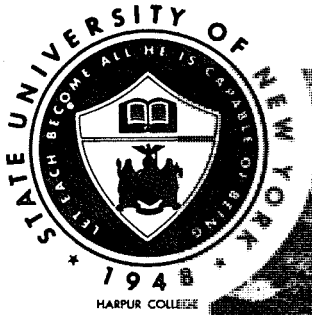


# G E O L O G Y

of

## SOUTH-CENTRAL NEW YORK



GUIDEBOOK FOR  
NEW YORK STATE GEOLOGICAL ASSOCIATION  
35th Annual Meeting — May 1963



GEOLOGY OF SOUTH-CENTRAL NEW YORK

a guidebook  
with articles and field trip logs  
prepared for the

NEW YORK STATE GEOLOGICAL ASSOCIATION

35th Annual Meeting

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Donald R. Coates, Editor

HOST

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## PREFACE

## INTRODUCTION

The geology of south-central New York, when compared with that of other sections of the State, is not well known having received rather limited attention in the geological literature. The following points may help explain this condition:

1. In the early days of the New York State geological survey, Lardner Vanuxem was assigned the task of reporting on the geology of central New York. He found the Finger Lakes Region more rewarding, however, and spent little time in south-central New York.
2. A main objective of this initial mapping project was the location of economic resources. In this quest south-central New York came out "second best". The Adirondacks were found to be rich in metals and other mineral products; northern New York had limestone and water resources; western New York produced oil and gas; and, the Hudson Valley area offered a wide variety of economic products. With the possible exception of a few small and scattered quarries of stone, sand and gravel, south-central New York was considered to be some sort of "waste land".
3. Until recent years the Binghamton area was much less populous than such cities and industrial centers as Buffalo, Rochester, Syracuse, Utica, Schenectady-Albany, and New York City. These communities attracted major universities and colleges many of which established geology departments at an early date. One notable exception was the smaller community of Ithaca which lured a fine university by the beauty of its landscape. During the growth and development of a geological department it is customary to undertake research and mapping problems in the immediate vicinity resulting in an early understanding of the local geology. Harpur College is barely 12 years old and only in the last few years has there been more than one geology professor.
4. The geology of south-central New York is also less diversified than that encountered in other parts of the State. Only sedimentary rocks of Devonian age are exposed in this region and they lack the structural complexities which so often have served as a valuable research stimulant.

Although some excellent geological work has been done in this area, the editor often wondered, during preparation of this guidebook, whether this region could support a series of interesting field trips. The history of geology and men, however, cannot be altered to serve our present purpose. Consequently, this guidebook attempts to accomplish a three-fold objective: First, to review the material that has already appeared in the geological literature; second, to present new material that either has not been published or is not readily accessible; and third, to offer a field guide to localities that reveal important aspects of the geology of south-central New York.

Taking into consideration the above-mentioned difficulties and acting in the dual role of editor and author, the undersigned has deemed it necessary to choose a format and select subject matter in an entirely different manner than found in previous NYSGA guidebooks. For better or worse, he assumes full responsibility for his unilateral judgment.

## ACKNOWLEDGMENTS

As in all cooperative efforts of this type a long list of acknowledgments could and perhaps should be cited. However, the editor trusts that he has already made it clear to the many individuals who have had a hand in the preparation of this guidebook that this task could not have been accomplished without their manifold devoted efforts. Special credits are given throughout the several reports. Particular appreciation is

reserved for the authors of the articles, for student geology departmental assistants at Harpur, and for the administrative officials of Harpur College.

The writers have had complete freedom in the preparation of their manuscripts and in the selection of field trip localities. They assume responsibility for the accuracy of their data and for the interpretations based upon them. The editor is charged with all errors committed in the process of putting the original manuscript into the final printed form.

#### GEOLOGY SUMMATION

The 350,000,000 year geologic history of south-central New York begins with the deposition of sediments during Middle Devonian time. Highlands to the south and east of the present State line were the original site of the materials. This source area is known as the "Acadian Mountains", named from mountain roots that are still visible in the maritime provinces of eastern Canada. Seas that invaded eastern North America were present in southern New York during the early growth of the mountains. Degradational processes in the highlands washed the waste products westward into lowlands and into the sea, forming alluvial plains and deltas of a size measured in thousands of square miles. The volume of these Devonian sediments is similar in magnitude to the Sierra Nevada Mountains. In the marine part of the delta, silts, muds, and clays with occasional sands were deposited while on land sands were most common with smaller amounts of silt and mud. With the gradual filling of the marine trough sea level migrated westward so that coarser materials transgressed on the earlier fine-grained sediments. Lithification processes have turned the sediments into the shales, siltstones, sandstones and graywackes that comprise the bedrock of the region.

