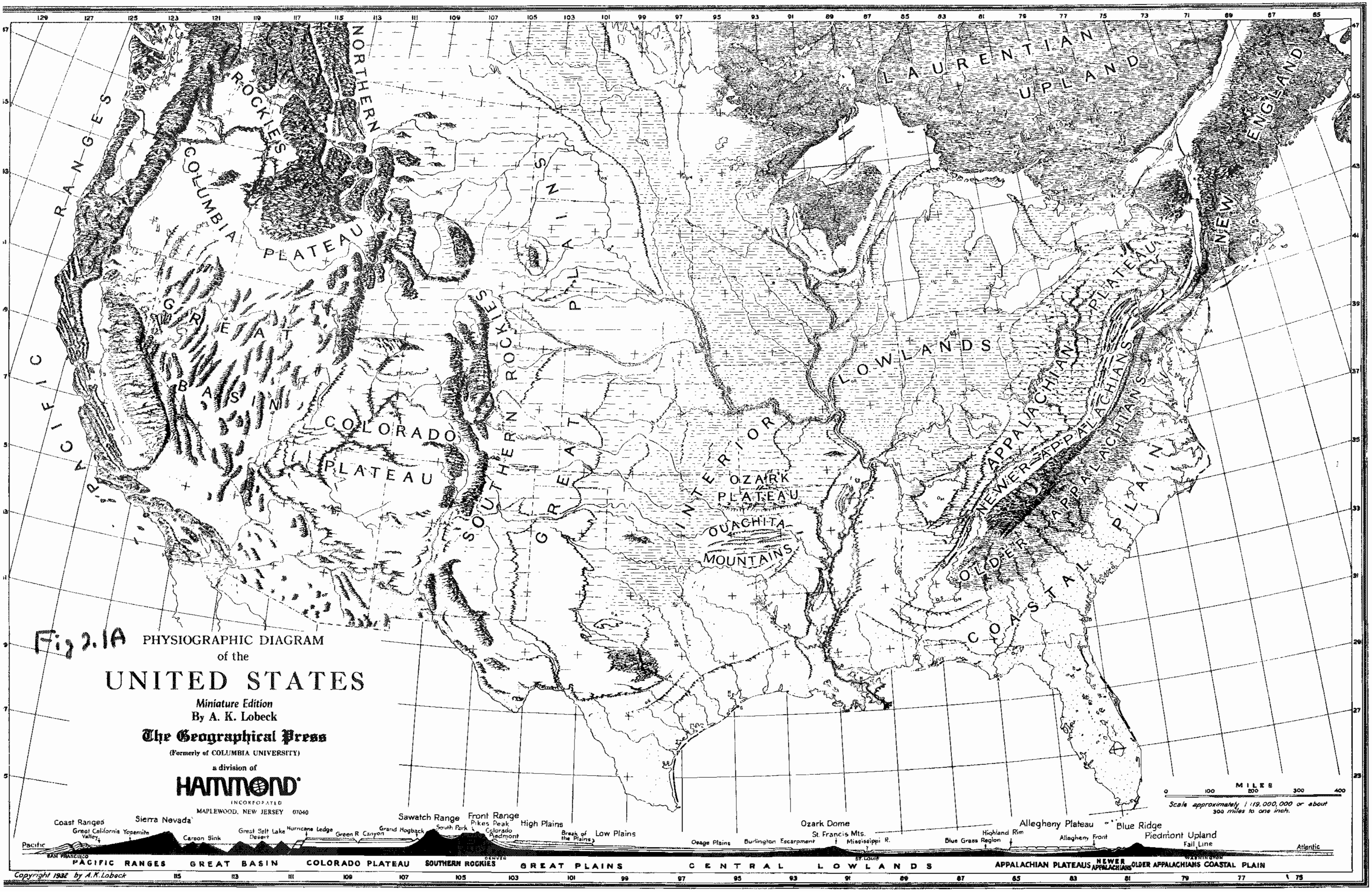
Post Triassic time was a time of erosion, during which the Appalachians and Pennsylvania were reduced to a low rolling plain near base level (a level which streams cannot erode any lower) (Table 2.1; Fig. 2.6-3, 2.6-4, and 2.7-B). This erosional surface has been named the Schooley Peneplain. In the late Tertiary about 10-20 million years, a broad upward warping started, centered somewhat North-South through Altoona and State College. The streams which previously had kept the land surface worn down to a near level plain began to deepen their channels (Fig. 2.6-5). As up-lift and channel sinking continued, the belts of the softer rocks (limestones and shales) were etched out into valleys leaving the more resistant rocks (sandstones and quartzites) as ridges (Fig.2.6-6 and 2.7-C). The main streams kept their courses down the slopes of the rising land cutting deep notches, across the harder standstone strata. The uplift of the Schooley was about 1000-3000 feet and is represented today by the numerous accordant ridge crests in the ridge and valley area, the top of the Allegheny Front and parts of the Allegheny Plateau region.

The uplift of the Schooley stagnated and an erosional surface called the Harrisburg Peneplain (Fig. 2.4-6 and 2.7-C) developed on the softer rock (limestone and shales), but it did not attain the advanced stage of development, as the Schooley because before the sandstones ridges could be beveled another uplift occurred. The uplift of the Harrisburg surface occurred about 1 million years ago (early Pleistocene) and did not exceed a few hundred feet and another erosion surface was initiated called the Somerville Peneplain (Fig. 2.6-7 and 2.7-D). Before very extensive removal could occur, the Somerville surface was uplifted and the streams began down cutting as we see them today (Fig. 2.6-8 and 2.7-D). In most central valleys, the Somerville and present cycle appear to be coincident.

The post Triassic geomorphic explanation given above is the classical approach which has been challenged by many since its development by William Morris Davis and his followers. In a recent discussion of the geomorphology of Pennsylvania presented by Sevon (1985), the dynamic equilibrium approach of Hack (1960) was followed. The basic premise of Hack is that erosion is in an equilibrium with the varying rock lithologies, and the landscape does not go through cycles of uplift, and planation. Using this approach, Sevon (1985) states that the landscape we see today in Pennsylvania has not changed greatly in the last 50 million years.

The last major geological event that occurred in Pennsylvania was glaciation. It is believed that ice advanced a total of 4 times during the Pleistocene. The glacial ice directly affected the northeast and northwest areas of Pennsylvania (Fig. 2.13 and 2.14). Although this is the case, climatic changes associated with the glacial advances greatly affected landscape stability by creating permafrost conditions across the state. These conditions triggered solifluction mass movement downslope and resulted in the accumulation of large masses of colluvium on the footslope areas of the Ridge and Valley area as well as in other parts of the state (Ciolkosz et al., 1979). Recent work indicates that there were two and possibly more major colluvial episodes in Pennsylvania (Hoover, 1983.)

Fig 2.1A



PHYSIOGRAPHIC DIAGRAM
of the
UNITED STATES

Miniature Edition
By A. K. Lobeck

The Geographical Press
(Formerly of COLUMBIA UNIVERSITY)
a division of
HAMMOND
INCORPORATED
MAPLEWOOD, NEW JERSEY 07040

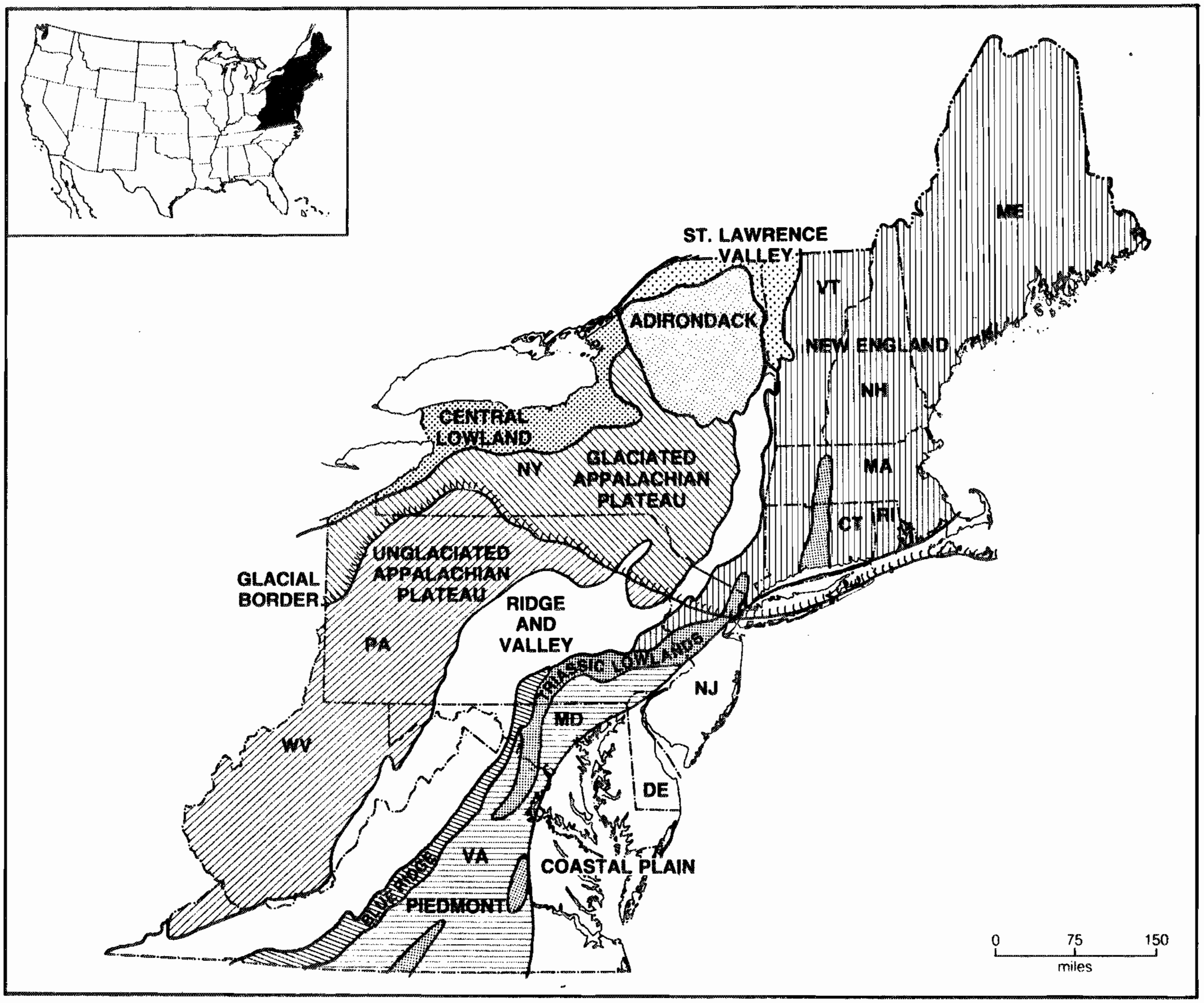
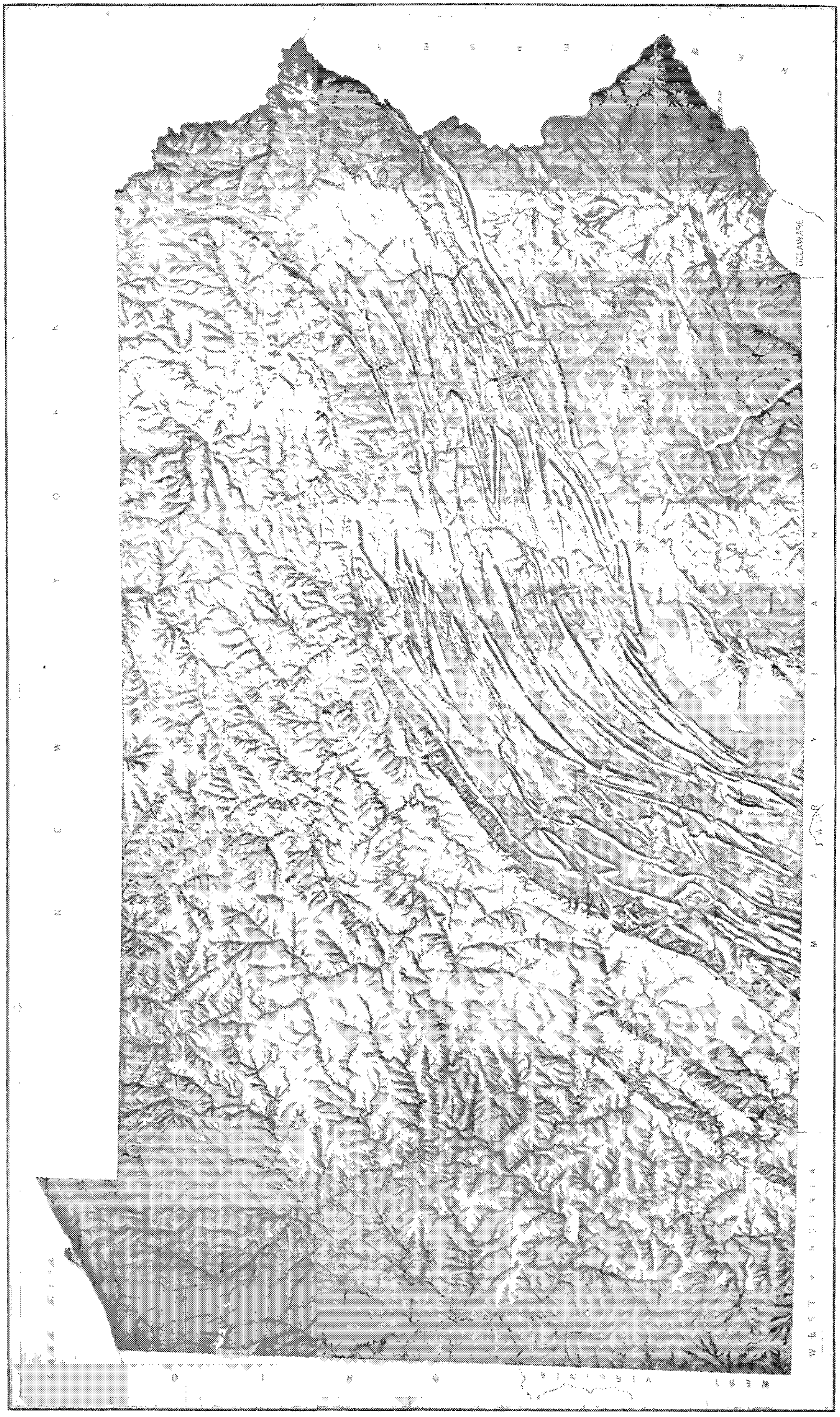


Fig. 2.1-B. Physiographic provinces of the northeastern United States.

NEW YORK
NEW JERSEY
DELAWARE
MARYLAND
WEST VIRGINIA
OHIO
LAKE ERIE

MAP 13

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, *State Geologist*

Fig 2.3 PHYSIOGRAPHIC PROVINCES OF PENNSYLVANIA

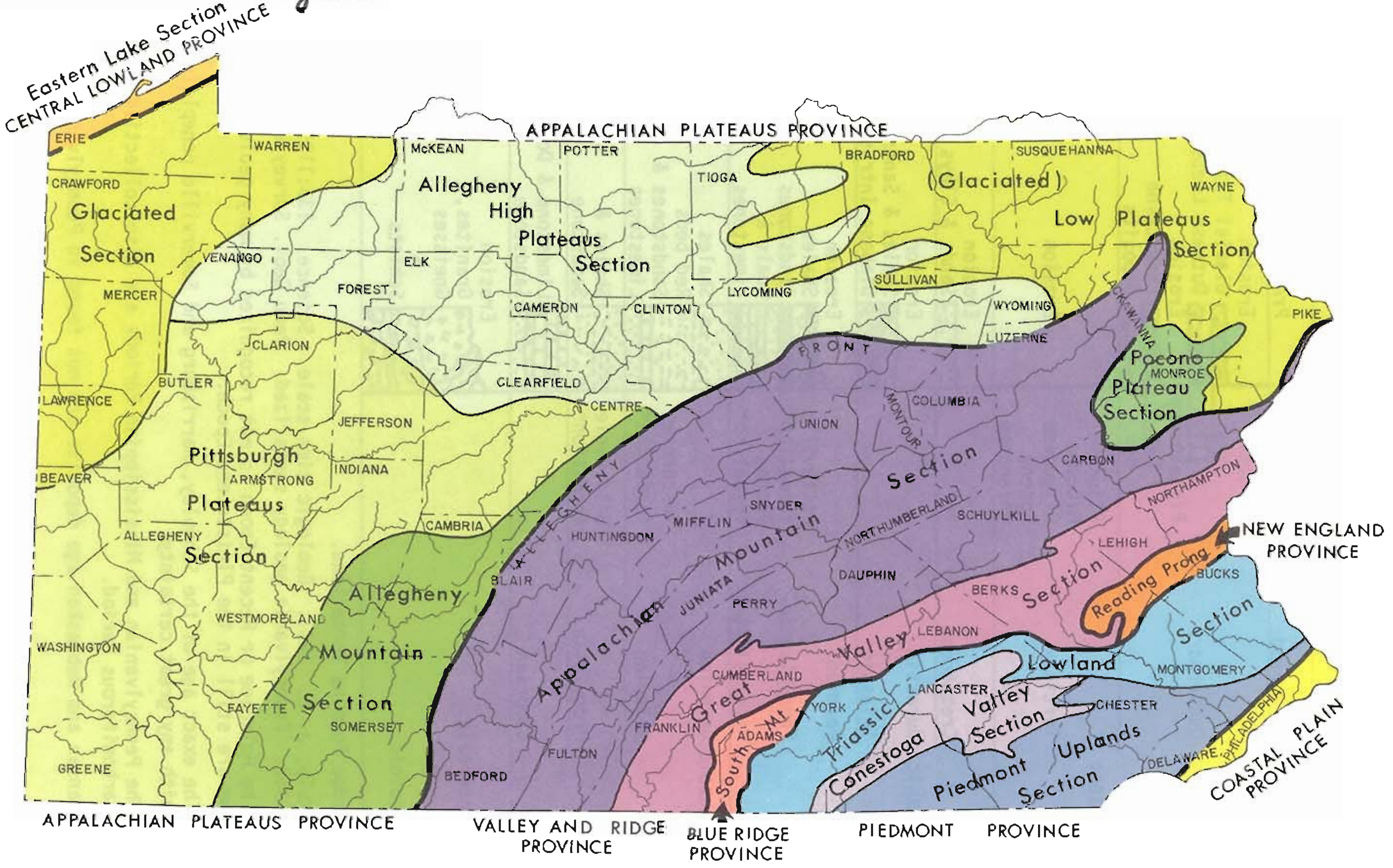
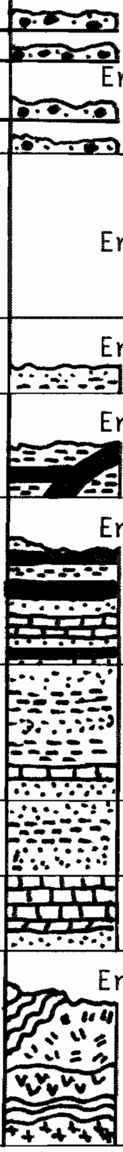


Table 2.1. Geologic time scale of Pennsylvania.[1]



Era	Period	Epoch	Predominant Rocks		Beginning of Interval in Year
		Holocene[2]	Erosion		10,000
		Wis.	Glacial Till		
	Quaternary	Ill.	Outwash Loess &		
		Pleistocene	Erosion		
		Kan.[5]	Lacustrine	Somerville	
		Neb.	Deposits	Peneplain	1 Million
Cenozoic		Pliocene		Harrisburg	13 Million
		Miocene		Peneplain	25 Million
	Tertiary	Oligocene	Erosion	Schooley	36 Million
		Eocene		Peneplain[3]	58 Million
		Paleocene			63 Million
			Erosion		
	Cretaceous		Sands & Clays		135 Million
Mesozoic	Jurassic		Erosion		181 Million
			Shales & Sandstone		
	Triassic		Diabase Intrusions		230 Million
	Permian		Erosion	Appalachian or Allegheny Orogeny	280 Million
		Pottsville	Shales		
	Pennsylvania[4]	formation*	Sandstones		310 Million
		Pocono	Coals &		
	Mississippian	formation*	Limestones		345 Million
Paleozoic	Devonian		Shales	Acadian	405 Million
			Red beds	Orogeny	
		Tuscarora	Sandstones &		
	Silurian	formation*	Limestones		425 Million
		Bald Eagle	Shales &	Taconic	
	Ordovician	formation*	Sandstone	Orogeny	500 Million
			Limestone & Dolomite		
	Cambrian		Sandstone		600 Million
Precambrian			Erosion		
Prototerozic			Granites,	Grenville	2 Billion
			Gneisses	Orogeny	
			&		
Archeozoic			Schists		4¼-5 Billion

*Ridge Forming formations.

[1] Kulp, J. L. 1961. Geologic time scale. Science. 133:1105-1115; Bradford, B. 1962. Pennsylvania geology summarized. Penn Geol. Survey Ed. Series 4. 17p.

[2] The Holocene or Recent Epoch is not recognized by many geologists who believe we are still in the Pleistocene Epoch.

[3] The exact age of the Schooley, Harrisburg and Somerville peneplains is not known with any great certainty.

[4] The Pennsylvanian and Mississippian Periods are also collectively known as the Carboniferous Period.

[5] Kansan and Nebraskan age deposits are not found in Pennsylvania at the surface.

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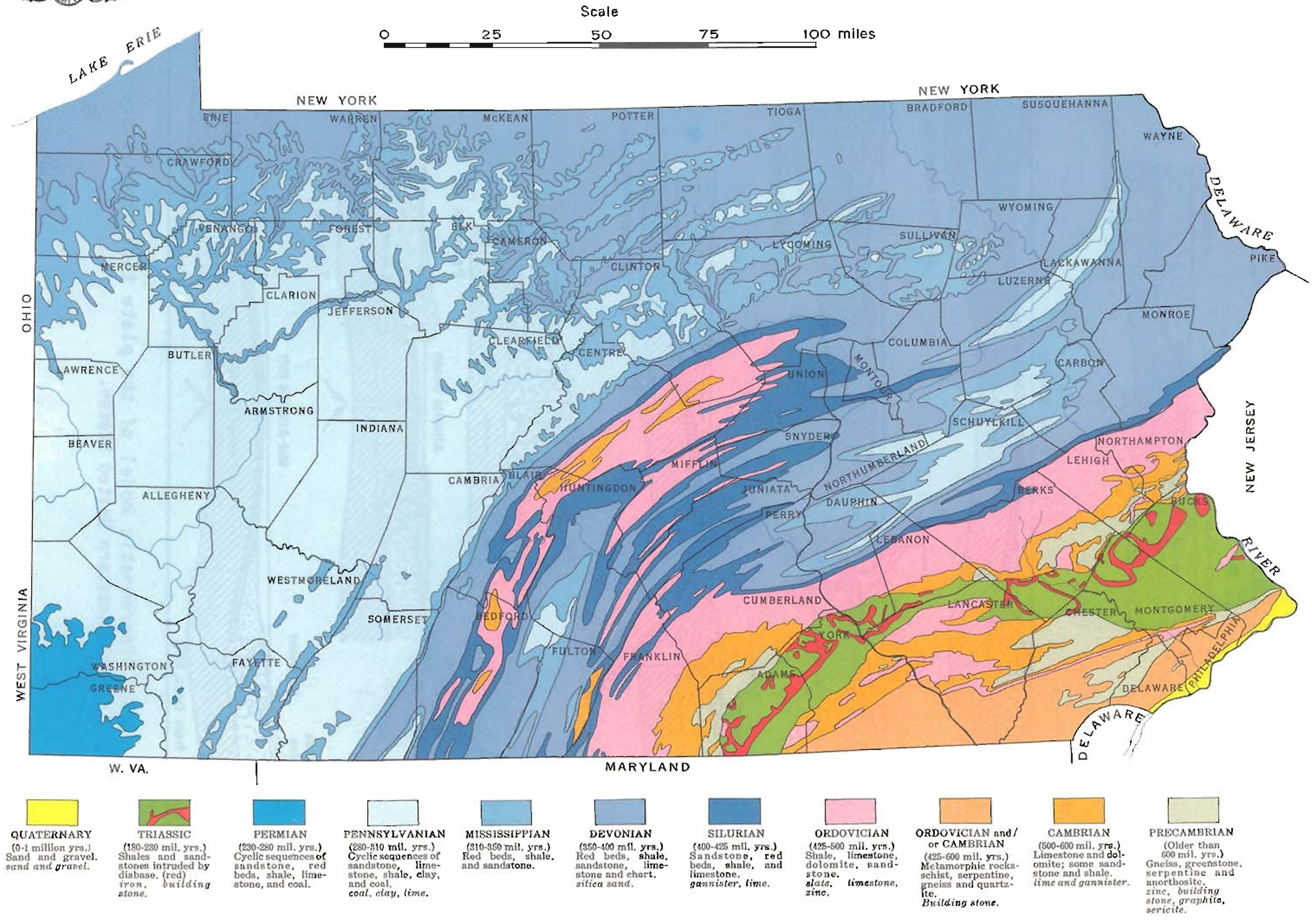
Fig. 24. GEOLOGIC MAP OF PENNSYLVANIA



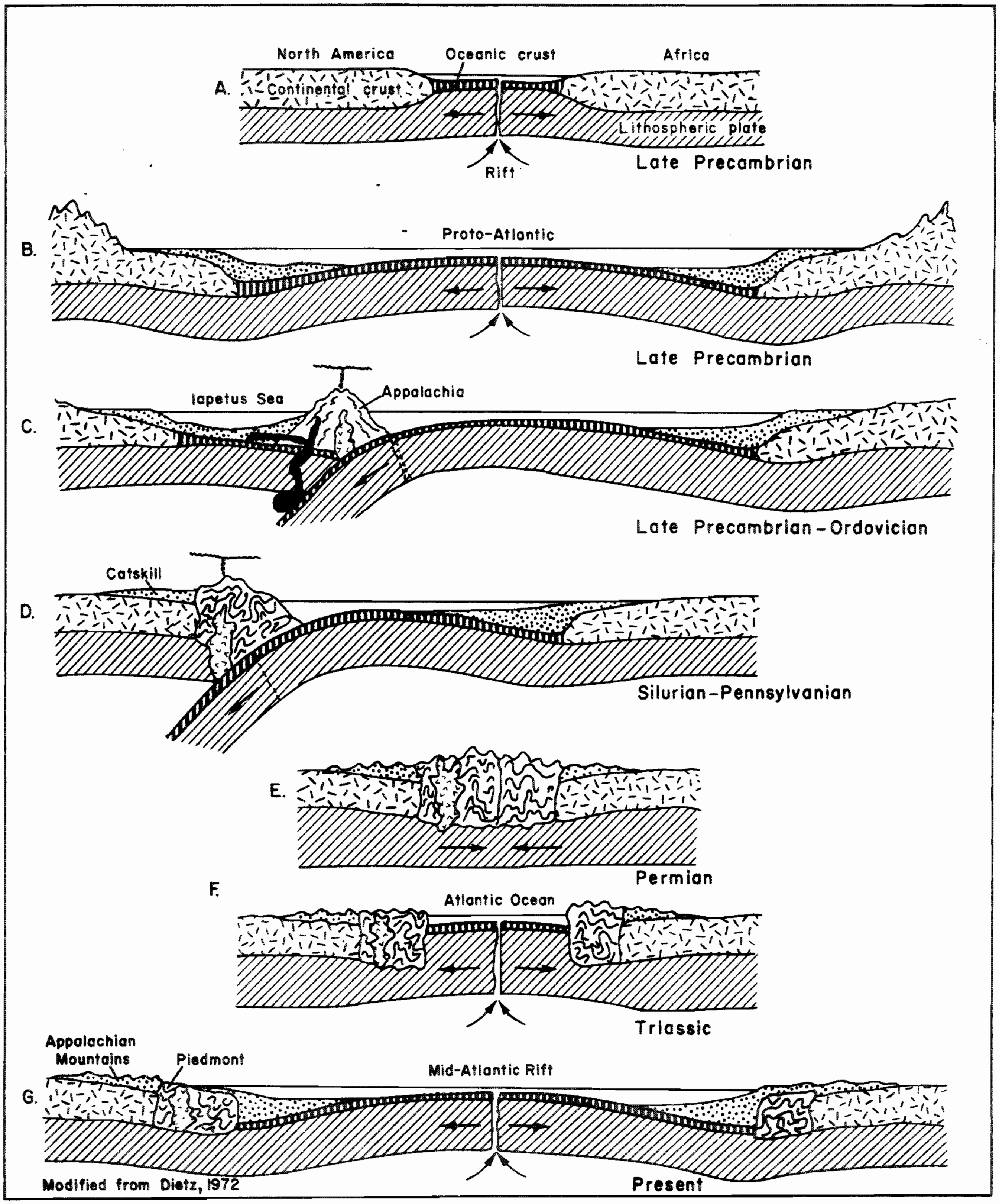


Fig. 2.5. Diagrammatic model of the plate tectonic history of the northeastern United States.

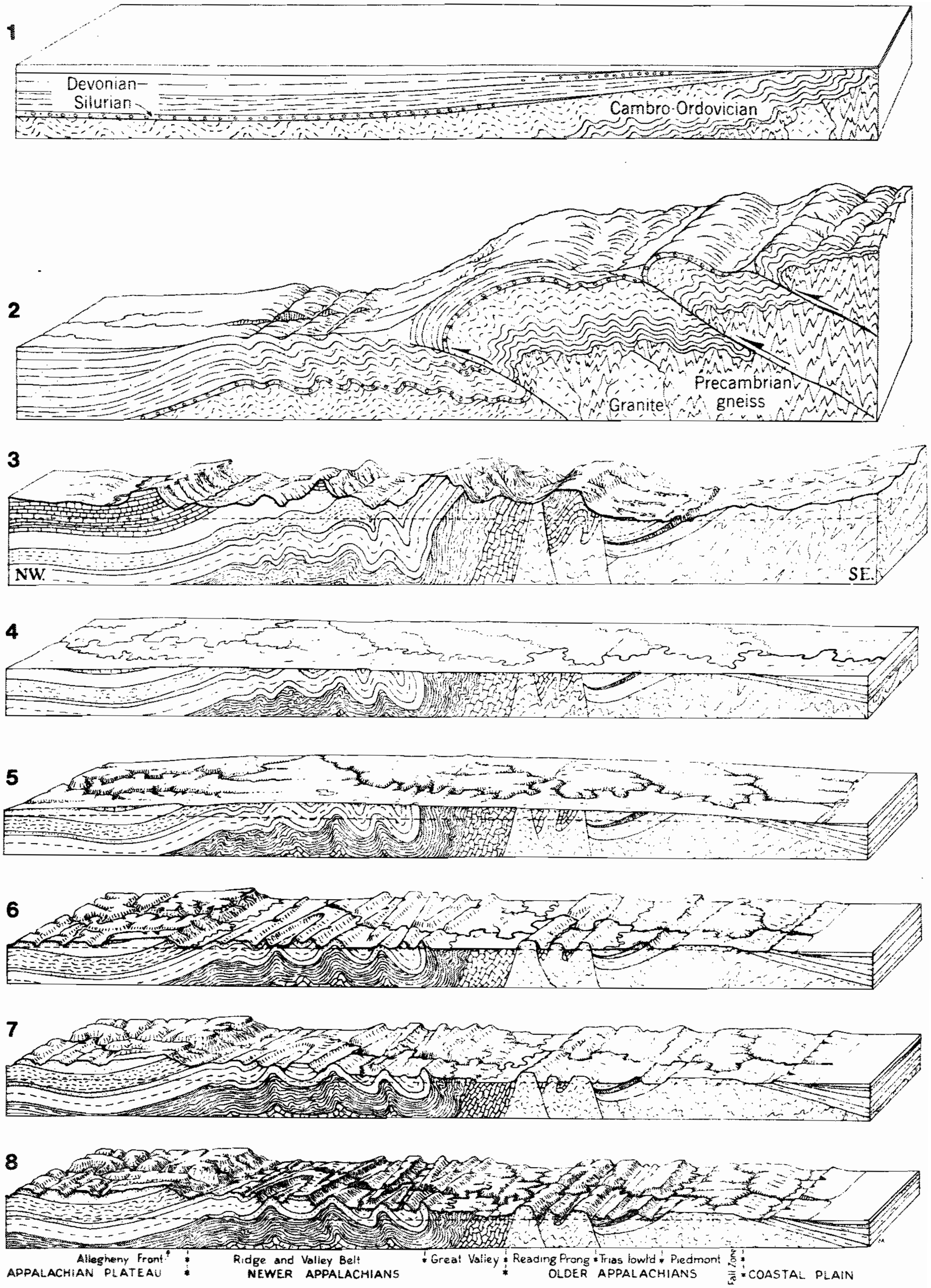


Fig. 2.6.

Physiographic evolution of the Appalachian Mountains: 1) Sediments accumulated in the Appalachian geosycline, 2) Folding of the sediments, 3) Erosion of the folded mountains, 4) Schooley peneplain formed, truncating older folded rocks of the Appalachians and Cretaceous formations of the coastal plain, 5) Arching of the Schooley peneplain, 6) Dissection of the Schooley peneplain and development of the Harrisburg erosion surface, 7) Uplift and dissection of the Harrisburg erosion surface and development of the Somerville erosion surface on the belts of weakest rocks, 8) Uplift and dissection of the Somerville erosion surface, producing the present conditions. (From D. W. Johnson, Stream Sculpture on the Atlantic Slope, Columbia Univ. Press, New York, 1931.)

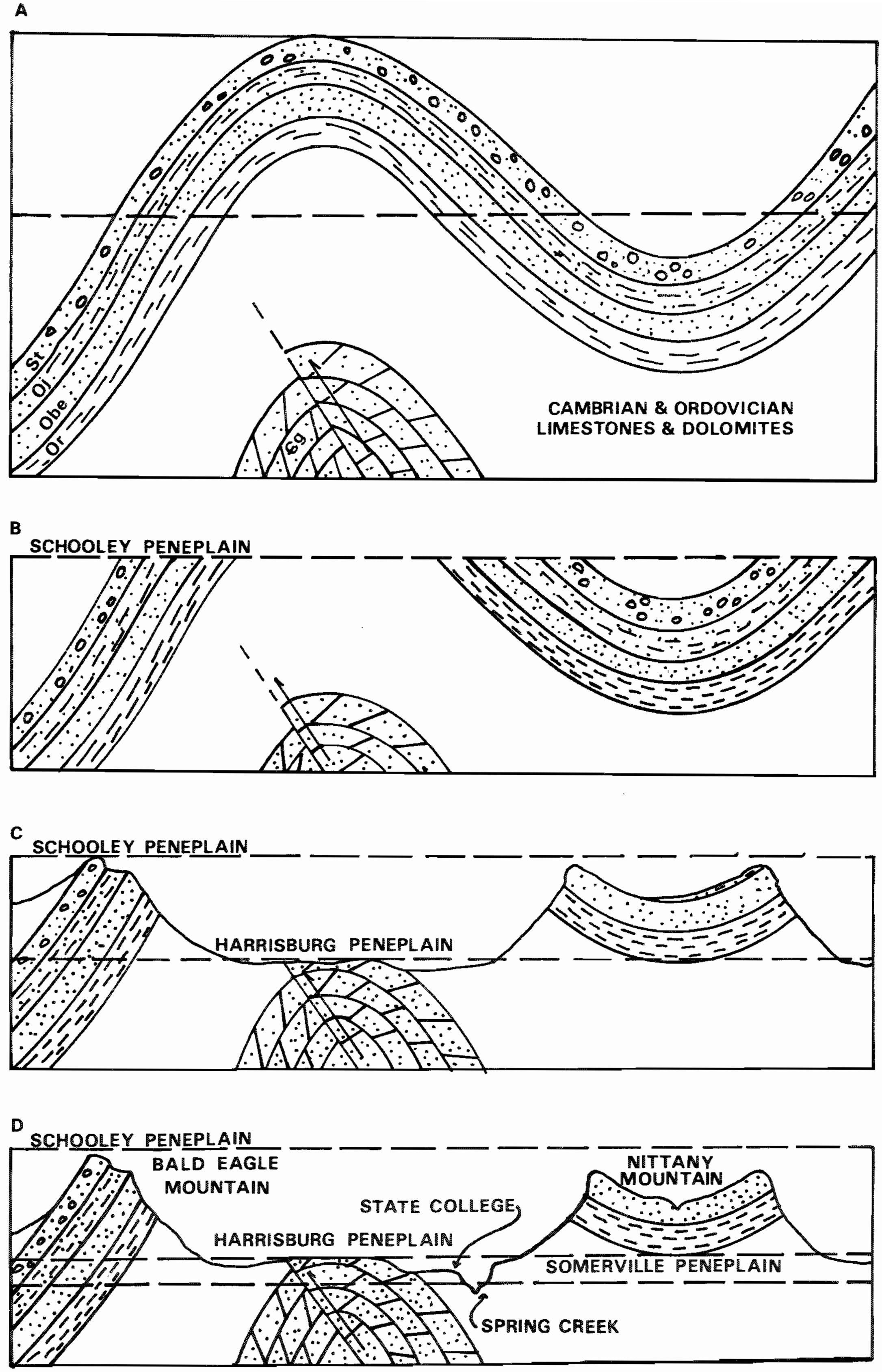


Fig. 2.7. Evolution of peneplain surfaces in the Nittany Valley area.

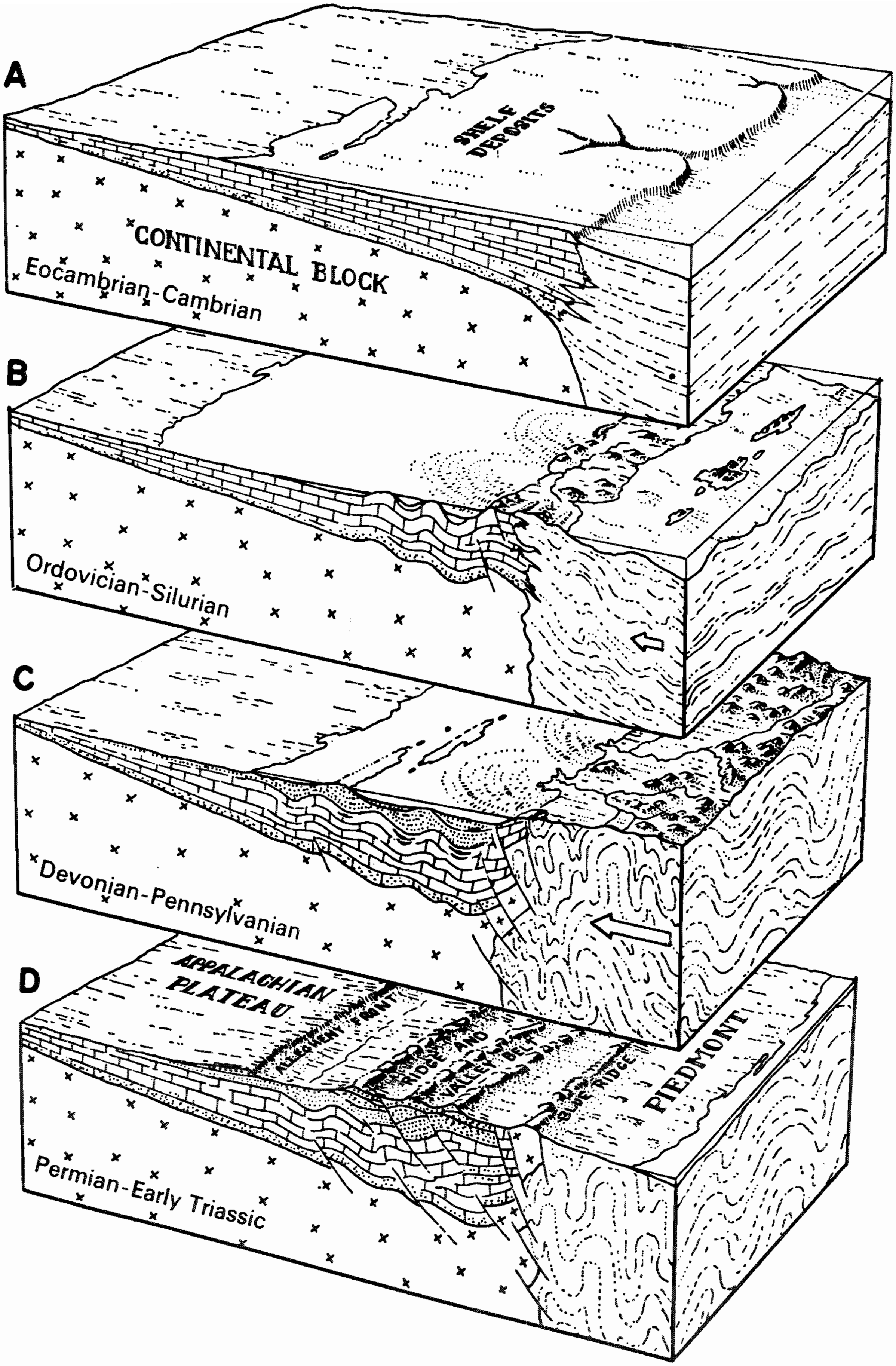
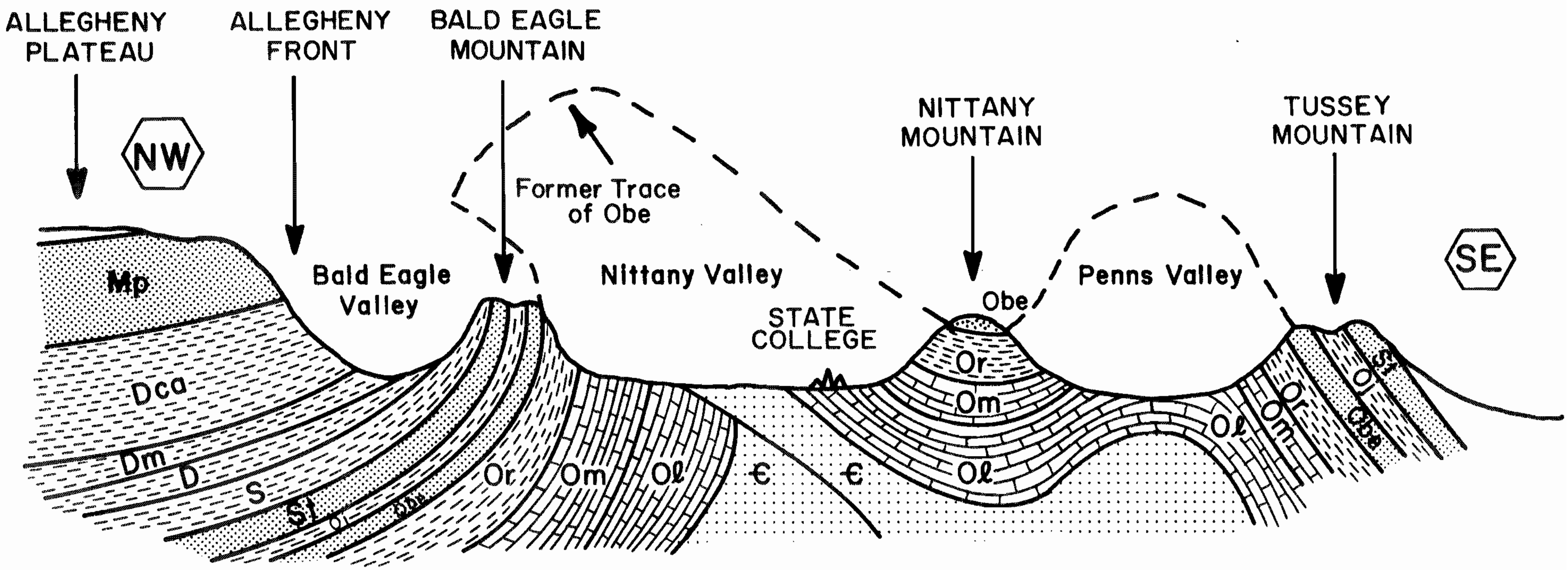


Fig. 2.8. Digrammatic evolution of the Appalachians.