South-central New York possesses no obvious clues to historical developments from the Devonian until the area is transformed by the Appalachian time of deformation. Although the Permian stresses severely contorted rocks in eastern New York and in Pennsylvania, the force was greatly diminished in vigor by the time it reached south-central New York. Thus, this part of the State has only mild left-over flexures with east and north-east trends that gently wrinkle a homocline that dips south to southwest.

New York undoubtedly had a profound erosional cycle in post-Permian-Triassic time that endured until Cretaceous time. The location of the Cretaceous shoreline and the evolution of drainage systems have been hotly debated for more than 70 years. There is a modest amount of agreement that many landforms in south-central New York are post-Cretaceous with some possibility of remnant drainage traces of an earlier vintage.

The last pages of geologic history were written during the Wisconsin age of glaciation when all of southern New York was entombed under ice at least one or more times. The richness of the glacial heritage is abundantly visible in the variety of erosional forms and glacial deposits found in the area. Indeed, the ice ages have provided extra flavor to the topography, as they were the stimulus for causing the superposition of youthful valleys on an otherwise maturely-dissected landscape.

Donald R. Coates  
Editor

## ORGANIZATION OF THIS BOOK

The sequence of articles in this volume begins with a broad view by H. A. Meyerhoff of the tectonic elements of eastern North America and their influence in subsequent landmass development of the region. Generalizations concerned with many facets of the geology of south-central New York are then discussed by D. R. Coates. Important stratigraphic features of the western part of the area are evaluated by D. L. Woodrow and R. C. Nugent along with discussion of methods that have proved rewarding in deciphering the depositional history. Finally, a detailed analysis of the Binghamton area is made. J. E. Sorauf and H. E. Roberson provide data on bedrock features, and D. R. Coates presents information on development of the topography and surficial deposits.

## COVER PAGE

An aerial view of the Cannonsville vicinity looking east and upstream the West Branch Delaware River. The picture was taken prior to construction activities by the Board of Water Supply, City of New York, in their preparation of this site for a dam and reservoir.



NEW YORK'S ROLE IN THE MESOZOIC AND TERTIARY  
EVOLUTION OF THE NORTHERN APPALACHIANS

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INTRODUCTION

There is irony in the fact that the Paleozoic history of the Appalachian Mountains is better known and less controversial than the Mesozoic development of this marginal upland. Bits and pieces - some of them of the utmost significance - are still being fitted into gaps in the jigsaw puzzle of events that preceded the Appalachian orogeny. Yet the relatively full stratigraphic record preserved in the fold belt forces general agreement on most of the major events of Paleozoic time and limits controversy to paleogeographic and correlative details.

In New England and Maritime Canada, gaps in the lithologic record are still troublesome despite the intensive research of the past quarter century, and the Precambrian is a veritable no man's land. Even in these areas of ignorance, thinking among members of the profession is not seriously at odds, if only because the conviction prevails that the problems are defined, and answers will be found as field and laboratory investigations proceed, and research techniques are refined.

Perhaps if all the basic elements in the pre-Mesozoic geology of the northeastern states are brought together and evaluated, the post-orogenic history can be made less controversial. In New York and its environs these elements fall into categories of structure, sedimentation and stratigraphy, and what may be called relic topography. Although they must of necessity be analyzed separately, they are interdependent, and it is only through an understanding of their interdependence that coherent interpretations can be made, not only of Paleozoic evolution but of the events that followed the mountain-making movements that terminated that era.

Notwithstanding the welter of structural detail in the northern Appalachians, the major structural features are comparatively few in number. They comprise the New England upland, the Champlain-Hudson trench, the Adirondack Dome, the Catskill-Pocono Prong, the Anthracite Basin, the normal fold belt, and the Precambrian marginal belt. Within the latter, constituting a distinct structural unit, is the Upper Triassic trough.

THE NEW ENGLAND BOUNDARY

The western margin of the New England upland (Fig.1) is a phenomenally straight and persistent mountain front which, despite erosional re-entrants, extends unbroken from

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Author's Acknowledgement: This article is based in large part on field, laboratory, and library research performed jointly with Elizabeth W. Olmsted, formerly of Smith College. Circumstances precluded joint authorship, but the writer appreciatively shares the credit with her for the factual material summarized herein, while assuming responsibility for the interpretation of the facts.

Editor's Note: This article heralds the welcome return of Professor Meyerhoff to academic affairs. The editor is honored to present this summarization of a much longer manuscript. This publication is a timely vehicle for the author's wide range of experience and interest in problems of post-Appalachian drainage in eastern North America.

northern Westchester County to the Canadian line in Vermont. In Canada this front becomes arcuate, swinging from a strike of  $N.10^{\circ} E.$  in the States to due east-west in Quebec, where it even hooks southeastward as it approaches Cape Gaspe. Slight discordance between the front and the fold structures of the Berkshire-Green Mountains component of the New England upland produces local en echelon re-entrants. Contrasts in rock types and in degrees of metamorphism between bedrock in the Champlain-Hudson trench and in the mountain element, as well as fensters in the latter, indicate that this section of New England was moved westward and slightly northward on a low-angle thrust.

The drainage and topographic form of the Berkshire-Green Mountains component merit more attention than they can be given in this summary paper. In general, the drainage divide is asymmetric as far north as White River, which heads less than 20 miles southwest of Montpelier. South of this point only the few west-flowing streams that developed subsequent courses in the en echelon structures mentioned above acquire any length or volume before they join the Hudson or empty into Lake Champlain. One striking topographic anomaly also deserves mention: There is at least one transverse pass that strikes almost due northwest-southeast, in marked discordance with the strike of the country rock. Used by the road and old railroad between Rutland and Bellows Falls, this high valley appears to be one of the relic topographic features inherited from early Mesozoic time.

#### THE CHAMPLAIN-HUDSON TRENCH

The Champlain-Hudson trench is customarily described as a subsequent valley or lowland, excavated in easily eroded Ordovician formations lying between the resistant rock of the Adirondacks and Green Mountains in the north, and between the Catskills and the Berkshires and Taconics in the south. This description is accurate enough, but it stops short of completion and misses a significant point related to the genesis of the trench. The subsequent lowland veers southwestward at Newburgh and Cornwall-on-Hudson to follow the Ordovician outcrop, narrowing to a constricted valley between the Precambrian of the Hudson Highlands and Shawangunk Mountain, whereas the trench continues its southerly course in the Croton River watershed, to the east of the sagging terminus of the Hudson Highlands. It loses its identity in Westchester County, where marginal marine planation has beveled all rocks indiscriminately and has destroyed the topographic break between the New England front and the trench. Until more definitive field research has been completed, the temptation to extend the western fault boundary of the New England upland into the Newark trough must be avoided.

#### THE ADIRONDACK DOME

Geologically, the Precambrian outlier that forms the Adirondacks is allied with the Canadian Shield, but its role in the paleogeographic and geomorphic development of eastern and south-central New York links the uplift even more closely with the Appalachian Mountains. Its eastern section is an area of high elevations and sharp relief, dominated by strong fracture lines that give its topography a northwest-southeast, and northeast-southwest grid pattern. The western section is an area of moderate to low relief, which is only partly explained by the change in rock types.

The east front rises in a prominent scarp above the Champlain lowland, whereas the other boundaries are those characteristic of marginal overlap of young sediments upon a structural dome. Stripping and differential erosion of the Paleozoic formations have developed a cuesta-lowland topography that is especially prominent to the south. In this direction the Paleozoic strata dip uniformly south with only minor structural complications. The subsequent Mohawk Valley breaks the topographic continuity of the southern Adirondacks and the Appalachian Plateau, but between the dome and the Pennsylvania state line the monoclinical dip is interrupted only by local structural terracing and minor rever-

sals in broad anticlinal structures. Subsurface irregularities in the form of folds and faults become more numerous and pronounced southward and south-westward, but they exert little, if any, influence on the surface features. In northern and west-central Pennsylvania, however, gentle folds strongly influence the topography and drainage.