Mp - Mississipian; Pocono - gray, hard sandstone with some shale.

Dck - Devonian; Catskill - red to brownish shales and sandstones

Dm - Devonian; Marine beds - gray to olive brown shales and sandstones

Dℓ - Devonian; Lower - sandstones, shales and limestones

S - Silurian; Upper and Middle - limestone, shales, and sandstones

St - Silurian; Tuscarora - white to grey sandstone.

Oj - Ordovician; Juniata - red sandstone and shale.

Obe - Ordovician; Bald Eagle - greenish gray sandstone.

Or - Ordovician; Reedsville - dark gray, olive weathering shale.

Om - Ordovician; Middle - gray limestone and dolomitic limestone

Oℓ - Ordovician; Lower - gray dolomite and limestone

Ꞓ - Cambria; Gatesburg - bluish gray dolomite and sandstone

▨ - Ridge forming sandstones - Tuscarora, Bald Eagle and Pocono

Fig. 2.9. Geologic cross-section at State College, Pennsylvania

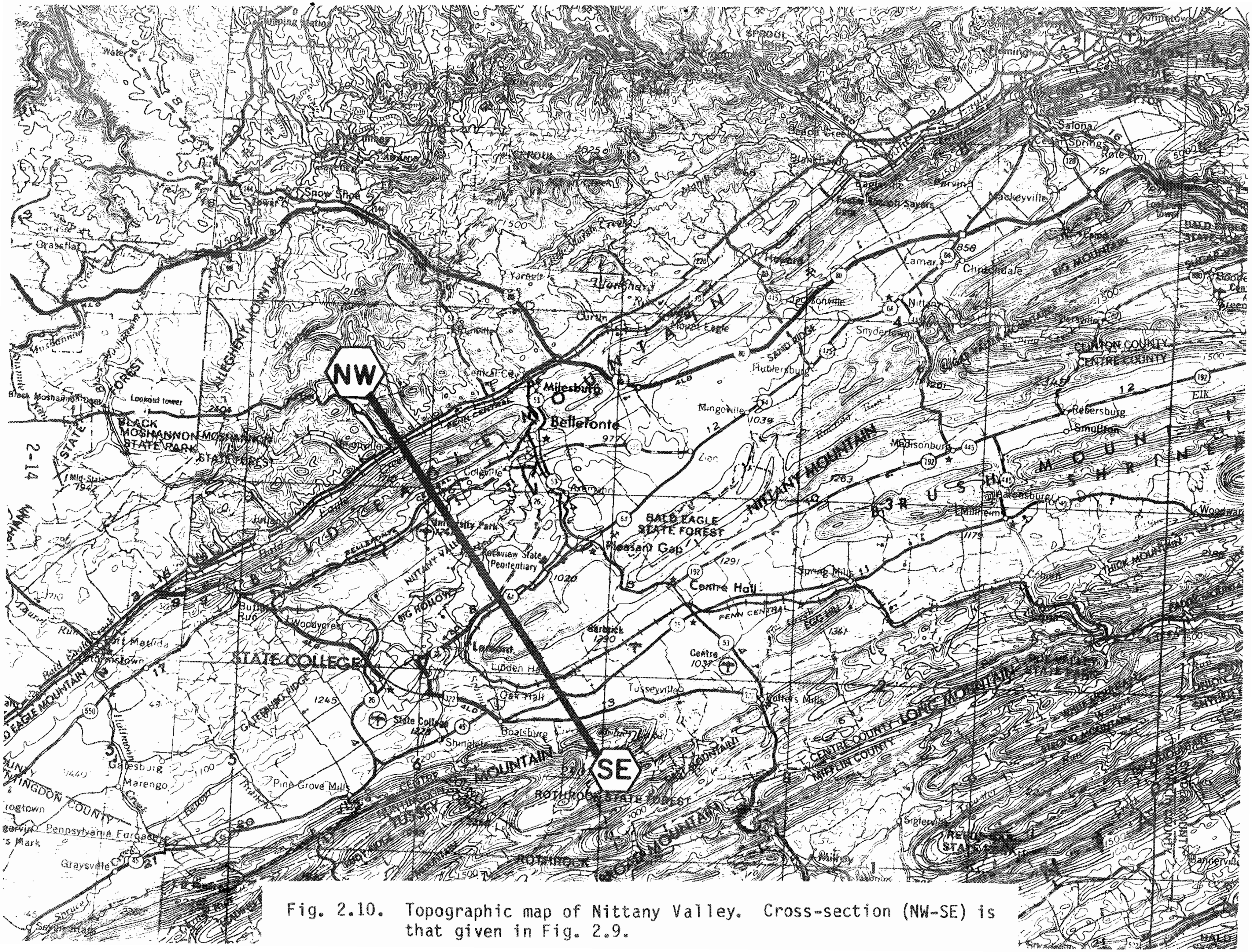


Fig. 2.10. Topographic map of Nittany Valley. Cross-section (NW-SE) is that given in Fig. 2.9.

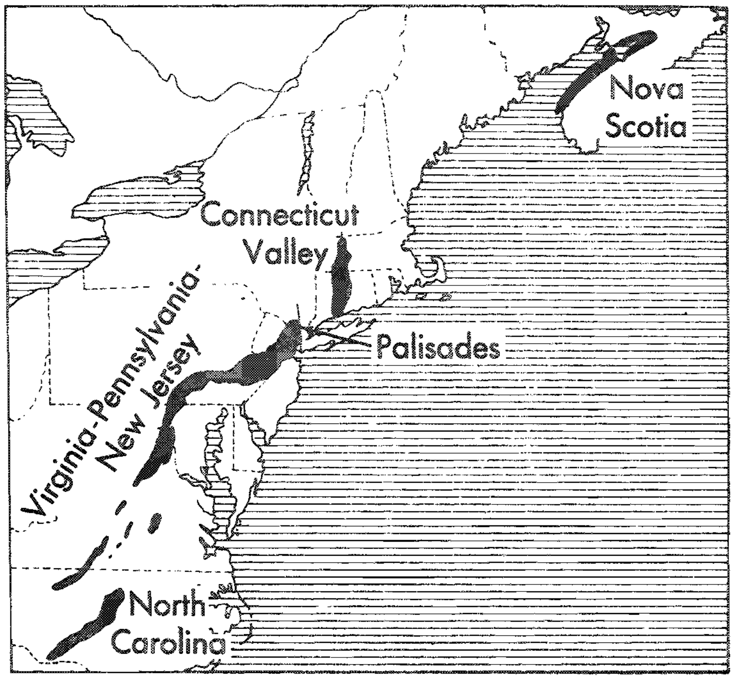


Fig. 2.11. Triassic basins of the Northeastern United States.

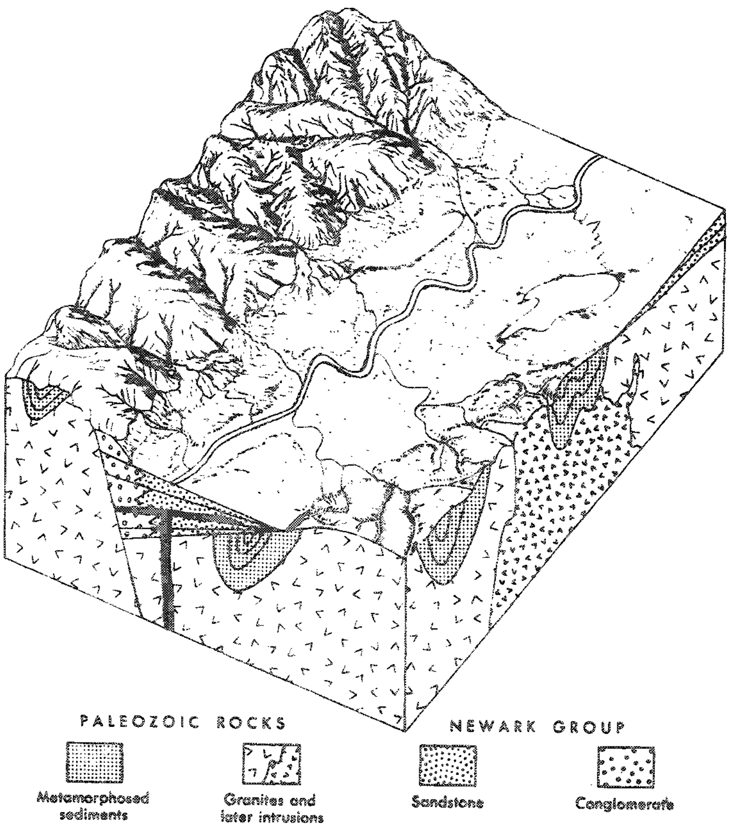


Fig. 2.12. Block diagram of typical Triassic basin of the eastern United States

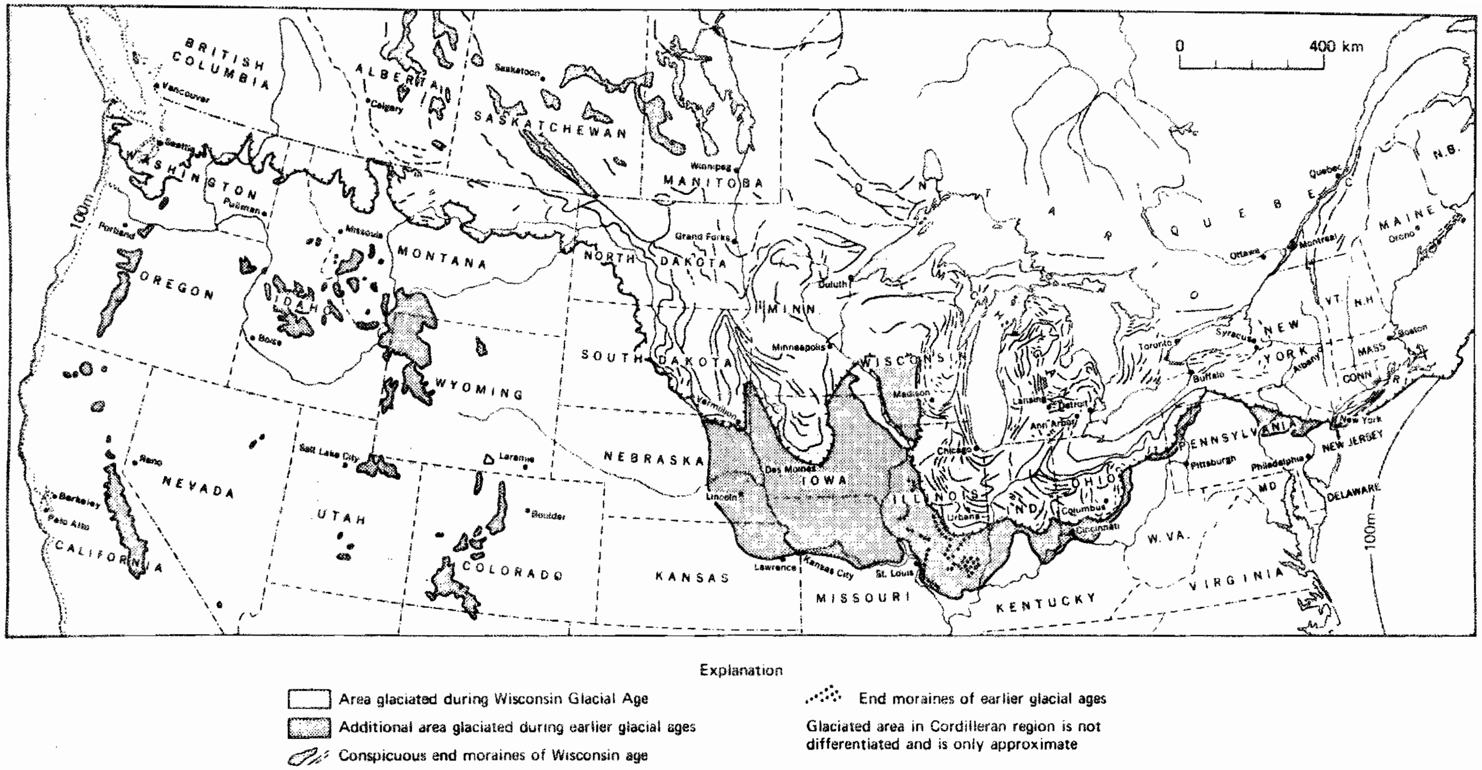


Fig. 2.13. Extent of glaciation in northern United States and southern Canada, showing lobation induced by configuration of the terrain beneath the ice. At maximum extent of glaciers, shoreline may have stood near -100 m isobath (from Flint, 1971, p. 490).

MAP 59

Fig 2.14

GLACIAL DEPOSITS OF PENNSYLVANIA

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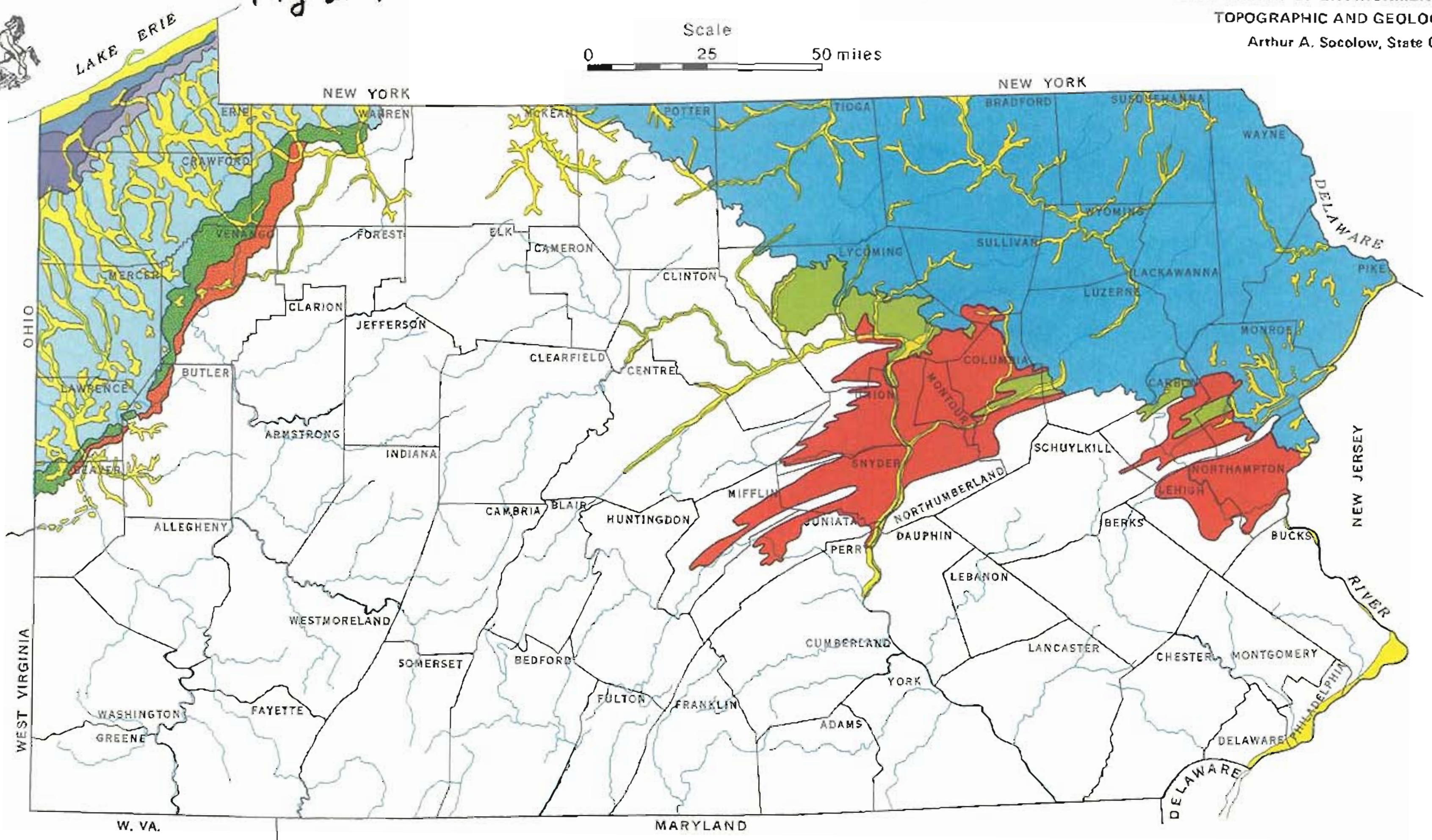

EXPLANATION

The heavy line on the southern part of a colored area represents the limit of that glacial advance. Within these areas, the tills occur as discontinuous deposits. The approximate percentage of each area that is actually covered by till is stated in the descriptions below.

RECENT TO ILLINOIAN
(0-550,000 yrs.)

🟨 STRATIFIED DRIFT

Sand and gravel in eskers, kames, kame terraces, and outwash, principally in valleys; silt and clay in lake deposits in formerly ice-dammed valleys; lake clays and beach sands and gravels along Lake Erie; thin (Recent) to thick (Illinoian) soils.

WISCONSINAN
Woodfordian
(12,500-22,000 yrs.)

🟦 ASHTABULA TILL
🟪 HIRAM TILL
⬜ LAVERY TILL
🟦 KENT TILL

Thick, gray, clayey to silty to sandy till covering over 75 percent of the ground; topography is mainly gently undulating, but there is also some knob-and-kettle topography; thin soil.

🟦 OLEAN TILL

Moderately thick, gray to grayish-red, sandy till covering 25 to 50 percent of the ground; very thin till covers an additional 25 percent of the ground; topography reflects the underlying bedrock; thin soil.

WISCONSINAN
Altonian
(28,000-75,000 yrs.)

🟩 TITUSVILLE TILL
🟩 WARRENSVILLE TILL

Thin, gray (Titusville) to grayish-red (Warrensville), clayey to sandy till covering 10 to 25 percent of the ground; topography reflects the underlying bedrock; moderately thick, well-developed soil.

ILLINOIAN
(350,000-550,000 yrs.)

🟥 MAPLEDALE TILL
🟥 MUNCY TILL

Thin, gray, clayey to silty till in patches covering up to 10 percent of the ground; topography reflects the underlying bedrock; thick, well-developed soil, often having a yellowish-red color.

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CHAPTER 3

Soils of Nittany Valley

Introduction

Nittany Valley is the first northwestern valley of the Ridge and Valley physiographic province of Pennsylvania. A discussion of the geology of the valley is presented by Butts and Moore (1936), and its geomorphic evolution is discussed by Gardner (1980), Parizek and Williams (1985), and Ciolkosz et al. (1986). The soils of the valley are diverse (Fig. 3.1) as are the soils of the state (Fig. 3.2 & Table 3.1). Additional soils information for Pennsylvania is given by Ciolkosz et al. 1987 and for the Northeast by Cunningham and Ciolkosz (1984).

The diversity of soils in Nittany Valley as well as in Pennsylvania is a reflection of the influence of the soil forming factors (parent material, organisms, climate, topography, and time) on the development of these soils. The effect on the development of a soil of anyone of these factors can vary from very great to very little. Of particular significance is the strong association of these soils to landform and parent material (Fig. 3.3). Because of these relationships, these soils have been arranged into parent material-drainage sequences (Table 3.2). This sequential arrangement is a natural association of these soils in the landscape and will be used along with the soil forming factors as a basis for discussing the characteristics, classification, and genesis of the soils of Nittany Valley.

Climate and Vegetation

On the broad scale, the climate of Nittany Valley and Central Pennsylvania is classified as warm summer, humid continental (Trewartha, 1957). This classification only approximates the type of climate of Pennsylvania, and in particular, central Pennsylvania. The physiographic features found in the central part of the state have a marked effect on its weather and climate. The central part of the state, in particular the Ridge and Valley Area, is not rugged enough for a true mountain type of climate, but it does have many of the characteristics of such a climate. The Ridge and Valley influence on air movement causes somewhat greater temperature extremes than are experienced in the southeastern part of the state where the modifying coastal influence holds the temperature more constant. For example the mean annual temperature in State College at an elevation of 1170 feet is 50^{o}F while at the Midstate Airport located 14 air miles Northwest and at an elevation of 1918 feet, it is 45^{o}F. Midstate Airport is located on the backside of the Allegheny front and is somewhat representative of the ridge tops of central Pennsylvania. Precipitation also varies between the valley bottoms and the ridge tops. State College receives on the average 39 inches of precipitation per year while Midstate get 45 inches. There is a slight seasonality of the precipitation both on the ridges and in the valleys with the summer months receiving about 1 inch more per month than winter months.

In the winter season, central Pennsylvania receives about 1/3 of the available sunshine while in the summer the reverse is the case (2/3 of available sunshine). Thus summers (from the sunshine viewpoint) are the more pleasant season. The clouds when conditions are right (primarily in the summer) show a banded appearance parallel to the ridges. This banded appearance is very evident on satellite imagery and from high flying aircraft. These clouds are formed as air rises over the ridges and the moisture condenses. The air then descends into the valleys and as it warms the condensed moisture is reabsorbed and the cloud dissipates. Thus the clouds are constantly forming and dissipating as the air moves over the ridges giving the banded cloud appearance. The differences in elevation also greatly affect the length of the frost free season on the ridges and in the valleys. In Nittany Valley, the frost free is about 50 days longer (about 160 vs. 110) than on the mountain tops. Even on the valley floor, the length of the growing season is somewhat variable. Hocevar and Martsolf (1971) report that on a clear, calm April night in Nittany

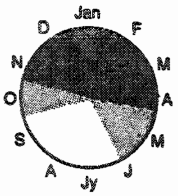
Table 3.3 Climatic data for Fort Collins, CO (just north of Denver); State College, PA; Phoenix, AZ; and Orlando, Florida. In the pie diagrams, winter equals the mean daily low temperature below 32°F (dark shade), spring and fall equal the mean daily temperature between 32° and 60°F (light shade), and summer equals the daily mean > 60°F.

FORT COLLINS, CO

Elevation: 5,004 feet

Relative Humidity: 60%
Wind Speed: 9 mph

Seasonal Change



Annual Rainfall 15 in

Annual Snowfall 41 in

Clear 118 days
Partly Cloudy 128 days
Cloudy 119 days

Precipitation Days: 37 Storm Days: 50

Average Temperatures

	Daily High	Daily Low	Monthly Mean
January	40.3	11.9	26.1
February	42.5	14.6	28.6
March	49.7	22.2	36.0
April	60.1	32.1	46.1
May	68.0	40.8	54.4
June	78.4	48.9	63.7
July	84.4	54.4	69.4
August	83.2	52.7	68.0
September	75.6	43.8	59.7
October	64.3	32.8	48.6
November	51.1	21.6	36.4
December	42.3	14.3	28.3

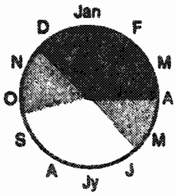
Zero-Degree Days: 15
Freezing Days: 175
90-Degree Days: 17
Heating- and Cooling-Degree Days: 7,052

STATE COLLEGE, PA

Elevation: 1,200 feet

Relative Humidity: 67%
Wind Speed: 7.8 mph

Seasonal Change



Annual Rainfall 37 in

Annual Snowfall 48 in

Clear 66 days
Partly Cloudy 114 days
Cloudy 185 days

Precipitation Days: 122 Storm Days: 35

Average Temperatures

	Daily High	Daily Low	Monthly Mean
January	34.2	19.8	27.0
February	36.1	20.2	28.2
March	45.4	27.7	36.5
April	59.2	38.9	49.1
May	70.2	48.8	59.3
June	78.7	57.3	68.0
July	82.6	61.1	71.9
August	80.7	59.1	69.9
September	73.5	52.0	62.8
October	62.9	42.5	52.7
November	48.7	33.2	41.0
December	36.3	22.9	29.6

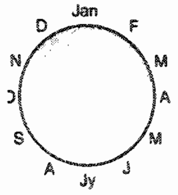
Zero-Degree Days: 4
Freezing Days: 132
90-Degree Days: 8
Heating- and Cooling-Degree Days: 6,797

PHOENIX, AZ

Elevation: 1,107 feet

Relative Humidity: 36%
Wind Speed: 6.2 mph

Seasonal Change



Annual Rainfall 7 in

Annual Snowfall 0 in

Clear 214 days
Partly Cloudy 81 days
Cloudy 70 days

Precipitation Days: 34 Storm Days: 23

Average Temperatures

	Daily High	Daily Low	Monthly Mean
January	64.8	37.6	51.2
February	69.3	40.8	55.1
March	74.5	44.8	59.7
April	83.6	51.8	67.7
May	92.9	59.6	76.3
June	101.5	67.7	84.6
July	104.8	77.5	91.2
August	102.2	76.0	89.1
September	98.4	69.1	83.8
October	87.6	56.8	72.2
November	74.7	44.8	59.8
December	66.4	38.5	52.5

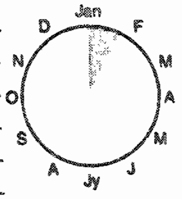
Zero-Degree Days: 0
Freezing Days: 32
90-Degree Days: 164
Heating- and Cooling-Degree Days: 5,060

ORLANDO, FL

Elevation: 106 feet

Relative Humidity: 74%
Wind Speed: 8.7 mph

Seasonal Change



Annual Rainfall 51 in

Annual Snowfall 0 in

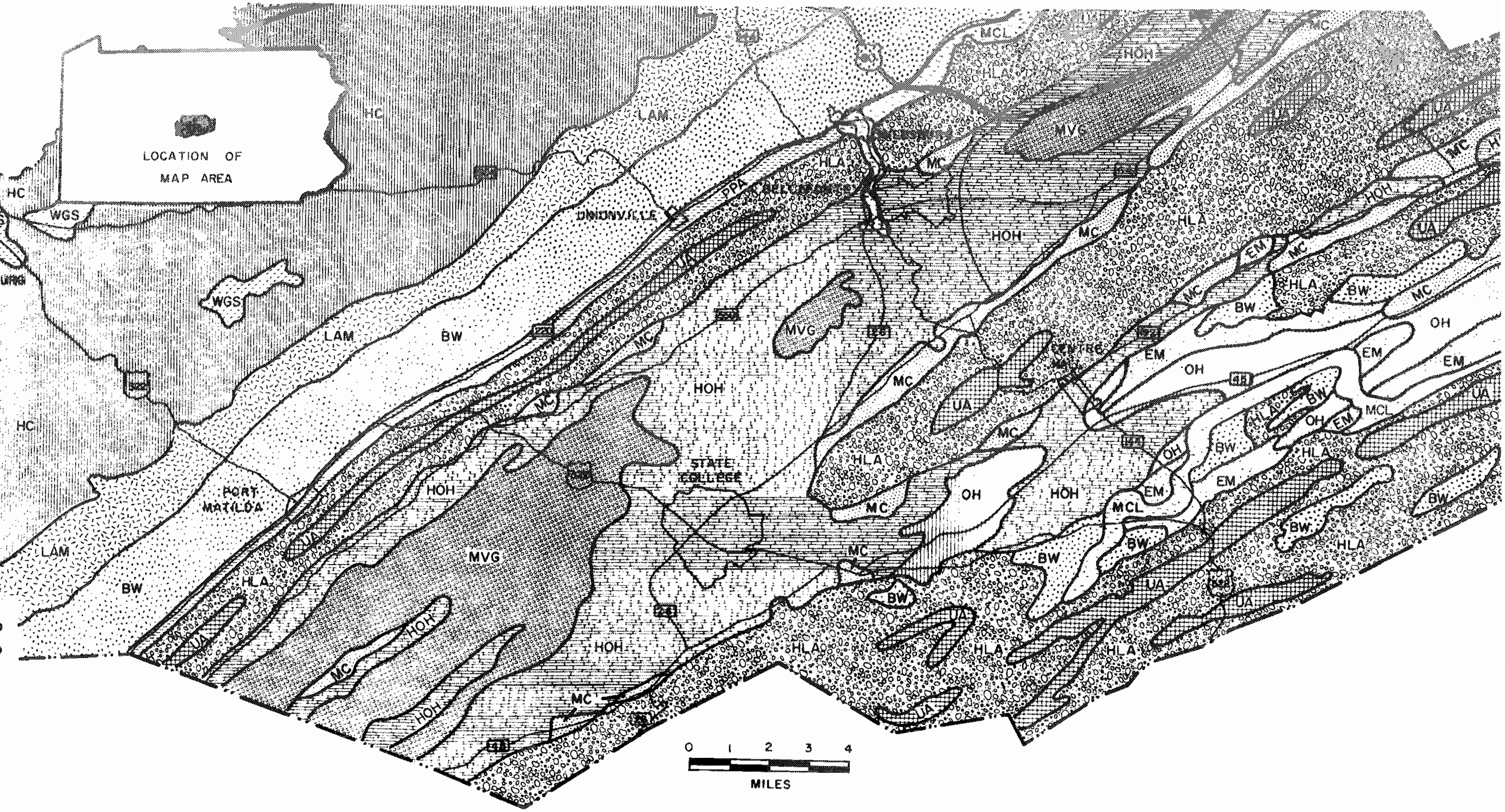
Clear 94 days
Partly Cloudy 148 days
Cloudy 123 days

Precipitation Days: 116 Storm Days: 81

Average Temperatures

	Daily High	Daily Low	Monthly Mean
January	70.5	50.0	60.3
February	71.8	51.2	61.5
March	76.0	55.7	65.9
April	81.5	61.1	71.3
May	86.7	66.1	76.4
June	89.3	71.1	80.2
July	89.8	72.9	81.4
August	90.0	73.5	81.8
September	87.9	72.3	80.1
October	82.5	66.0	74.3
November	76.2	56.9	66.6
December	71.5	51.5	61.5

Zero-Degree Days: 0
Freezing Days: 2
90-Degree Days: 104
Heating- and Cooling-Degree Days: 3,950



SOILS OF THE VALLEYS FORMED IN RESIDUAL AND COLLUVIAL MATERIAL WEATHERED DOMINANTLY FROM LIMESTONE

- HOH Hagerstown-Opequon-Hublersburg association: Dominantly nearly level to sloping, deep and shallow, well drained soils underlain by limestone bedrock
- MVG Morrison-Vanderlip-Gatesburg association: Dominantly gently sloping to moderately steep, deep, well drained soils underlain by limey sandstone
- OH Opequon-Hagerstown association: Dominantly gently sloping and sloping, shallow and deep, well drained soils underlain by limestone bedrock
- MC Murrill-Clarksburg association: Dominantly nearly level to sloping, deep, well to somewhat poorly drained soils underlain by limestone bedrock
- EM Edom-Millheim association: Dominantly gently sloping and sloping deep, well drained soils underlain by calcareous shale bedrock

SOILS OF THE RIDGES THAT FORMED IN RESIDUAL AND COLLUVIAL MATERIAL WEATHERED FROM SANDSTONE AND SHALE

- HLA Hazleton-Laidig-Andover association: Dominantly gently sloping to very steep, deep, well drained and poorly drained soils underlain by brown acid sandstone and shale bedrock
- UA Ungers-Albrights association: Dominantly gently sloping to moderately steep, deep, well to somewhat poorly drained, soils underlain by red acid sandstone bedrock

SOILS OF THE VALLEY FLOODPLAINS

- PPA Pope-Philo-Atkins association: Dominantly gently sloping, deep, well to poorly drained soils developed in alluvium from acid sandstone and shale bedrock
- MCL Melvin-Chagrin-Lindside association: Dominantly gently sloping, deep, poorly to moderately well drained soils developed in alluvium from limestone bedrock

SOILS OF THE ALLEGHENY PLATEAU FORMED IN RESIDUAL MATERIAL WEATHERED FROM SANDSTONE AND SHALE

- HC Hazleton-Clymer association: Dominantly gently sloping to very steep, deep, well drained soils underlain by acid sandstone bedrock
- WGS Wharton-Gilpin-Strip Mines association: Dominantly gently sloping deep and moderately deep, moderately well drained and well drained soils and strip mines, underlain by acid shale bedrock

SOILS OF THE RIDGE AND VALLEY PROVINCE FORMED IN RESIDUAL MATERIAL WEATHERED FROM SHALE

- BW Berks-Weikert association: Dominantly sloping to very steep moderately deep and shallow, well drained soils underlain by brown acid shale bedrock
- LAM Leck Kill-Albrights-Meckesville association: Dominantly sloping to very steep, deep, well drained and moderately well drained soils underlain by red acid shale bedrock

Fig. 3.1. Soil association map of Southcentral Centre County.

Table 3.1 and Fig. 3.2. Soil associations of Pennsylvania.

By

Edward J. Ciolkosz, Robert L. Cunningham, and Gary W. Petersen

Agronomy Series No. 62, The Pennsylvania State University

1980 (Revised 1984)

Map Symbol	Soil Series	Depth Class†	Drainage Class	Surface Texture	Subsoil Texture	Color	Parent Material	Classification
AR	Abbottstown	Deep**	Somewhat Poorly	Silt Loam	Silt Loam+	Grayish Red	Acid Red Shale	Aeric Fragiaqualf
	Readington	Deep**	Moderately Well	Silt Loam	Silt Loam+	Reddish Brown	Acid Red Shale	Typic Fragiudalf
BL	Berks	Mod. Deep	Well	Loam+	Loam++	Yellowish Brown	Acid Brown Shale	Typic Dystrochrept
	Leck Kill	Deep	Well	Silt Loam	Silt Loam+	Reddish Brown	Acid Red Shale	Typic Hapludult
BW	Berks	Mod. Deep	Well	Loam+	Loam++	Yellowish Brown	Acid Brown Shale	Typic Dystrochrept
	Weikert	Shallow	Well	Loam+	Loam++	Yellowish Brown	Acid Brown Shale	Lithic Dystrochrept
CB	Conotton	Deep	Well	Sandy Loam+	Sandy Loam++	Brown	Sand and Gravel	Typic Hapludult
	Birdsall	Deep	Very Poorly	Silt Loam	Silt Loam	Gray	Glacial Silts	Typic Humaquept
CC	Cavode	Deep	Somewhat Poorly	Silt Loam	Silty Clay	Grayish Brown	Acid Clay Shale	Aeric Ochraquult
	Cookport	Deep**	Moderately Well	Loam	Clay Loam+	Yellowish Brown	Acid Brown Shale	Aquic Fragiudult
CG	Chester	Deep	Well	Silt Loam	Silty Clay Loam	Brown	Gneiss and Schist	Typic Hapludult
	Glenelg	Deep	Well	Loam+	Silt Loam+	Brown	Gneiss and Schist	Typic Hapludult
DH	Duffield	Deep	Well	Silt Loam	Silty Clay Loam	Yellowish Brown	Shaly Limestone	Ultic Hapludalf
	Hagerstown	Deep	Well	Silt Loam	Clay	Red	Limestone	Typic Hapludalf
EH	Edgemont	Deep	Well	Sandy Loam+	Loam+	Yellowish Brown	Quartzite	Typic Hapludult
	Highfield	Deep	Well	Silt Loam+	Silt Loam+	Yellowish Brown	Metarhyolite	Ultic Hapludalf
EL	Erie	Deep*	Somewhat Poorly	Silt Loam+	Loam+	Grayish Brown	Calcareous Till	Aeric Fragiaqualf
	Langford	Deep**	Moderately Well	Silt Loam+	Loam+	Yellowish Brown	Calcareous Till	Aqueptic Fragiudalf
DC	Dormont	Deep	Moderately Well	Silt Loam	Silty Clay Loam+	Yellowish Brown	Limestone and Shale	Ultic Hapludalf
	Culleoka	Mod. Deep	Well	Silt Loam	Silt Loam+	Brown	Limestone and Shale	Ultic Hapludalf
GW	Gilpin	Mod. Deep	Well	Silt Loam+	Silt Loam+	Yellowish Brown	Shale and Sandstone	Typic Hapludult
	Wharton	Deep	Moderately Well	Silt Loam	Silty Clay Loam+	Brown	Shale and Siltstone	Aquic Hapludult
HA	Hanover	Deep**	Well-Mod. Well	Silt Loam+	Silt Loam+	Yellowish Brown	Leached Till	Typic Fragiudult
	Alvira	Deep**	Somewhat Poorly	Silt Loam+	Silt Loam+	Grayish Brown	Leached Till	Aeric Fragiaquult
HC	Hazleton	Deep	Well	Sandy Loam+	Sandy Loam++	Yellowish Brown	Acid Sandstone	Typic Dystrochrept
	Cookport	Deep**	Moderately Well	Loam	Clay Loam+	Yellowish Brown	Acid Sandstone	Aquic Fragiudult
HD	Hagerstown	Deep	Well	Silt Loam	Clay	Red	Limestone	Typic Hapludalf
	Duffield	Deep	Well	Silt Loam	Silty Clay Loam	Yellowish Brown	Shaly Limestone	Ultic Hapludalf
HE	Hagerstown	Deep	Well	Silt Loam	Clay	Red	Limestone	Typic Hapludalf
	Edom	Deep	Well	Silty Clay Loam	Clay+	Yellowish Brown	Shaly Limestone	Typic Hapludalf
HL	Hazleton	Deep	Well	Sandy Loam+	Sandy Loam++	Yellowish Brown	Acid Sandstone	Typic Dystrochrept
	Laidig	Deep**	Well	Loam+	Loam+	Brown	Sandstone Colluvium	Typic Fragiudult
HP	Howell	Deep	Well	Sandy Loam	Clay	Brown	Sand, Silt and Clay	Typic Hapludult
	Pope	Deep	Well	Loam	Loam	Yellowish Brown	Silty Alluvium	Fluventic Dystrochrept
LM	Leck Kill	Deep	Well	Silt Loam	Silt Loam+	Reddish Brown	Acid Red Shale	Typic Hapludult
	Meckesville	Deep**	Well	Loam	Clay Loam	Reddish Brown	Red Shale Colluvium	Typic Fragiudult
LO	Lordstown	Mod. Deep	Well	Silt Loam+	Silt Loam+	Yellowish Brown	Acid Brown Till	Typic Dystrochrept
	Oquaqa	Mod. Deep	Well	Loam+	Loam+	Reddish Brown	Acid Brown Till	Typic Dystrochrept
MV	Morrison	Deep	Well	Sandy Loam	Sandy Clay Loam+	Brown	Sandy Limestone	Ultic Hapludalf
	Vanderlip	Deep	Well	Loamy Sand	Loamy Sand+	Yellowish Brown	Sandy Limestone	Typic Quartzipsamment
NL	Neshaminy	Deep	Well	Silt Loam	Clay Loam+	Yellowish Red	Diabase	Ultic Hapludalf
	Lehigh	Deep	Mod. Well-S.W. Poorly	Silt Loam	Silt Loam+	Gray	Metamorphosed Shale	Aquic Hapludalf
PL	Penn	Mod. Deep	Well	Silt Loam+	Silt Loam+	Reddish Brown	Red Shale	Ultic Hapludalf
	Lewisberry	Deep	Well	Sandy Loam+	Sandy Loam+	Reddish Brown	Red Sandstone	Ultic Hapludalf
RC	Ravenna	Deep**	Somewhat Poorly	Silt Loam	Loam+	Grayish Brown	Neutral Till	Aeric Fragiaqualf
	Canfield	Deep**	Moderately Well	Silt Loam	Loam+	Yellowish Brown	Neutral Till	Aquic Fragiudalf
SP	Sheffield	Deep**	Poorly	Silt Loam	Silty Clay Loam	Brownish Gray	Fine Textured Till	Typic Fragiaqualf
	Platea	Deep**	Somewhat Poorly	Silt Loam	Silt Loam	Grayish Brown	Fine Textured Till	Aeric Fragiaqualf
VC	Venango	Deep**	Somewhat Poorly	Silt Loam	Loam+	Grayish Brown	Calcareous Till	Aeric Fragiaqualf
	Cambridge	Deep**	Moderately Well	Silt Loam	Loam+	Yellowish Brown	Calcareous Till	Aqueptic Fragiudalf
VM	Volusia	Deep*	Somewhat Poorly	Silt Loam+	Silt Loam+	Grayish Brown	Acid Brown Till	Aeric Fragiaquept
	Morris	Deep*	Somewhat Poorly	Loam+	Loam+	Grayish Red	Acid Red Till	Aeric Fragiaquept

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*Fragipan at 10-16 inches from the soil surface; **Fragipan at 16-36 inches from the soil surface

†Depth to bedrock: Shallow <20"; Mod. Deep 20-40"; Deep >40"

+Some (15-35%) rock fragments; ++Many (>35%) rock fragments

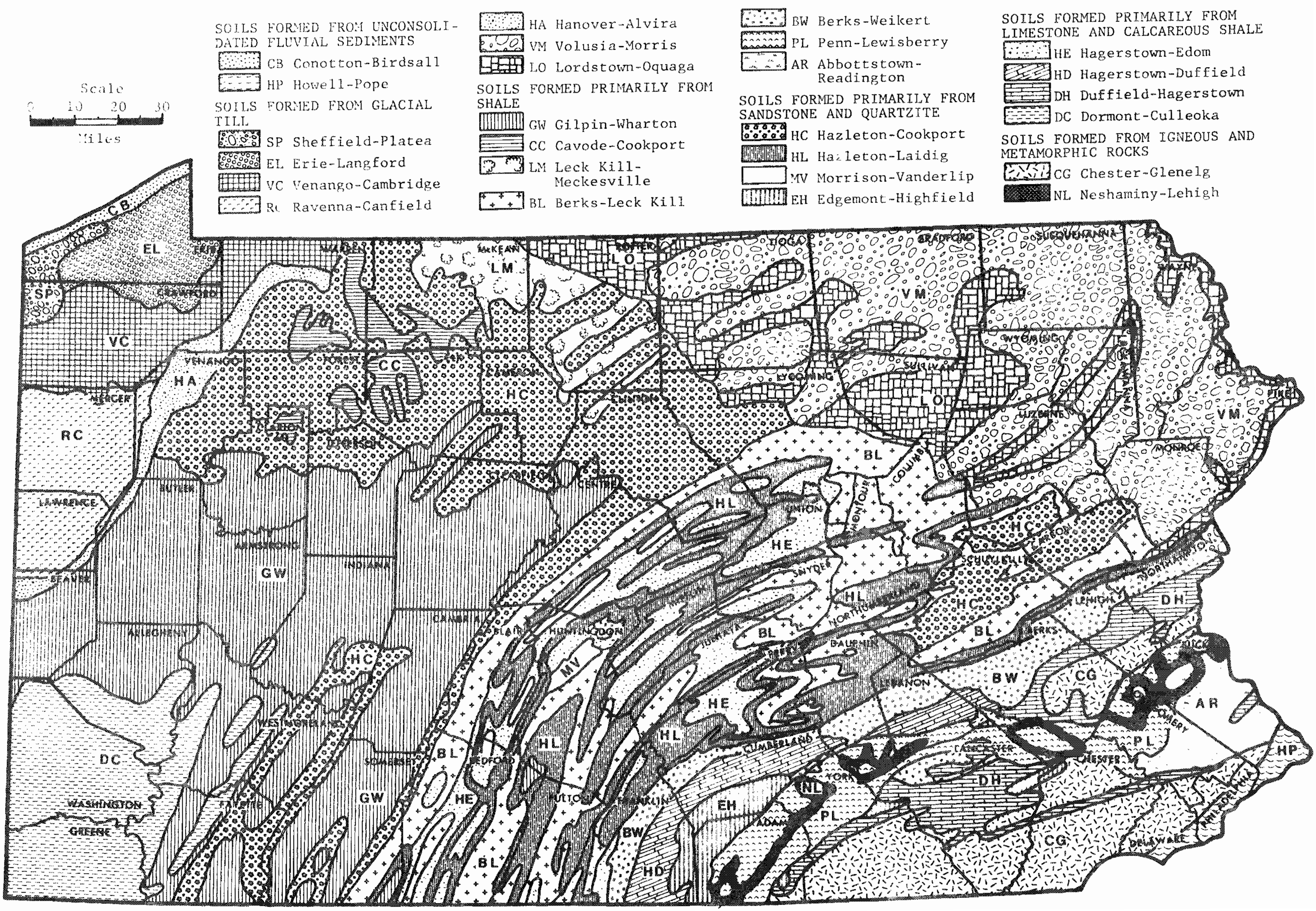
Scale
0 10 20 30
Miles
SOILS FORMED FROM UNCONSOLIDATED FLUVIAL SEDIMENTS
CB Conotton-Birdsall
HP Howell-Pope
SOILS FORMED FROM GLACIAL TILL
SP Sheffield-Platea
EL Erie-Langford
VC Venango-Cambridge
RC Ravenna-Canfield
HA Hanover-Alvira
VM Volusia-Morris
LO Lordstown-Oquaga
SOILS FORMED PRIMARILY FROM SHALE
GW Gilpin-Wharton
CC Cavode-Cookport
LM Leck Kill-Meckesville
BL Berks-Leck Kill
BW Berks-Weikert
PL Penn-Lewisberry
AR Abbottstown-Readington
SOILS FORMED PRIMARILY FROM SANDSTONE AND QUARTZITE
HC Hazleton-Cookport
HL Hazleton-Laidig
MV Morrison-Vanderlip
EH Edgemont-Highfield
SOILS FORMED PRIMARILY FROM LIMESTONE AND CALCAREOUS SHALE
HE Hagerstown-Edom
HD Hagerstown-Duffield
DH Duffield-Hagerstown
DC Dormont-Culleoka
SOILS FORMED FROM IGNEOUS AND METAMORPHIC ROCKS
CG Chester-Glenelg
NL Neshaminy-Lehigh
CB
EL
ERIE
SP
CRAWFORD
VC
WARREN
McKEAN
LM
POTTER
LO
TIOGA
BRADFORD
SUSQUEHANNA
WAYNE
VM
VENANGO
HA
FOREST
CC
HC
ELK
CAMERON
CLINTON
LYCOMING
SULLIVAN
WYOMING
LO
LUZERNE
PIKE
VM
MONROE
MERCER
RC
CLARION
JEFFERSON
BL
COLUMBIA
MONTOUR
UNION
HL
HE
CENTRE
LAWRENCE
BUTLER
ARMSTRONG
GW
INDIANA
SNYDER
HL
SCHUYLKILL
CARBON
HC
NORTHAMPTON
LEHIGH
DH
BEAVER
ALLEGHENY
CAMBRIA
BLAIR
HUNTINGDON
MV
JUNIATA
BL
NORTHUMBERLAND
HC
BL
BERKS
PERRY
DAUPHIN
BUCKS
LEBANON
BW
CG
AR
HC
HE
MONTGOMERY
WESTMORELAND
HL
CUMBERLAND
PL
DC
BL
BEDFORD
HL
HL
LANCASTER
CHESTER
HP
SOMERSET
YORK
DH
WASHINGTON
GREENE
FAYETTE
GW
HE
FULTON
FRANKLIN
NL
EH
PL
ADAMS
CG
DELAWARE
PHILADELPHIA
BW
BL
HD