It is generally believed that the Adirondack dome has functioned as a positive mass at least since early Cambrian time. Cambrian, Ordovician, and Siluric strata exhibit overlap or offlap relations to it. It may have been covered in large part, possibly in toto, by Devonian formations, but not by any of the younger Paleozoic beds. The deep dissection of the faulted eastern section has lured some investigators into the belief that faulting and displacement occurred in Mesozoic or even Cenozoic time, but every attempt to support this hypothesis with tangible proof has failed. On the contrary, the limited evidence available suggests that the fracturing was genetically related to the orogenic forces that thrust the Green Mountains-Berkshire mass westward. Canadian and New England geologists have favored an Acadian or post-Devonian date for this movement, but an Appalachian or post-Permian date is far more probable.

#### THE CATSKILL-PRONG - ANTHRACITE BASIN

The Catskill and Pocono mountains comprise a stratigraphic unit, as well as a single structural form. The 4,000-foot elevations attained by the Catskills within a few miles of the Hudson Valley reflect the erosional resistance of the conglomeratic cap rock of this Devonian-Mississippian fan, but there is reason to believe that its initial height was enhanced by differential uplift, possibly in the Acadian Disturbance but more probably in the Appalachian orogeny. The component strata dip radially south-westward and westward from the front overlooking the Hudson Valley, and progressively younger formations appear southwestward. How much of the regional dip is depositional and how much is deformational is not known, but it has produced a crude concentric cuesta-lowland topography that apparently played a significant part in fixing the courses of the upstream sections of the Delaware and Susquehanna rivers.

Although the Catskill and Pocono formations thin southwestward into the Pocono Mountains, they retained sufficient competence to resist deformation and to transmit the lateral force of the Appalachian orogeny to the Anthracite Basin. The latter was pinched between the massive and more highly indurated materials of the fan and the rising crystalline basement of the Appalachian Plateau. Its plunging synclinal form is complicated by faulting, but it was obviously one of the lowest points in elevation, not only during late Paleozoic sedimentation, but also during and following the mountain-making that ended the era.

#### THE FOLD BELT

West and southwest of the Poconos and the Anthracite Basin, the folds of the mountain range become open and they fill the broadened geosynclinal belt from the Reading Prong to the margin of the plateau. Their plunging, asymmetric forms have been so well and so frequently described that any new exposition of their general characteristics is unnecessary. A single point will be made: The intensity of deformation increases southeastward and southward, and in this direction, also, the post-Ordovician stratigraphic section thins and loses much of its competence. Although it is evident that the Precambrian crystalline rocks that now appear in the Highlands of the Hudson, the Ramapo Mountains, the New Jersey Highlands, Reading Prong, and the Blue Ridge, do not mark the position of a Paleozoic shoreline, there is reason to believe that the basement shelved along this line and that, when covered at all, it received sediments that were thin as compared with those deposited to the north and west in the miogeosyncline. Evidence suggests that, despite fluctuations, the Paleozoic shorelines tended to shift

northward and westward in the course of the era.

### THE PRECAMBRIAN MARGINAL BELT

The Precambrian rocks that border the fold belt starting near the boundary of New York and Connecticut in the Highlands of the Hudson trend southwestward across northern New Jersey and taper to a fragmented sliver near Reading, Pennsylvania. Here they are engulfed by Ordovician strata and/or buried beneath Triassic sediments of Newark age. Some 45 miles to the west-southwest they reappear in the attenuated extension of Blue Ridge and in the broadening band of the Piedmont. The pre-Paleozoic age of the rocks that compose most of this structural element is conclusively established. Although much of boundary between these metamorphics and the Paleozoic formations to the northwest is a fault contact, Cambrian strata have been found resting unconformably against or upon the crystalline rocks. In northern New Jersey infaulted and folded Paleozoics occur within Reading Prong and exhibit a clearly defined unconformable relationship.

In the geologically allied Piedmont, on the other hand, the ages of the component rocks are not so firmly established, but the age controversy is not the concern of this paper. More troublesome is the pronounced topographic break between the highlands of Reading Prong and Blue Ridge, and the much lower belt of metamorphic rocks that form the Piedmont. In the area under consideration the problem could be ignored, because the break is limited to a twelve- or fourteen-mile stretch east of the Hudson between Peekskill and Putnam or Brewster in Westchester and Putnam counties. Even here the problem could be finessed because the break coincides with a structural boundary. West of the Hudson, the boundary is usually drawn between the crystalline rocks of Reading Prong and the Upper Triassic sediments and volcanics of the Newark trough. This custom may be geologically sound but it blandly ignores the fact that some of the fanglomerates and diabase flows and intrusives attain, or approach, the high elevations of the Precambrian rocks of the Prong.