Table 3.2. Major Soils of Central Pennsylvania Arranged According to Parent Material and Drainage.*

	(Shallow) <20" to bedrock	(Moderately Deep) 20-40" to bedrock	(------ Deep >40" to consolidated bedrock ------)				
	Drainage Class and Depth to Mottling						
Parent Material	(------ Well Drained ------)		(------ >40" ------)	Moderately Well Drained (20-40")	Somewhat Poorly Drained (10-20")	Poorly Drained 0-10"; some gleying)	Very Poorly Drained (0-10"; strong gleying)
Residual							
Gray and brown acid shale and siltstone	Weikert Lithic Dystrochrept; loamy-skeletal	Berks Typic Dystrochrept; loamy-skeletal	Bedington Typic Hapludult; fine-loamy Hartleton Typic Hapludult; loamy-skeletal	Blairton [Mod. deep------] Aquic Hapludult; fine-loamy Comly--------------------) Typic Fragiudalf; fine-loamy		Markes [Mod. deep] Typic Ochraqualf; loamy-skeletal Brinkerton Typic Fragiaqualf; fine-silty	
Gray and brown acid shale siltstone and some clay shale	Weikert Lithic Dystrochrept; loamy-skeletal	Gilpin Typic Hapludult fine-loamy	Rayne Typic Hapludult; fine-loamy	Wharton Aquic Hapludult; clayey	Cavode Aeric Ochraquult; clayey	Armagh Typic Ochraquult; clayey	
Red acid shale and siltstone; dull red 4 chroma or less	Klinesville Lithic Dystrochrept; loamy-skeletal	Calvin Typic Dystrochrept; loamy-skeletal	Leck Kill Typic Hapludult; fine-loamy	Albrights----------------) Aquic Fragiudalf; fine-loamy		Conyngham Unclassified	
Gray and brown acid sandstone	Ramsey Lithic Dystrochrept; loamy-skeletal	Dekalb Typic Dystrochrept; loamy-skeletal	Hazleton Typic Dystrochrept; loamy-skeletal Clymer Typic Hapludult; fine-loamy	Cookport-----------------) Aquic Fragiudult; fine-loamy		Nolo Typic Fragiaquult; fine-loamy	Lickdale Humic Haplaquept; fine-loamy
Red acid sandstone; dull red 4 chroma or less	Ramsey Lithic Dystrochrept; loamy-skeletal	Lehew Typic Dystrochrept; loamy-skeletal	Ungers Typic Hapludult; fine-loamy	Albrights----------------) Aquic Fragiudalf; fine-loamy		Conyngham Unclassified	
Grayish brown sandstone (in some places a very sandy limestone)			Vanderlip Typic Quartzipsamment; coated Morrison Ultic Hapludalf; fine-loamy Leetonia Entic Haplorthod; sandy-skeletal, siliceous Gatesburg Entic Haplorthod; sandy, siliceous				
Very cherty limestone			Elliber Typic Hapludult; loamy-skeletal	Kreamer Aquic Hapludult; clayey	Evendale------------------) Aeric Ochraquult; clayey		
Cherty limestone			Hublersburg Typic Hapludult; clayey				
Relatively pure limestone	Oqequon Lithic Hapludalf; clayey		Hagerstown Typic Hapludalf; clayey**	Clarksburg Typic Fragiudalf; fine-loamy	Penlaw Aquic Fragiudalf; fine-silty	Thorndale Typic Fragiaqualf; fine-silty	

Parent Material	(Shallow) <20" to bedrock	(Moderately Deep) 20-40" to bedrock	(------ Deep >40" to consolidated bedrock ------)				
			Drainage Class and Depth to Mottling				
		(------ Well Drained ------) (------ >40" ------)		Moderately Well Drained (20-40")	Somewhat Poorly Drained (10-20")	Poorly Drained (0-10"; some gleying)	Very Poorly Drained (0-10"; strong gleying)
Residual (cont'd.)							
Thin bedded limestone and calcareous shale		Ryder Ultic Hapludalf; fine-loamy	Duffield Ultic Hapludalf; fine-loamy Edom Typic Hapludalf; clayey**, illitic Frankstown Typic Hapludult; fine-loamy	Clarksburg Typic Fragiudalf; fine-loamy	Penlaw Aquic Fragiudalf; fine-silty	Thorndale Typic Fragiaqualf; fine-silty	
Colluvium							
Brown and gray acid shale, siltstone and fine grain sandstone			Shelocta Typic Hapludult; fine-loamy	Ernest------) Aquic Fragiudult; fine-loamy		Brinkerton Typic Fragiaqualf; fine-silty	
Red acid shale, siltstone and fine grain sandstone; dull red chroma 4 or less			Meckesville Typic Fragiudult; fine-loamy	Albrights------) Aquic Fragiudalf; fine-loamy		Conyngham Unclassified	
Gray and brown acid sandstone and shale			Laidig Typic Fragiudult; fine-loamy	Buchanan------) Aquic Fragiudult; fine-loamy		Andover Typic Fragiaquult; fine-loamy	
Brown and gray limestone, shale and sandstone			Murrill Typic Hapludult; fine-loamy	Clarksburg Typic Fragiudalf; fine-loamy	Penlaw Aquic Fragiudalf; fine-silty	Thorndale Typic Fragiaqualf; fine-silty	
Very cherty limestone and shale			Mertz Typic Hapludult; loamy-skeletal	Kreamer Aquic Hapludult; clayey	Evendale------) Aeric Ochraquult; clayey		
Recent Alluvium (Floodplains)							
Alluvium from acid gray and brown shale, siltstone and sandstone uplands.			Pope Fluventic Dystrochrept; coarse-loamy	Philo Fluvaquentic Dystrochrept; coarse-loamy	Stendal Aeric Fluvaquent; fine-silty	Atkins Typic Fluvaquent; fine-loamy	Elkins Humaqueptic Fluvaquent; fine-silty
Alluvium from acid red shale, siltstone and sandstone uplands; dull red chroma 4 or less			Barbour; Linden Fluventic Dystrochrept; coarse-loamy	Basher------) Fluvaquentic Dystrochrept; coarse-loamy		Holly Typic Fluvaquent; fine-loamy	Papakating Mollic Fluvaquent; fine-silty
Alluvium from limestone, shale and siltstone upland			Nolin Dystric Fluventic Eutrochrept; fine-silty	Lindside Fluvaquentic Eutrochrept; fine-silty	Newark Aeric Fluvaquent; fine-silty	Melvin Typic Fluvaquent; fine-silty	Dunning Fluvaquentic Haplaquoll; clayey**
Old Alluvium (Terraces) and Lacustrine							
Gray and brown acid shale siltstone and sandstone			Allegheny Typic Hapludult; fine-loamy	Monongahela Typic Fragiudult; fine-loamy	Tyler-Aeric Fragiaquult; fine-silty Tygart - Aeric Ochraquult; clayey	Purdy Typic Ochraquult; clayey	

* Almost all soils are also mixed, mesic.

** These soils are classified in the fine family but for the purpose of this table clayey will be used.

*** In Pennsylvania most pedons are skeletal.

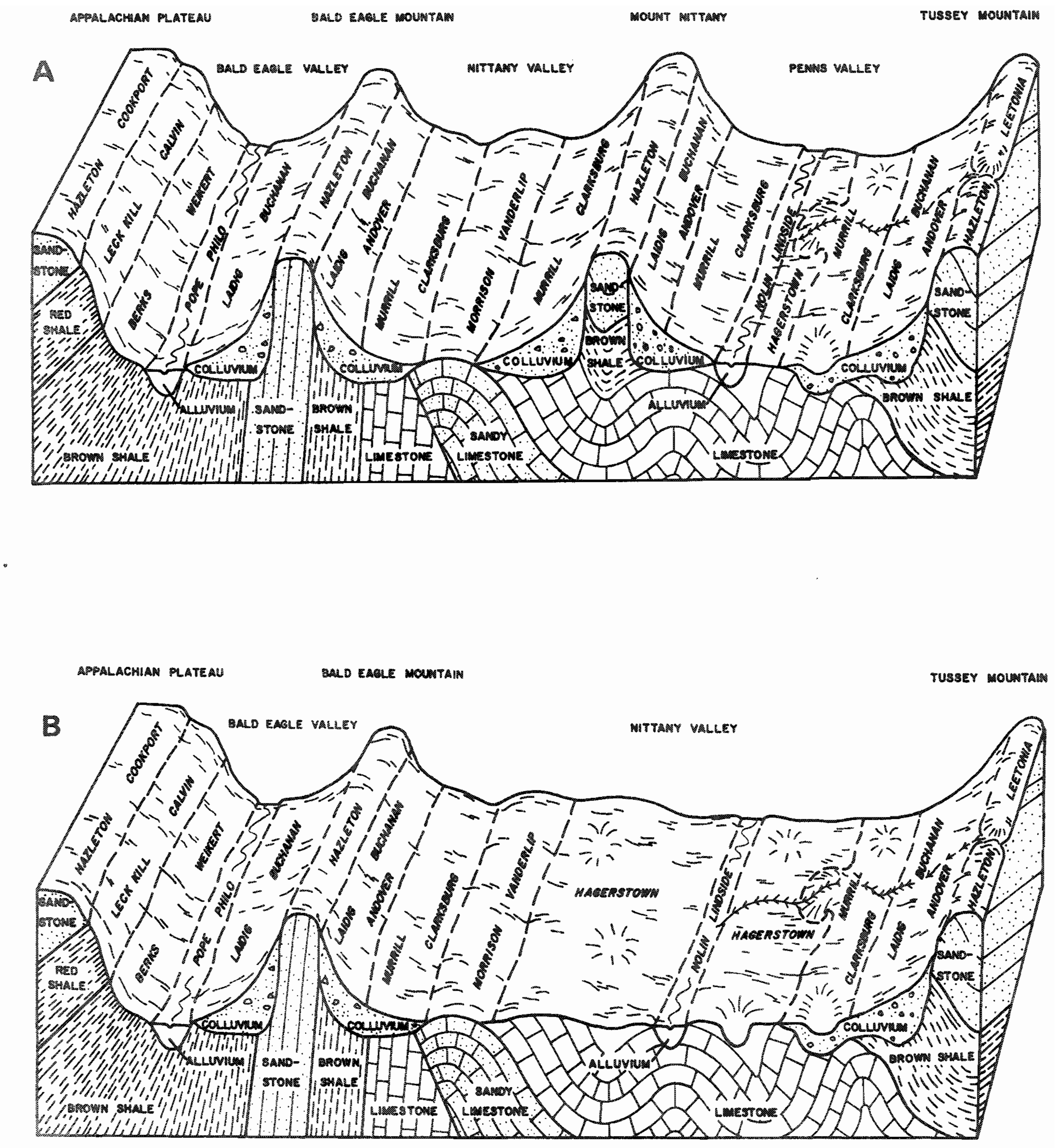

Fig. 3.3. General soil-landscape relations of Nittany Valley (A is northeast and B is southwest of State College).

Valley, the temperature can vary with the relief on the valley floor from 28° to 39° F. This variation is due to radiation heat loss and cold air drainage into the low areas. The cold air drainage, in addition to being a frost problem, causes a signficant amount of fog to form in the valleys in the spring and particularly in the fall. October is the month in which the valleys of central Pennsylvania have the most days of fog. Another interesting elevational relationship is that if we use the rule of thumb that 1000 feet of elevation equals 300 miles of latitude, the ridge tops in this area would have a climate different than the valley bottoms and similar to that found in Ottawa, Canada. Additional climatic data are given in Table 3.3 and by Braker (1981).

These data indicate that the present day microclimate is quite variable in the Ridge and Valley area. These climate variations are small in comparison to the changes this area underwent during the Pleistocene and post-Pleistocene or Holocene time. During the Pre-Wisconsinan time, glacial ice came within 15 miles of Nittany Valley (Leverett, 1934; Marchand, 1978) and in the late Wisconsinan (Woodfordian) time, it came within 25 miles (Crowl and Sevon, 1979). During these ice advances, the climate was much different than today. It has been proposed that during these times the Ridge and Valley area had a tundra type of climate (Guilday et al., 1964; Martin, 1958; Watts, 1980; Maxwell and Davis, 1972). Although the evidence indicates a tundra type of climate, Stingelin (1965) in a study of Bear Meadows concluded there was no tundra vegetation in this area during the last glacial advance. If this area had a tundra type of climate during the last ice age then the vegetation has changed greatly since the retreat of the Woodfordian glacial ice 18,500 years ago (Cotter et al., 1985).

Braun (1950) indicates that the present day natural vegetation of Nittany Valley falls within the oak-chestnut association of the Ridge and Valley Province. The oak-chestnut association occurs in very close proximity to the hemlock-white pine northern hardwoods association which begins on the Allegheny Plateau some ten miles to the northwest of State College. Braun (1950) also indicates that approximately ninety miles to the southwest, the mixed mesophytic association of the south reaches its northern limits in Bedford County, Pennsylvania, and an extension of the Blue Ridge section of the oak-chestnut association extends northward into the lower tier counties of southecentral Pennsylvania.

Although chestnut was a major (20-30%) part of the forest at the time of settlement, today it is only found as stump sprouts which grow to a height of 10 to 20 feet and then die. The reason for this is that in 1904 chestnut blight (a fungus) was introduced into the United States via New York City, and in 40 years, all chestnut trees from Maine to Georgia and westward to Ohio and Tennessee were killed. More detailed information on the vegetation of Nittany Valley is given by Shipman (1980) and Baldwin (1961).

One unique form of vegetation in the Nittany Valley area is that of tall grass prairie. At the time of settlement, an area near Centre Hall in Penns Valley of about 4,000-5,000 acres was vegetated with native prairie grasses (Losensky, 1961). This prairie area as well as others noted in Pennsylvania (Losensky, 1961) may well be remnants of more extensive prairie areas that were established during the warmer, dryer Hypsithermal period which occurred 4,000 to 7,000 years ago (Schmidt, 1938; Guilday et al., (1964). According to Flint (1971) during the Hypsithermal, the mean annual temperature was about 4°F higher and the mean annual precipitation was about 5 inches less than today. This would give the valleys during the Hypsithermal time, a climate similar to what we have today in eastern Kansas, which is an area that has tall grass prairie as its native vegetation. The presence of prairie vegetation poses some interesting possibilities. Do these areas have Mollisol soils (soils of the tall grass prairies of the Midwest)? The soil survey of Centre County (Braker, 1981) does not identify any Mollisols in the Centre Hall area. In addition, field investigations by Waltman (1986) in the summer of 1982 indicated no soils in this area with Mollisol morphology. Although this is the case, a more detailed soils study may indicate a signficant effect of priarie vegetation on the soils of the area and even possibly that these soils should have been classified as Mollisols.

Soils Developed in Residuum

Generally, in the Ridge and Valley area of Pennsylvania, soils formed in residuum occupy 67% of the area while soils formed in colluvium occupy 27%, and soils formed in fluvial deposits (floodplain and terrace) occupy the remaining 6% of the area (Table 3.4). Soils developed in residuum are found on the ridge tops and on the valley floors in the Nittany Valley area. The ridge tops are usually relatively narrow and have hard sandstone as the underlying bedrock. On the valley floors, the soils are developed primarily in limestones and dolomites and interbedded sandstones and dolomite. In some places on the side slopes where the colluvial mantle is absent, soils developed in acid gray shales are found.

Table 3.4. The relative proportion of colluvial, fluvial (floodplain and terrace), and residual soils in four counties in Pennsylvania (from Ciolkosz, 1978b).

Physiographic Area and County	Percent		
	Colluvial	Fluvial	Residual
Ridge and Valley			
Fulton	27.2	6.2	66.6
Huntingdon	27.3	6.4	66.3
Plateau			
Fayette	14.3	4.6	81.1
Westmoreland	12.5	8.5	79.0

Soils from Sandstone

The major soils found on the ridge tops are Hazleton and Cookport. Some Leetonia is also found but its distribution is very irregular. Hazleton is by far the most extensive of the soils found on the ridge tops, and it is also the most extensive soil found in Pennsylvania (Table 3.5) Hazleton is a deep soil (> 40" to bedrock). In past surveys (Mooney et al., 1910), much of the ridge tops and large areas on the Appalachian Plateau to the west were thought to be moderately deep to bedrock (20-40") and the soils in these areas were classified as Dekalb. Many observations of excavations made with power equipment has indicated that these soils are deep to bedrock and they have a high content of rock fragments. When making observations with hand tools, the high content of rock fragments gives the impression that the soil is much shallower than it actually is. The cracked and fractured nature of the sandstone bedrock of these soils apparently aides in the development of deep soils. These cracks and fractures act as zones of weakness to the weathering processes and allow the weathering to follow the zones creating deep soils with a high percentage of rock fragments. Although the soils are deep (> 40"), the bedrock is usually found at depths of 6 to 8 feet and in many cases > 10 to 15 feet (Carter, 1983). Thus, these very hard parent materials greatly resist deep weathering when compared to other parent materials in this area.

Table 3.5. Ranking, acreage, and percent on a state basis of the common soils in the Nittany Valley area. Pennsylvania has a total of 28.9 million acres. Data from Cunningham and Day (1986).

Soil	Rank According to Acreage	Acres in PA	Percent of PA Soils	Soil	Rank According to Acreage	Acres in PA	Percent of PA Soils
Hazleton	1	2,945,000	10.39	Leetonia	55	123,000	0.43
Gilpin	2	1,347,000	4.75	Murrill	57	120,000	0.43
Weikert	4	856,000	3.02	Andover	60	112,000	0.40
Cookport	6	854,000	3.01	Clarksburg	67	90,000	0.32
Berks	7	831,000	2.93	Morrison	69	87,000	0.31
Laidig	11	605,000	2.14	Pope	72	84,000	0.30
Buchanan	14	509,000	1.80	Opequon	75	81,000	0.29
Hagerstown	18	425,000	1.50	Melvin	113	40,000	0.14
Leck Kill	20	384,000	1.36	Lindside	116	39,000	0.14
Calvin	31	249,000	0.88	Nolin	121	35,000	0.12
Duffield	37	206,000	0.73	Vanderlip	171	15,000	0.05
Philo	48	144,000	0.51				

The Hazleton soil is classified as an Inceptisol (Dystrochrept) which means it shows weak soil development (Cambic B horizon). The weak development does not indicate a very young soil, it indicates a parent material that is very resistant to weathering and soil formation. Further evidence supporting this conclusion is the juxtaposition of Cookport soils with Hazleton soils. Cookport soils are classified as Ultisols (Fragiudults--fragipan and argillic horizon) which indicates moderate development. Although found associated with Hazleton soils, Cookport soils usually are located in low lying or depressional areas that may have had some finer material washed in or they are on large flat areas which have shale material interbedded with the sandstone. Thus, the argillic horizon and fragipan of the Cookport are a reflection of parent material more than of any other soil forming factor.

Leetonia soils are found on the ridge tops and are classified as Spodosols. They will be discussed in a later section on the Gatesburg soils.

Soils from Limestones

Two groups of soils dominate the residual soils of the valley floor. These are the soils developed in limestones and those developed from interbedded sandstone and limestone.

The major soils developed in the limestones are Opequon and Hagerstown. The Opequon is shallow (< 20") to bedrock while Hagerstown is deep (> 40") to bedrock. These soils are well drained, red in color, and have a clayey, argillic B horizon. They are found in karst topography areas with many sink holes and a limited integrated drainage network on the landscape. A good part of the runoff of these soils does not drain directly from the land but it drains into sink holes, and then into the ground water. It is then discharged via springs into streams (see Parizek et al., 1971 and Wood, 1980 for a discussion of karst hydrology).

These soils are developed from limestone and it is assumed that the soil material found at the surface is residuum from the limestone. Table 3.6 gives soil and rock data from Hagerstown and Duffield soils from Nittany Valley and southeastern Pennsylvania. Duffield is a siltier, browner soil than Hagerstown, but it is also developed from limestone.

These data and other Pennsylvania data (total of 15 pedons of Hagerstown and 10 of Duffield--not all pedons were analyzed for free iron oxides) indicate a range of free iron oxides in B horizons of 4 to 7% for Hagerstown and 2 to 4% for Duffield soils (Table 3.6). From these data a logical conclusion might be that the higher the iron content, the redder the soil. Observations of other soils and data in the literature does not support this conclusion. The more probable reason for these color differences is the type of mineral present. Hematite and Goethite are the major secondary iron minerals in soils with Hematite imparting red colors and Goethite imparting brown colors (Schwertmann and Taylor, 1977). No data are available to indicate that the major iron mineral in Hagerstown is Hematite and in Duffield, Goethite. Although no data are available for these soils, a review of the literature (see Dobos, 1986) indicates that soils with hues of 7.5 YR or yellower (10 YR) have 10% or less of Hematite. Thus, the color of Duffield soils is due to Goethite, and the color of Hagerstown is due to Hematite (hues of 2.5 YR probably indicate about 50% Hematite and 50% Goethite). This suggests an interesting question. If the iron mineralogy between these soils is different, why is it different? According to Schwertmann and Taylor (1977), in humid temperate zones, Hematite is not formed in soils and that cool, wet, low pH, high organic matter soils favor Goethite formation over Hematite formation. The application of these factors to the Hagerstown-Duffield soil color question is not clear-cut but the work of Hsu and Wang (1980) which indicates a higher Fe^{+++} concentration favors the formation of Hematite over Goethite may well explain the differences noted. Recent reports by Kampf and Schwertmann (1985) also support the contention that a high release rate of iron during rock weathering favors the formation of Hematite over Goethite. Although it may be a factor, limited data do not indicate that the type of limestone (calcic vs. dolomitic) is a factor in the development of Hagerstown and Duffield soils.

Another interesting question about the Hagerstown soil concerns the origin of the soil material. If all the material is of residual origin, then it would take about 100 feet of bedrock to give about 10 feet of soil (2-8% acid insoluble residue--Table 3.6). The time required to accumulate these residual materials is also an interesting question. Studies of limestone tombstone weathering give rates of limestone dissolution of 10 to 100 mm/1,000 yrs. (Colman, 1981). Trudgill (1976) gives rates of 1000 to 5000 mm/1000 yrs. (under acid organic soil) to 10 to 1,000 mm/1000 yrs. (under calcareous brown earths) for limestone dissolution. These rates are a little higher than those given by Saunders and Young (1983) of 20 to 100 mm/1000 yrs. or by Jennings (1983) of 5 to 30 mm/1000 yrs. For Nittany Valley, Parizek and White (1985) give a rate of 30 mm/1000 yrs. It is interesting to note

Table 3.6. Soil and rock data for selected soils developed from limestone.

				Percent				
Horizon	Depth Inches	Color	Rock Mineral	Fe_2O_3	Acid Insoluble residue	Sand	Silt	Clay
				<u>Hagerstown</u>				
Ap*	0-7	10YR 3/2		2.5		14.1	64.5	21.4
Bt	7-38	5YR 4/6		4.6		19.7	41.5	38.8
C	38-40	5YR 3/3		6.0		20.9	24.3	54.8
R	40+	N 4/0	dolomite	0.4	3.5			
Ap*	0-7	10YR 2/2		2.1		11.4	64.2	24.5
Bt	7-36	5YR 4/6		3.9		7.8	39.1	53.1
R	36+	N 5/0	dolomite	0.5	8.7			
Ap*	0-8	10YR 3/2		2.6		15.0	65.6	19.4
Bt	8-30	5YR 4/6		5.2		6.0	27.0	67.0
R	40+	N 3/0	calcite	0.2	2.6			
R*		N 5/0	dolomite	1.2	6.4			
R**			dolomite		5.8			
Bt3*	33-46	2.5YR 4/6		5.8		8.2	31.7	60.1
Bt2*	23-33	5YR 5/6		6.9		9.7	31.2	59.1
Bt3*	28-34	5YR 5/4		4.4		7.6	43.6	48.7
				<u>Duffield</u>				
Ap*	0-13	10YR 3/3		2.0		5.7	73.8	20.5
Bt2	22-30	7.5YR 5/6		3.6		11.0	53.6	35.4
C1	52-67	10YR 5/6		2.4		15.8	56.1	28.2
R	80+	N 6/0	dolomite	1.9	11.8			
Bt3*	31-39	7.5YR 5/6		4.4		9.3	64.2	26.5
Bt2*	22-33	7.5YR 5/8				13.0	52.7	34.3
Bt3*	34-46	7.5YR 5/8				16.6	52.2	31.2
Bt4*	34-48	10YR 4/4		2.0		13.0	51.2	35.8
Bt2*	29-40	10YR 5/6		2.3		29.6	44.8	25.6

*Soil Characterization Laboratory (1986)
**Jeffries and White (1940)

that over 100 years ago, Ewing (1885) published a dissolution rate of 27 mm/1000 yrs. for Nittany Valley. These data can be used to compute some general accumulation rates for the residual soils of the valley (Table 3.7). Residual material on the stable landscape surfaces in the valley varies from 2 to 6 meters in thickness. This would give an age of about 1 to 2 million years for these soils using Parizek and White's (1985) dissolution rate of 30 mm/1000 yrs. An estimate of 2.5 to 5 million yrs. for 5 meters of residual soil accumulation in the great valley near Harrisburg has been given by Sevon (1985). Thus an age of 1 to 2 million years for the deep limestone soils of the valley seems reasonable.

Table 3.7. Accumulation of residual soil from a limestone with 6% acid insoluble residues, assuming varying rates of dissolution over time. A bulk density of 2.85 (g/cc) for the rock and 1.65 for the soil is used in the calculations.

Dissolution rate mm/1000 yrs.	Time (years)			
	10,000	100,000	1,000,000	2,000,000
	cm of residuum			
10	1	10	100	200
30	3	30	300	600
100	10	100	1000	2000

The insoluble residue of the Hagerstown soil is also apparently mainly clay size material. Duffield, on the other hand, contrasts with Hagerstown in subsoil texture. Limited laboratory data do not indicate if Duffield has a higher concentration of acid insoluble residue (field observations do support this contention) but apparently most of it is silt and sand size material. The high clay content of the Hagerstown B also contrasts strongly with the texture of its A horizon (Table 3.6). There can be a 40-70% increase in clay content from the A to the B, particularly the lower B. This increase can be attributed to eluviation of clay from the A into the B during the formation of an argillic horizon. Another possibility is that aeolian additions of silt size material may have accumulated on the surface of the Hagerstown soil. The silt size material would dilute the clay content and exaggerate the difference in clay content between the A and B horizons. Observations of clay coatings in the B of the Hagerstown indicate that some clay has been illuviated in this soil. Aeolian loess (Carey, Cunningham, and Williams, 1976; Millette and Higbee, 1958) and sand deposits (Marchand et al., 1978) are known in various parts of Pennsylvania. In addition, the work of Jackson et al. (1971) and Smith et al. (1970) who indicate that significant amounts of dust have been added to soils in the Eastern United States, and the work of Cronce (1986) in Nittany Valley indicate that a significant amount of dust has been added to soils in central Pennsylvania.

Another interesting aspect of the genesis of these soils is a landscape overturning model of the genesis of limestone derived soils proposed by Simpson (1979). This model was developed during a research project in Nittany Valley at the waste-water irrigation site 2 miles north of the Penn State Campus. In this model (Fig. 3.4), a sink hole forms (stage 2) which fills with material (stages 3 and 4) and then other sink holes form in the area that was the source area of the sediment for the filling in stage 1 (stage 6). Next the sediment from the filling

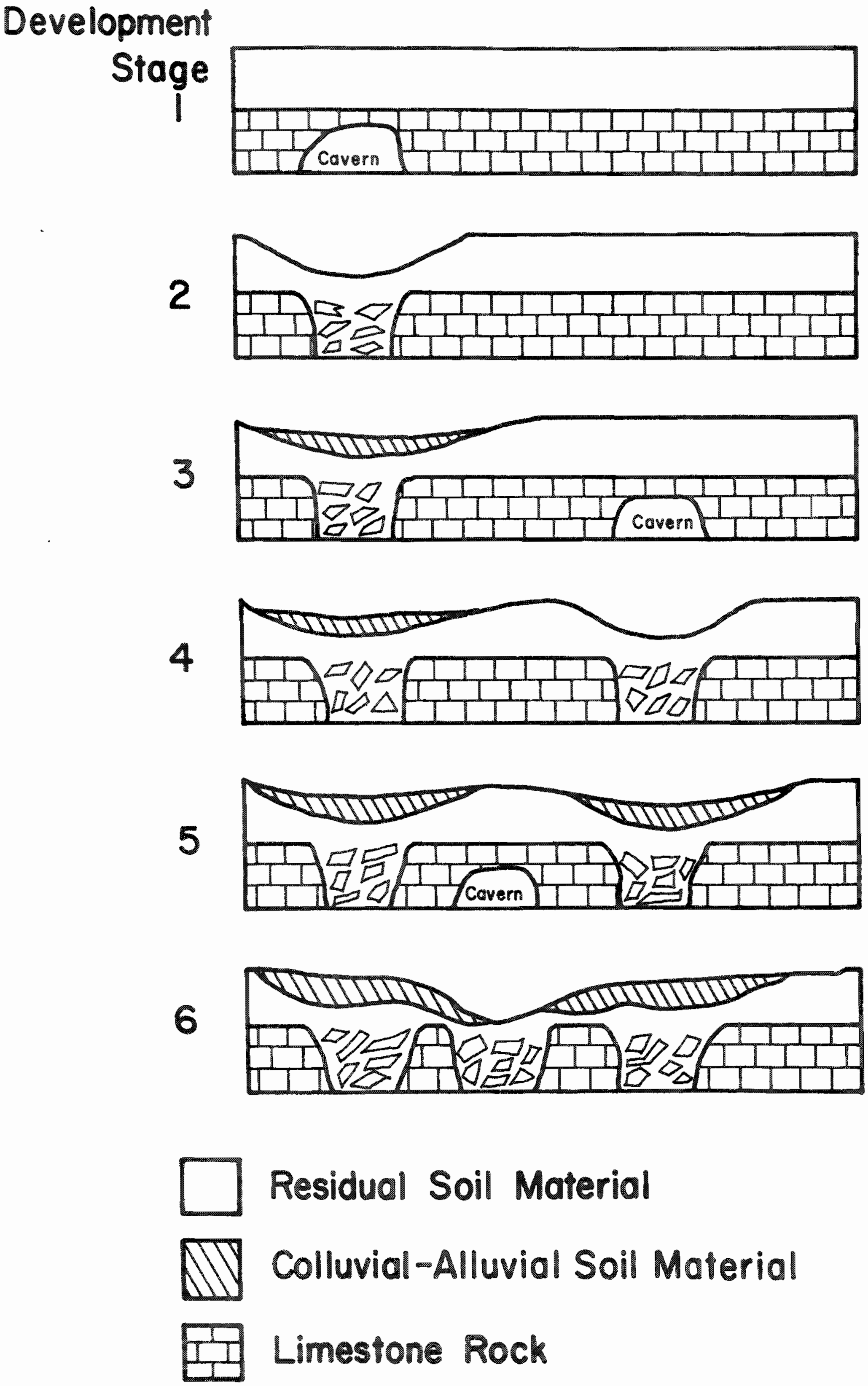

Fig. 3.4. Soil developmental sequence for soils developed from limestone in Nittany Valley (from Simpson, 1979).

of stages 3, 4, and 5 is eroded into the new sink holes. This model could be viewed as a group of pistons that are being lowered into the earth's crust.

These data and observations have interesting significance in the soil-geomorpholoy of the valley floor. The valley floor has significant relief. The main limestone uplands are at an elevation of about 1200 feet and the stream bottoms are at 950 to 1000 feet. Thus, there is 200-250 feet of relief on the limestone areas of the valley floor. Observations of excavations give varying results of depth to bedrock. This is probably a result of varying lithogies of the limestone, but in general, one trend does seem to be evident. This is that the relatively flat upland area has deeper soils (deeper to bedrock) than are found on the slopes. In addition, although this is a karst area, there is an integrated drainage network with drainage ways working headward into surrounding upland areas. These headward working drainage ways are most evident close to Spring Creek (the major stream draining of the valley). Thus, Nittany Valley is a fluviokarst area (karst landforms superimposed on a fluvial landscape; White and White, 1979). The karst areas of the valley underlain by dolomite show subdued landforms compared to karst areas underlain by limestone (calcitic). Although this is the typical situation, the denudational rates for both types of carbonate rock is about the same (White, 1984).

Soils from Dolomite and Sandstone

The last group of residual soils to be discussed are these formed from interbedded dolomite and sandstone. These soils are the Vanderlip, Morrison, and Gatesburg. All three of these soils are sandy and have developed in a deep residual accumulation of sandy material that has weathered from the parent rock. The Vanderlip is classified as a Psamment while Morrison is classified as a Udalf. The parent rock of these soils is an interbedded dolomite and sandstone (Gatesburg formation). As the bedrock weathered, the dolomite beds dissolved leaving the insoluble materials as bands of finer textured material in a very thick sandy regolith. Although the sandy material is most evident, Butts and Moore (1936) state that the sandstone probably makes up only about 20% of the formation. Butts and Moore also state that some of the sandstone beds are as much as 10 feet thick. Where the thicker sandstone beds intercept the surface, the Vanderlip soils are found. Apparently the sandstone beds did not have enough clay in them (Vanderlip soils have 4-8% clay) to be illuviated to form an argillic horizon, but where the sandstone beds were thinner, some of the finer materials has been eluviated from the dolomite residual beds and has accumulated as an argillic horizon. In these places, Morrison soils are found. In the Vanderlip and below the argillic B horizon in the Morrison, lamellae (thin bands of slightly higher clay and iron oxide content) are frequently found. They have not been studied in these soils but their origin in other sandy soils has been attributed to clay flocculation by free Fe oxides, clay flocculation by carbonates, periodic chemical precipitation of Fe with subsequent flocculation of the clay, evapotranspiration at the wetting front or by sieving by a layer having fine pores (Bond, 1986). In Centre county, there are about 300 acres of Vanderlip and 28,000 acres of Morrison soils. On a state wide basis, there are about 87,000 acres of Morrison and 15,000 acres of Vanderlip (Table 3.5). The Gatesburg soil is found in the same area as the Morrison and Vanderlip soils. The Gatesburg is also sandy, but it has the morphology of a Spodosol. This means it has a B horizon of Fe, Al, and humus accumulation. The Gatesburg soil is unique in that it is the only soil with Spodosol morphology that is found on valley floors at low elevations in Pennsylvania. It is of limited extent (400 acres) and all of it is located just outside of State College. Other soils with Sposodol morphology

(Leetonia) are found only at higher elevations in Pennsylvania, and like the Gatesburg, they are developed in sandy parent materials.

Well drained Spodosols are believed to form in coarse textured material at high latitudes and usually associated with coniferous vegetation (McKeague et al., 1978; Soil Survey Staff, 1975). Stanley and Ciolkosz (1981) as a part of a study of Spodosols in West Virginia and Pennsylvania studied the Gatesburg soil. At their study area in the Barrens north of State College just off U. S. 322 two pedons were sampled; one with Spodosol morphology (E, Bhs, Bs), and one without Spodosol morphology (E, Bs). The data in Table 3.8 indicate that neither of these pedons (14-2, 14-3) met the chemical criteria of Soil Taxonomy (Soil Survey Staff, 1975) for a Spodosol nor the criteria for the Podzol of the Canadian Classification System (Canada Soil Survey Committee, 1978). Apparently, the Gatesburg soil is at a critical threshold in which the soil forming processes which form the Spodic horizon (B horizon of accumulation of humus, Al, and Fe) does not function well. Although McKeague et al. (1978) indicates that vegetation is only a partial factor in Spodosol formation, the very small acreage of Gatesburg soil in the Barrens area indicates that the white and pitch pine which were part of the vegetation of the Barrens were probably the natural vegetation of the Gatesburg soil. Although the pine formed an acid litter necessary for Spodosol formation (McKeague, 1978), the temperature was apparently high enough that most of the humus in the surface horizon decomposed in place and was not eluviated or the humus that was eluviated had a tendency to decompose fairly rapidly. The trend of decreasing humus and iron oxides content with increasing soil temperature noted by Stanley and Ciolkosz (1981) tends to support this conclusion (Fig. 3.5).

Table 3.8. Chemical criteria for spodic horizon identification of Gatesburg pedons 14-2 and 14-3 (from Stanley, 1979).

Horizon	Depth cm	$\frac{\text{Pyro Fe + Al}}{\text{Clay}}$	$\frac{\text{Pyro Fe + Al}}{\text{D-C Fe + Al}}$	Index of Accumulation
Pedon 14-2				
A	0- 5	0.01	0.47	---
E	5-36	----	0.10	---
Bhs	36-38	0.03	0.26	7
Bs	38-51	0.02	0.39	9
Bw1	51-71	0.02	0.21	52
Bw2	71-91	0.01	0.18	41
Bw3	91-122	0.01	0.36	37
Bt	122-132	0.01	0.04	83
Pedon 14-3				
E	0-20	0.01	0.42	---
Bs	20-30	0.02	0.06	15
Bw1	30-46	0.02	0.51	6
Bw2	46-63	0.01	0.33	13
Bt1	63-89	0.01	0.21	120
Bt2	89-109	0.01	0.04	120
C	109+	0.01	0.06	---

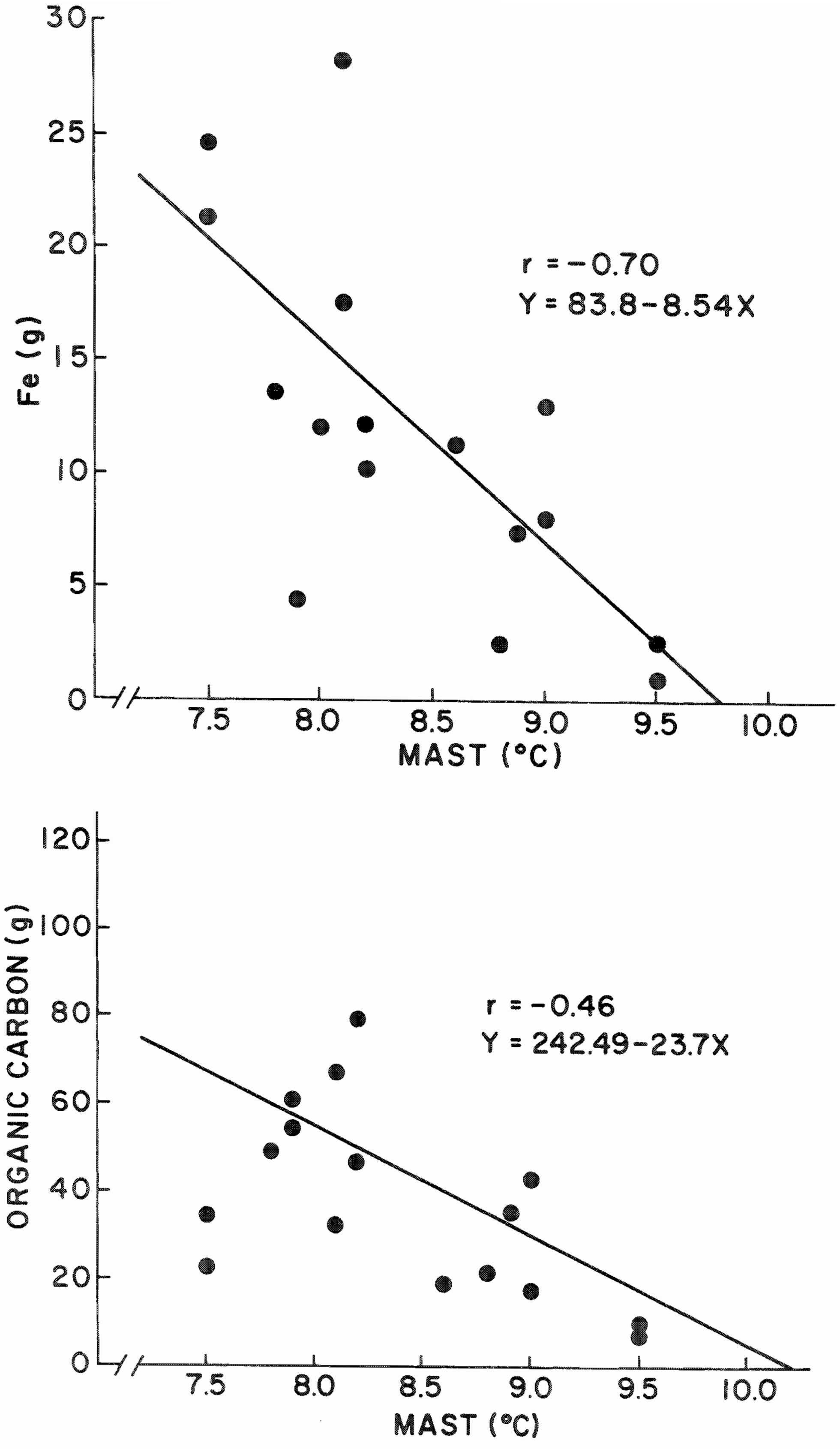

Fig. 3.5. Total accumulated (includes all subhorizons of the B) of organic carbon (humus) and iron (Fe) in Pennsylvania Spodosols (Stanley and Ciolkosz, 1981).