### THE TRIASSIC TROUGH

The Triassic troughs that lie within the New England-Acadian upland and the Piedmont have been extensively described and variously interpreted. In the Connecticut Valley of Connecticut and Massachusetts, the eastern boundary is a fault of some complexity, along which there was active displacement throughout - and probably following - the late Triassic epoch of deposition and volcanism. In the Newark trough, which is of primary concern in this paper, the active fault scarp coincided with the present Precambrian-Triassic contact as far southwest as Reading. For the 45 miles between the Reading Prong and Blue Ridge, the Newark sediments rest on Ordovician strata, and the boundary between the trough and the fold belt is geologic, not geomorphic. Triassic and Paleozoic formations are in direct fault contact.

The Newark or Palisades Disturbance evidently lasted through all of Upper Triassic time, and perhaps longer. The dominant forces were clearly compressional, because movement along the marginal faults was persistently upward, presumably along high-angle thrust planes. Simultaneously, the troughs were pressed down differentially, as is indicated by a) the maximum thickness of the section; b) the longitudinal variations in thickness; c) the regional monoclinical dip of sediments and flows; and d) local structures, which include open, plunging folds, tear faults, and other deformational features.

It has been claimed that restoration of the general surface configuration of the northern Appalachians following the Appalachian Revolution is impossible because of the denudation that has taken place since, and because of the magnitude of the movements that affected the region during the protracted Newark disturbance. This claim must be

rejected, with the frank admission that restoration of detail would be debatable, but with the unequivocal assertion that the general outlines and pattern of the post-orogenic topography are perfectly clear.

The Adirondack dome was a topographic high, raised to maximum elevations along part of its eastern border where the New England thrust plate was brought into forcible contact with it, as well as with the Catskill fan farther south. In the Adirondacks, evidence for this interpretation is provided by the impact-fracture pattern in the eastern section. In the Catskill area circumstantial but convincing proof is found in the slaty cleavage imparted to the Hudson River slaty shales, the overturn and shear faulting of the Upper Silurian-Lower Devonian Helderberg escarpment, the drag folding and tear faulting between this escarpment and the Hamilton escarpment, and the pronounced eastward upturn of the Catskill formation along the "Catskill Front".

More problematical is the relatively high elevation of the eastern stub-end of Reading Prong in the Highlands of the Hudson, for this can be interpreted satisfactorily as a case of differential erosion. Yet the Precambrian fault splinter in Snake Hill near Newburgh and the ominous, even fatal, rock bursts experienced when the siphon was tunneled under the Hudson for New York City's water supply, suggest that compression and drag were as potent forces here as they were in the Paleozoic strata in the Helderbergs between Kingston and Ravena. These facts strongly suggest that the New England upland overrode the Highlands on a low-angle thrust as far west as the present course of Hudson River and that the front was eroded, retreating eastward to the Croton watershed. In its course through the Highlands, the Hudson exhibits none of the characteristics of a superposed stream, nor does it follow any detectable single structure across the grain of this resistant upland. The initial location of drainage along the postulated fault front offers the most plausible explanation of its course, and the concept finds some support in its alignment with the upturned and faulted Helderberg escarpment just a few miles to the north. It is doubtful that any single pre-Newark stream flowed southward across the Highland belt from the subsequent lowland north of Cornwall-on-Hudson. The breakthrough was apparently triggered by late Triassic faulting, which stimulated headward erosion from the northern limits of the Newark trough, and it may not have been completed until post-Triassic time.

#### THE NITTANY ARCH AND ALLEGHENY FRONT

In north-central Pennsylvania the Nittany Arch, or anticline, and the Allegheny Front form two additional structural and topographic "highs" that exerted a dominating influence on post-orogenic development. The Nittany Arch is the highest structure within the fold belt. In its excavated core Ordovician strata are now exposed, and restoration of the complete stratigraphic section indicates that its initial height above rocks of comparable age at the contact between Triassic and Paleozoics along the course followed by Susquehanna River, was at least 3,000 feet. Even assuming rapid erosion during the Appalachian orogeny, this prominence must have acquired and retained a higher elevation than any other point in the fold belt to the south.