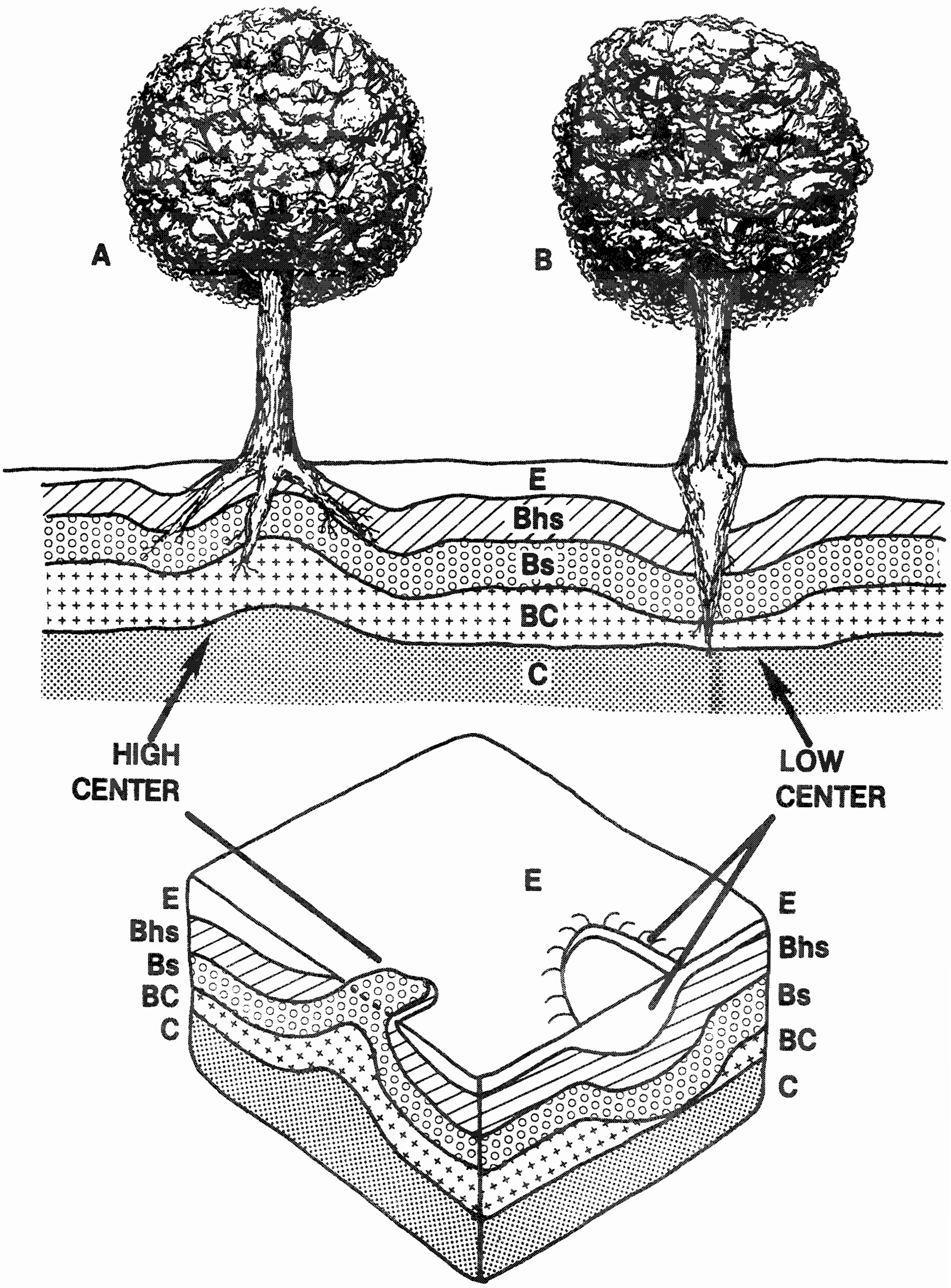

Fig. 3.6. Diagramic presentation of high centers (A) and low centers (B) in Spodosols (modified from Stanley, 1979).

Another interesting aspect of Spodosol genesis is the undulating spodic horizon. It is believed that the undulating surface of the spodic horizon is a reflection of the vegetation of an area and its effect on the movement of water through the soil. These undulations were studied in three dimensions by Stanley (1979) at the State College Gatesburg site. Stanley concluded that there were two types of patterns (high centers and low centers), and that these patterns were a reflection of water draining down into the soil from trees with tap root (low centers) and fibrous root (high centers) systems (Fig. 3.6). Stanley's conclusion is partially supported by the work of Crampton (1982) and Ryan and McGarity (1983), but in conflict with the conclusion of Lag (1951). Lag concluded the undulations were a reflection of the surface topography which concentrated water in low spots, which promoted deeper leaching and thicker E horizons under the low spots.

The sandy soil Barrens area contributed greatly to the initial settlement of central Pennsylvania. Although it did not produce good crops; hence the name, Barrens, it did have deposits of iron ore which was used by the iron furnaces in this region to make iron. According to Butts and Moore (1936), the ore was a hydrous oxide of iron which was a weathering product of the interbedded dolomite and sandstone. The ore occurs as concretionary or irregular masses mixed with clay, chert, and sand. The ore was relatively rich in iron, having about 40-50% iron (Butts and Moore, 1936). The last ore was mined in this area in 1909 and many of the buildings that made up the main mining town of Scotia were sold in 1911 and carted away. The railroad was taken up in 1924 and today the only thing that remains of Scotia or the mining era are the many holes in the ground that the iron ore was taken from both near Scotia and throughout the Barrens.

Soils Developed in Alluvium

The only other soils of any acreage on the valley floor in this area are the Nolin, Lindside, and Melvin. These soils are developed in recent alluvium and are found on floodplains. They have formed in the silty alluvium derived primarily from the limestone upland areas. These soils are relatively young probably 200-300 years old (Bilzi and Ciolkosz, 1977). The age of the soils on the floodplain areas in Nittany Valley are probably related in part to man's activity in the surrounding watersheds. For example, in Nittany Valley, the extensive logging for charcoal during the early 1800's probably accelerated erosion in the Spring Creek watershed. The sediment from this erosion in turn buried the soil forming on the floodplain with 2 to 3 feet of material. Subsequent better management of the land in this area has apparently decreased the erosion and sedimentation. This sequence of events is apparent on the floodplain of Spring Creek. On the floodplain, there is a buried soil 2 to 3 feet below the surface. Above the buried soil, there is the Nolin soil with an ochric epipedon and a cambic B horizon (an Inceptisol soil). The presence of the Nolin in this relative young material also indicates that a cambic horizon and ochric epipedon can form relatively rapidly in floodplain sediments (Bilzi and Ciolkosz, 1977). Data for the Nolin pedon studied by Bilzi and Ciolkosz are given in Table 3.9).

The streams of Nittany Valley, as well as the large rivers in Pennsylvania such as the Allegheny, Juniata, Susquehanna, and Delaware, have relatively narrow floodplains. This feature plus the large amount of sloping land (Table 3.10) which promotes rapid runoff contributes to the frequent flooding experienced in Pennsylvania.

Table 3.9. Selected soil characterization data for Nolin silt loam (from Bilzi and Ciolkosz, 1977).

Horizon	Depth cm	Sand (2-0.5 mm)	Silt (0.5-0.002 mm)	Today Clay, (<0.002 mm)	Fine Clay, (<0.0002mm)	pH	Base Saturation	Free Iron Oxides (Fe_2O_3)	Organic Carbon
		%					%		
A	0-8	22.3	58.3	19.4	10.5	7.1	72.9	2.0	2.76
Bw1	8-25	17.7	59.9	22.4	13.3	7.4	75.4	2.3	1.23
Bw2	25-40	28.8	53.6	18.6	9.9	7.6	82.3	2.2	1.59
BC	40-59	44.1	34.6	21.3	13.2	7.7	83.3	1.9	1.82
Ab	59-78	36.1	47.1	16.8		7.7	82.9	1.6	2.18
Bw1b	78-90	50.6	31.1	18.3		7.8	81.0	1.4	1.71
Bw2b	90-99	54.4	28.8	16.8		7.8	80.5	1.5	1.91
2C	99-120	63.1	21.9	15.0		7.8	83.1	2.2	1.34

Table 3.10. Percentage of land in various slope classes in Pennsylvania (Cunningham and Day, 1986).

Area and County	Slope Classes (Percent) 0-3	3-8	8-15	15-25	> 25
	%				
Southeast					
Bucks	38	44	10	6	2
Lancaster	24	39	23	7	5
Ridge and Valley					
Fulton	5	19	22	26	28
Huntingdon	6	17	17	29	31
Centre	7	35	13	21	25
Unglaciated Plateau					
Armstrong	6	22	23	16	33
Indiana	13	20	22	24	21
Greene	7	8	9	26	50
Clinton	7	24	5	23	41
Glaciated Plateau					
Crawford	42	41	10	5	2
Mercer	35	50	10	3	2
Pennsylvania	12	33	17	20	18

Soils Developed in Colluvium

The valley side slopes of Nittany Valley, as well as all of the major ridges in the Ridge and Valley area, have the lower one-half to three-fourth of their slopes mantled with colluvium. The colluvium ranges from less than one foot to more than 100 feet in the thickness, and it forms simple side slope as well as more complex fan deposits. The simple slope deposits extend on the average one-half mile from the ridge crests while the fan deposits (adjacent to gaps in the ridges) commonly extend one-quarter to one-half mile beyond the simple slope deposits. The colluvial material also commonly extends down the slopes until a secondary ridge or stream is encountered. In general, there are two kinds of colluvium. The first kind was probably deposited only by mass movement (probably solifluction). This type of colluvium has many rock fragments in it. The second type might be better classed as alluvium. It is usually silty and has only a limited number of pea size rounded pebbles in it. The second type of material is found in close proximity to the stony colluvium in drains and low areas which extends beyond the stony colluvium into the valley. Limited data indicate this material can be at least 10 feet thick. Apparently, as the stony colluvium was moving down slope, a considerable amount of material was carried by very fluid mud flows or by running water and was deposited in the lower areas adjacent to the footslopes. The deposition of these materials had the effect of reducing the relief adjacent to the footslopes creating a more gently rolling landscape than was there prior to the movement and deposition of these materials.

The occurrence of colluvium is not restricted to the Ridge and Valley area; it is also extensive in the Appalachian Plateau area. The data in Table 3.4 indicate that in the Ridge and Valley area a typical county has about 27% of its area covered by colluvium; while on the Plateau, colluvium occupies an area of about 13% of a typical county. These data indicate the extensive nature of this material in Pennsylvania.

The genesis of the soils developed in these colluvial deposits is discussed by Ciolkosz et al. (1979). Data from a Buchanan and Andover soil from their publication is presented in Table 3.11. In this publication, these authors indicated that these soils may have textural changes with depth. These changes are a reflection of both textural variation in the parent material and argillic horizon development. They also indicate that these soils have fragipans in them if they are not too clayey or if they do not have much limestone influence (Murrill and associated soils) in the parent material. The authors concluded from these features and an evaluation of the weathering of clay minerals in the soils that these soils show only a moderate degree of soil development. They also state that the colluvial slopes today appear to be stable unless the toe of the slope is undercut. The material on these slopes does not appear to be moving down slope today. Little, if any deformation of trees, is noted and the argillic horizons and fragipans in these soils seems to indicate landscape stability. These materials may well be in a "super stable" condition. Under periglacial conditions, the angle of repose of this material was lower than under today's conditions. This would indicate that under present conditions these slopes are at a lower angle of repose for this material making these slopes "super stable" to natural downslope movement.

Thus, if these slopes are currently stable, when did the colluviation take place? Early workers attributed the movement and deposition to periglacial activity associated with Wisconsinan glaciation (Denny, 1956; Peltier, 1949). Although to the authors' knowledge, there is no direct evidence such as radiocarbon dates, there is indirect evidence that seems to substantiate these conclusions. The major line of this evidence points to a periglacial environment and permafrost associated with the Wisconsinan glacial time. This would indicate mass movement of material downslope and its accumulation on the lower side slopes. This evidence comes from pollen analyses (Watts, 1979; Maxwell and Davis, 1972; Martin, 1958) and the presence of other periglacial features such as patterned ground (Walters, 1978; Clark, 1968); and boulder fields, grezes litees, and involutions (Ciolkosz, 1978b); and Pingos (Marsh, 1985) in New Jersey and Pennsylvania. The similarity in soil development between the soils of the colluvial deposits and Wisconsinan glacial till deposits also indicates Wisconsinan periglacial movement and deposition (Ciolkosz, 1978a).

The chronology of deposition of the colluvium is difficult to ascertain. To the authors' knowledge, there are no radiocarbon dates available to date the colluvium. The colluvium seems to be of a similar age in that soils developed in the same kind (same lithology) of colluvium throughout the state have similar soil development. The soils developed in the colluvium are similar in some respects to Woodfordian age soils developed in glacial till in that they have fragipans, but in addition to fragipans, they have argillic horizons. This may indicate that they are older than late Woodfordian, possibly middle or early Woodfordian or even Altonian in age. A speculative chronology might start with the early Woodfordian or possibly Altonian, and as the ice moved forward, a periglacial climate with tundra vegetation

Table 3.11. Selected soil characterization data for a Buchanan and Andover soils (from Ciolkosz et al., 1979).

Soil and Horizons	depth cm	Bulk density g/cc	IWP* ------ illite	pH	Base Saturation	Coarse Fragments >2 mm	Sand 2-.05 mm	Silt .05 - .002mm	Clay <.002 mm	Textural Class
					----------	----------	----%----	----------	----------	
Buchanan (39-41)**										
Ap	0-28	1.40	2.84	5.6	22	17	36.0	49.1	14.9	l
Bt1	28-40	1.53	1.89	5.9	33	32	36.8	44.8	18.4	l
Bt2	40-50	1.60	0.71	5.7	34	58	32.2	39.7	28.1	cl
Bx1	50-75	1.56	0.46	5.2	17	13	32.7	37.9	29.4	cl
Bx2	75-95	1.64	----	5.2	10	13	33.8	37.0	29.2	cl
Bx3	95-113	1.67	0.62	5.2	12	14	31.3	37.2	31.5	cl
Bx4	113-135	1.67	----	5.2	9	15	31.2	38.6	30.2	cl
Bx5	135-160	1.68	0.60	5.2	9	14	31.6	38.3	30.1	cl
Bx6	160-188	1.67	0.54	5.2	8	29	35.7	36.3	28.0	cl
Andover (18-13)**										
Ap	0-23	1.24	1.59	6.0	56	8	29.6	46.6	23.8	l
E	23-35	1.48	----	6.2	57	36	34.4	46.4	19.2	l
Bt1	35-45	1.61	0.31	6.1	58	26	33.5	42.4	24.1	l
Bt2	45-68	----	----	5.4	53	34	31.7	40.4	27.9	cl
Bx1	68-80	----	0.30	5.1	37	28	28.6	46.6	24.8	l
Bx2	80-95	----	----	5.1	39	26	41.0	39.5	19.5	l

*IWP = Illite Weathering Products (see Ciolkosz et al., 1979)

**Pennsylvania State University Soil Characterization Lab. Number

(H. E. Wright, personal communication) triggered solifluction movement down slope. As the climate warmed and the ice retreated, soil formation progressed on the stabilized slopes. Because the colluvial material was derived from weathered material and not fresh rock, the soils in the colluvium may have developed an argillic horizon more rapidly. Another possibility is that the bulk of the solifluction took place in the early Woodfordian or Altonian and soil formation progressed through most of Woodfordian time. This may also explain the differences noted between soils developed in colluvium and glacial till of similar lithology.

Some recent work by Hoover (1983) indicates that the colluvial deposits are more complex than previously reported. Hoover indicates that many of the slopes in the Ridge and Valley area have older colluvium (pre-Wisconsinan deposits and paleosols) buried by many recent Wisconsinan age material. He also indicates that where the old Wisconsinan colluvium is thin, present soil forming processes extend into the older material.

Although Denny (1956) states that periglacial activity decreases rapidly with distance from the Wisconsinan moraine, the presence of colluvium on all the major ridge slopes in Pennsylvania indicates signficant periglacial mass movement a considerable distance south of the Wisconsinan moraine. This has particular significance when related to the work of Clark (1968), who has found patterned ground sites, presumably associated with periglacial activities, at high elevations in the Appalachians as far south as southern Virginia and Walters (1978) who has found patterned ground in southern New Jersey. Thus, soils developed from colluvium similar to those in Pennsylvania probably extend as far south in the Appalachians as Virginia and Tennesee. Although not studied in detail, soil scientists in Virginia indicate that the present mesic-thermic soil temperature boundary (Washington, DC west to the blue ridge and then south along the blue ridge) may separate the zone of periglacial erosion to the north from non-altered areas to the south. This conclusion is based on presence of thin soils north of the line and thick, well developed soils south of the line on the same landforms and lithologies.

Concluding Remarks

The discussion given above on the soils of the Nittany Valley area indicates that parent material, time, and topography (erosion) are locally the most important soil forming factors. Most of the soil surfaces we see are Wisconsinan in age (< 75,000 years old). Soils older than Wisconsinan age are fount but their genesis is complex. For example, the red colluvium buried by the brown colluvium on the mountain sides is a pre-Wisconsinan soil. This soil may be buried so deep that present day forming soil processes do not affect it greatly, or it may be near enough to the surface that the present processes are affecting its development and the two soils are being welded together. Only on the stablest landscape surfaces have pre-Wisconsinan soils been preserved, and even on these surfaces, the upper part of many of the soils have been modified by cryoturbation and the addition of aeolian dust. the major erosion and turbation that has affected the soils of the area is associated with periglacial climates of the Wisconsinan glacial time and to a certain extent the pre-Wisconsinan. Because these soils are relatively young, the effect of parent material is greater than if these soils were very old. For example, a Berks soil is brownish-grey in color and has a loamy texture with amny shale chip rock fragments, while a Murrill is yellowish-brown, silty with some sandstone rock fragments. With time, both of these soils will develope toward a soil with red color, no rock fragments, and a clayey texture.

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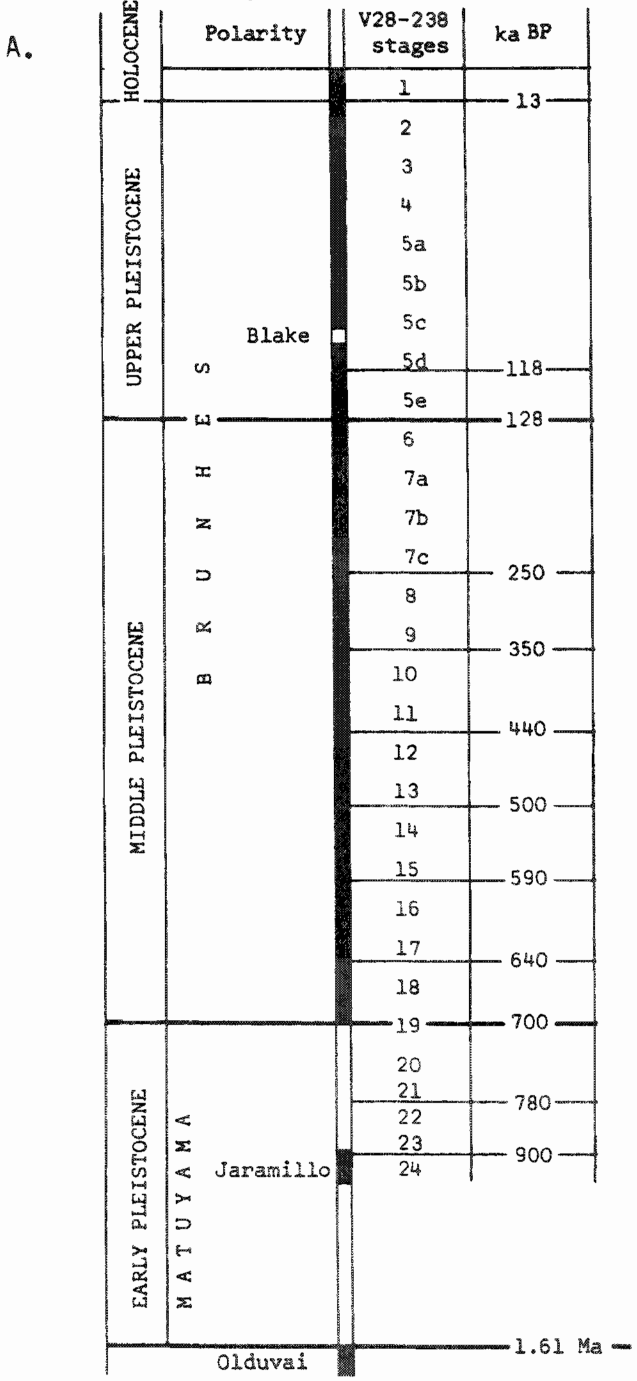
CHAPTER 4

Paleoclimate

Climate is an important factor affecting soil formation. Although landforms in Pennsylvania may date back many millions of years (Sevon, 1985), the soils on these landforms are much younger. Most soils in Pennsylvania are of the Pleistocene age. The age of the Pleistocene has varied since this segment of geologic time was first established but it now appears that there is some agreement on its start at 1.61 million YBP (Fig. 4.1).



B.

Stage and Substage	Years Before Present (YBP)
Holocene	10,000
*Valdern	11,000
Twocreekan	12,500
*Woodfordian	25,000
Farmdalian	28,000
*Altonian	75,000
Sangamonian	128,000
*Illinoian (Pre-Wisconsinan)	>128,000

*Glacial Advances

Fig. 4.1 Pleistocene correlation diagram (A from Bowen, 1978; B from Berg et al., 1985).

Until the advent of deep sea isotope studies, there has been no continuous function chronology to trace climatic change with time. Fig. 4.2 and Table 4.1 give the isotope data of Shackleton and Opdyke (1973), and Fig. 4.3 gives a plot of the last segment of the Pleistocene by the CLIMAP (1984) group. The interpretation of

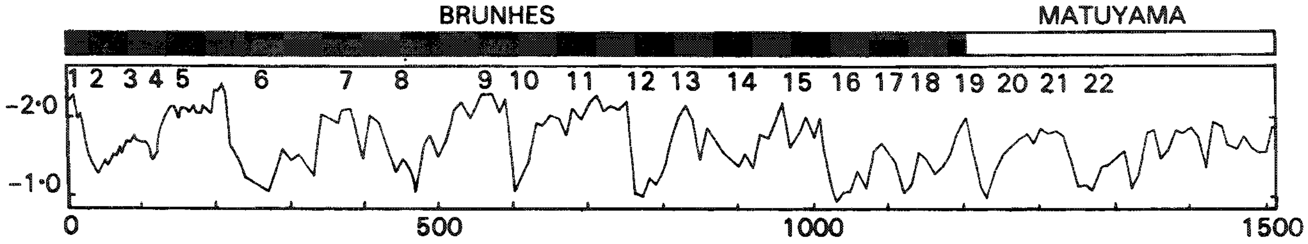


Fig. 4.2 Oxygen isotope diagram (from Shackleton and Opdyke (1973).

Table 4.1 Estimated ages of isotope stage boundaries (from Shackleton and Opdyke, 1973).

Boundary	Age (YBP)	Boundary	Age (YBP)
1-2	13,000	10-13	472,000
2-3	32,000	13-14	302,000
3-4	64,000	14-15	342,000
4-5	75,000	15-16	592,000
5-6	128,000	16-17	627,000
6-7	195,000	17-18	647,000
7-8	251,000	18-19	688,000
8-9	297,000	19-20	706,000
9-10	347,000	20-21	729,000
10-11	367,000	21-22	782,000
11-12	440,000		

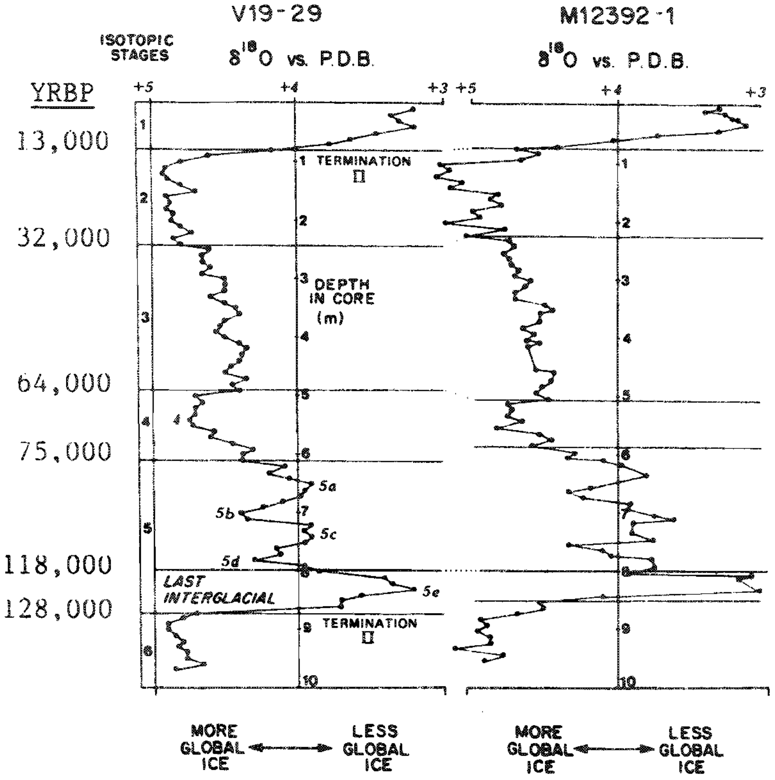


Fig. 4.3 Oxygen isotopic records of the last 150,000 yr. from Pacific core V19-29 and Atlantic core M12392-1 (data from Shackleton (1977)). Last interglacial level (Substage 5e) marks the last time that isotopic values were as light as they are today, suggesting global ice volumes at least as small as those today (from CLIMAP, 1984).

these data is still controversial, but in general, it is believed that these curves indicate volumes of ice on the earth's surface which should be indicators of temperature. Davis et al. (1980) indicates that from the Hypsithermal (9,000 to 5,000 YBP) to today in New England, there has been a decrease in mean annual temperature (MAT) of 2°C which would be equal to the small dip in the curves on Fig. 4.3. The presence of ice wedge casts (Cronce and Ciolkosz, 1986) and Pingos (Marsh, 1985) in Pennsylvania indicate a MAT of -5 to -10°C (Washburn 1980; Pewe, 1983) during the Woodfordian (25,000 to 12,500 YBP). The present MAT at State College is 10°C, thus there has been a 15 to 20°C rise in MAT between the Woodfordian and today in central Pennsylvania. If we take these data and extend them to the post 128,000 year time (post Illinoian time), it would appear from the isotope curve that the period of 128,000 to 118,000 YBP (Stage 5e) was similar to today in temperature and that the period of 118,000 to 75,000 YBP (5a-d) was much colder than today. The data of King and Saunders (1986) and King (1986) does not support this conclusion. Their data indicates that in central Illinois the climate during the 128,000 to 118,000 YBP period was much warmer in which there was no annual frost (possibly equivalent to Cuba today) and the precipitation was less (equivalent to western Iowa today. They also believe that the climate during the period 118,000 to 75,000 YBP was similar to that of today. Thus the isotope curve gives trends but the absolute value needs to be calibrated.

These data are very helpful in interpreting the paleoclimate that soils have undergone during their development. Much still needs to be uncovered but the deep sea record appears to be the only continuous function indicator available although its absolute value as a climatic indicator needs to be investigated more closely.

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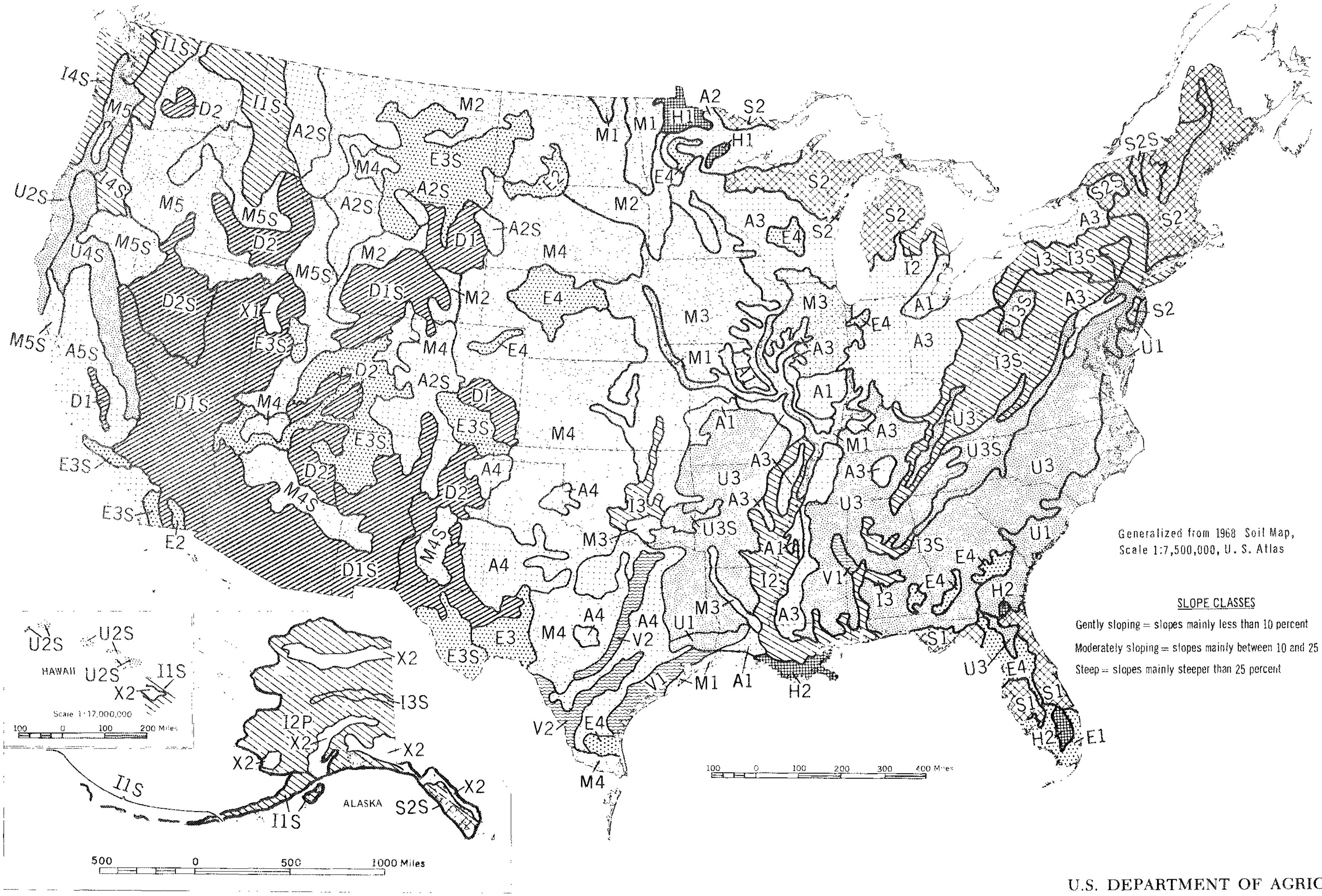
PATTERNS OF SOIL ORDERS AND SUBORDERS OF THE UNITED STATES



Generalized from 1968 Soil Map,
Scale 1:7,500,000, U. S. Atlas

SLOPE CLASSES

Gently sloping = slopes mainly less than 10 percent

Moderately sloping = slopes mainly between 10 and 25 percent

Steep = slopes mainly steeper than 25 percent

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Only the dominant orders and suborders are shown. Each delineation has many inclusions of other kinds of soil. General definitions for the orders and suborders follow. For complete definitions see Soil Survey Staff, Soil Classification, A Comprehensive System, 7th Approximation, Soil Conservation Service, U.S. Department of Agriculture, 1960 (for sale by U.S. Government Printing Office) and the March 1967 supplement (available from Soil Conservation Service, U.S. Department of Agriculture). Approximate equivalents in the modified 1938 soil classification system are indicated for each suborder.

▒ ALFISOLS . . . Soils with gray to brown surface horizons, medium to high base supply, and subsurface horizons of clay accumulation; usually moist but may be dry during warm season

A1 AQUALFS (seasonally saturated with water) gently sloping; general crops if drained, pasture and woodland if undrained (Some Low-Humic Gley soils and Planosols)

A2 BORALFS (cool or cold) gently sloping; mostly woodland, pasture, and some small grain (Gray Wooded soils)

A2S BORALFS steep; mostly woodland

A3 UDALFS (temperate or warm, and moist) gently or moderately sloping; mostly farmed, corn, soybeans, small grain, and pasture (Gray-Brown Podzolic soils)

A4 USTALFS (warm and intermittently dry for long periods) gently or moderately sloping; range, small grain, and irrigated crops (Some Reddish Chestnut and Red-Yellow Podzolic soils)

A5S XERALFS (warm and continuously dry in summer for long periods, moist in winter) gently sloping to steep; mostly range, small grain, and irrigated crops (Noncalcic Brown soils)

▨ ARIDISOLS . . . Soils with pedogenic horizons, low in organic matter, and dry more than 6 months of the year in all horizons

D1 ARGIDS (with horizon of clay accumulation) gently or moderately sloping; mostly range, some irrigated crops (Some Desert, Reddish Desert, Reddish Brown, and Brown soils and associated Solonetz soils)

D1S ARGIDS GENTLY SLOPING TO STEEP

D2 ORTHIDS (without horizon of clay accumulation) gently or moderately sloping; mostly range and some irrigated crops (Some Desert, Reddish Desert, Sierozem, and Brown soils, and some Calcisols and Solonchak soils)

D2S ORTHIDS gently sloping to steep

▒ ENTISOLS . . . Soils without pedogenic horizons

E1 AQUENTS (seasonally saturated with water) gently sloping; some grazing

E2 ORTHENTS (loamy or clayey textures) deep to hard rock; gently to moderately sloping; range or irrigated farming (Regosols)

E3 ORTHENTS shallow to hard rock; gently to moderately sloping; mostly range (Lithosols)

E3S ORTHENTS shallow to rock; steep; mostly range

E4 PSAMMENTS (sand or loamy sand textures) gently to moderately sloping; mostly range in dry climates, woodland or cropland in humid climates (Regosols)

▒ HISTOSOLS . . . Organic soils

H1 FIBRISTS (fibrous or woody peats, largely undecomposed) mostly wooded or idle (Peats)

H2 SAPRISTS (decomposed mucks) truck crops if drained, idle if undrained (Mucks)

▨ INCEPTISOLS . . . Soils that are usually moist, with pedogenic horizons of alteration of parent materials but not of accumulation

I1S ANDEPTS (with amorphous clay or vitric volcanic ash and pumice) gently sloping to steep; mostly woodland; in Hawaii mostly sugar cane, pineapple, and range (Ando soils, some Tundra soils)

I2 AQUEPTS (seasonally saturated with water) gently sloping; if drained, mostly row crops, corn, soybeans, and cotton; if undrained, mostly woodland or pasture (Some Low-Humic Gley soils and Alluvial soils)

I2P AQUEPTS (with continuous or sporadic permafrost) gently sloping to steep; woodland or idle (Tundra soils)

I3 OCHREPTS (with thin or light-colored surface horizons and little organic matter) gently to moderately sloping; mostly pasture, small grain, and hay (Sols Bruns Acides and some Alluvial soils)

I3S OCHREPTS gently sloping to steep; woodland, pasture, small grains

I4S UMBREPTS (with thick dark-colored surface horizons rich in organic matter) moderately sloping to steep; mostly woodland (Some Regosols)

☐ MOLLISOLS . . . Soils with nearly black, organic-rich surface horizons and high base supply

M1 AQUOLLS (seasonally saturated with water) gently sloping; mostly drained and farmed (Humic Gley soils)

M2 BOROLLS (cool or cold) gently or moderately sloping, some steep slopes in Utah; mostly small grain in North Central States, range and woodland in Western States (Some Chernozems)

M3 UDOLLS (temperate or warm, and moist) gently or moderately sloping; mostly corn, soybeans, and small grains (Some Brunizems)

M4 USTOLLS (intermittently dry for long periods during summer) gently to moderately sloping; mostly wheat and range in western part, wheat and corn or sorghum in eastern part, some irrigated crops (Chestnut soils and some Chernozems and Brown soils)

M4S USTOLLS mostly sloping to steep; mostly range or woodland

M5 XEROLLS (continuously dry in summer for long periods, moist in winter) gently to moderately sloping; mostly wheat, range, and irrigated crops (Some Brunizems, Chestnut, and Brown soils)

M5S XEROLLS moderately sloping to steep; mostly range

▒ SPODOSOLS . . . Soils with accumulations of amorphous materials in subsurface horizons

S1 AQUODS (seasonally saturated with water) gently sloping; mostly range or woodland; where drained in Florida, citrus and special crops (Ground-Water Podzols)

S2 ORTHODS (with subsurface accumulations of iron, aluminum, and organic matter) gently to moderately sloping; woodland, pasture, small grains, special crops (Podzols, Brown Podzolic soils)

S2S ORTHODS steep; mostly woodland

☐ ULTISOLS . . . Soils that are usually moist, with horizon of clay accumulation and a low base supply

U1 AQUULTS (seasonally saturated with water) gently sloping; woodland and pasture if undrained, feed and truck crops if drained (Some Low-Humic Gley soils)

U2S HUMULTS (with high or very high organic-matter content) moderately sloping to steep; woodland and pasture if steep, sugar cane and pineapple in Hawaii, truck and seed crops in Western States (Some Reddish-Brown Lateritic soils)

U3 UDULTS (with low organic-matter content; temperate or warm, and moist) gently to moderately sloping; woodland, pasture, feed crops, tobacco, and cotton (Red-Yellow Podzolic soils, some Reddish-Brown Lateritic soils)

U3S UDULTS moderately sloping to steep; woodland, pasture

U4S XERULTS (with low to moderate organic-matter content, continuously dry for long periods in summer) range and woodland (Some Reddish-Brown Lateritic soils)

▤ VERTISOLS . . . Soils with high content of swelling clays and wide deep cracks at some season

V1 UDERTS (cracks open for only short periods, less than 3 months in a year) gently sloping; cotton, corn, pasture, and some rice (Some Grumusols)

V2 USTERTS (cracks open and close twice a year and remain open more than 3 months); general crops, range, and some irrigated crops (Some Grumusols)

☐ AREAS with little soil . . .

X1 Salt flats

X2 Rock land (plus ice fields in Alaska)

NOMENCLATURE

The nomenclature is systematic. Names of soil orders end in *sol* (L. *solum*, soil), e.g., ALFISOL, and contain a formative element used as the final syllable in names of taxa in suborders, great groups, and subgroups.

Names of suborders consist of two syllables, e.g., AQUALF. Formative elements in the legend for this map and their connotations are as follows:

and	—Modified from Ando soils; soils from vitreous parent materials
aqu	—L. *aqua*, water; soils that are wet for long periods
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hum	—L. *humus*, earth; presence of organic matter
ochr	—Gr. base of ochros, pale; soils with little organic matter
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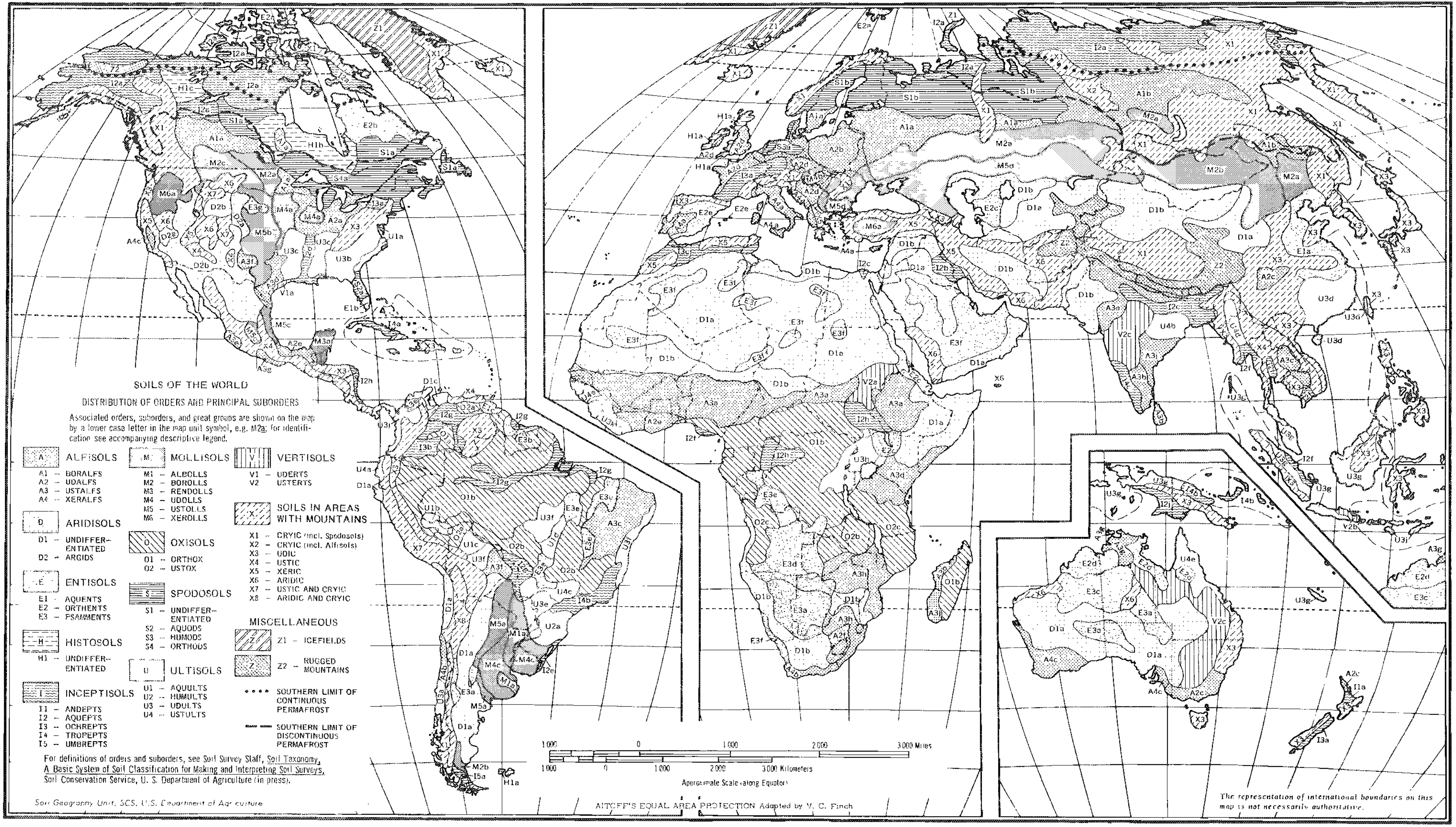
psamm	—Gr. *psammos*, sand; sandy soils
sapr	—Gr. *sapros*, rotten; most decomposed
ud	—L. *udus*, humid; of humid climates
umbr	—L. *umbra*, shade; dark colors reflecting much organic matter
ust	—L. *ustus*, burnt; of dry climates with summer rains
xer	—Gr. *xeros*, dry; of dry climates with winter rains

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

SOILS OF THE WORLD
Distribution of Orders and Principal Suborders



MAY 1972

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D2S ORTHIDS gently sloping to steep

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