West and southwest of Nittany Arch, the Allegheny Front is formed by a sharp upturn of the plateau cap rock toward the fold belt. Stratigraphic studies of the Paleozoic succession have shown that the section above the Lower Ordovician thickens across the geosyncline from southeast to northwest, chiefly as a result of the appearance of new, formational units; and that thinning takes place immediately to the west-northwest of the front, where the crystalline basement rises rapidly beneath the plateau. The rise of the basement imposed an obstacle to orogenic compression that was initially reflected by the pile-up of the thickened stratigraphic section above a point approximating the projection of the ascending plane of the basement. Evidence for this view is circumstantial, resting upon simple principles of mechanics, and upon the marked deformational features that

recent drilling and geophysics have disclosed beneath the surface of the plateau.

Given pressure ridges of maximum elevation along the limited lines, or zones, of impact between the New England thrust plate and the Adirondacks and Catskills; the Adirondack Dome as a positive structural and topographic element in its own right; the Catskill-Pocono fan with sufficient acquired erosional resistance to outlast the rocks of the upland from which its materials were derived; the high Nittany Arch and Allegheny Front, it is difficult to imagine the initial early Triassic drainage of the Appalachian Mountains flowing westward from some unproven highland in the present position of Reading Prong, Blue Ridge, and the Piedmont. Downhill may have been tortuous, but it was southward from the Adirondacks, southwestward from the Catskills, thence southeastward toward the principal breaks and gaps through the relatively low Precambrian barrier. Broadest and deepest of these gaps was the 45-mile opening between the northeast terminus of Blue Ridge and the southwestern end of Reading Prong. In part of this gap the Precambrian basement never was exposed, for Ordovician strata flank the narrow band of Triassic sediments on the northwest and southeast, and presumably underlie the red beds.

Diversion of the original streams took place from several causes. Whenever and wherever Cambro-Ordovician limestones, dolomites and shales were exposed, they were rapidly eroded into subsequent lowlands. The Mohawk Valley must have developed early and has no doubt migrated down dip in the course of time. Its development was in part controlled by the excavation of the Hudson-Champlain trench on similar rocks, which were bared as streams worked headward into the fracture zone along the edge of the New England thrust plate from the St. Lawrence lowland to the north, the Lower Paleozoic reentrant between Adirondacks and Catskills, and the Wallkill Valley to the south. Transverse valleys evolved with cuesta-subsequent lowland development on the southwestern flank of the Catskill-Pocono prong and in the monocline of the central New York plateau. Notwithstanding the adjustments to structure, the initial direction of flow from high structure to low was maintained. The Delaware-Lehigh drainage crosses the Precambrian barrier at a point where Paleozoic inliers have not yet been completely removed. The eastern components of the Susquehanna moved into the structural depression formed by the Anthracite Basin, thence along the erosionally weak zone of the Harrisburg axis and out of the fold belt where the Precambrian had not surfaced. The Nittany Arch and Allegheny Front guided the Susquehanna's western tributaries.

#### THE PALISADES DISTURBANCE

Diversion of the initial and partially adjusted initial drainage in the Appalachian range is also attributable to the structural and topographic changes that accompanied the differential but essentially vertical movements that took place in late Triassic time. It is probably that the Connecticut River system is entirely a creation of this epoch, except in its upper reaches north of Hanover. In the sections of southeastern New York, northern New Jersey and southeastern Pennsylvania, drainage modifications were, for the most part, restricted to secondary stream systems because the primary drainage was already too well established to be diverted or drastically changed. That the main drainage came from the fold belt has been heatedly challenged in the face of incontrovertible evidence.

The Newark Series of sediments was deposited in a structural trough, and the material composing it was washed in from both sides, as well as from the ends. The Series has been divided into three formations - the basal Stockton, the Lockatong, and the Brunswick, in ascending order. In the Newark trough they are tilted northwestward toward the marginal fault, hence most outcrops of the Stockton are found along the southeastern margin of the basin, whereas the Brunswick tends to hug the northwest boundary. In these normal positions the Stockton contains clastic materials derived dominantly from the crystalline rocks still preserved in the Piedmont, and the Brunswick is composed of sediment that came from the northwest. Faulting has brought the basal Stockton into sight at several points within the trough, and near Clinton, New Jersey, the Flemington fault has exposed

it almost at the contact with the marginal fault. Here the formation contains abundant identifiable fragments of Paleozoic rocks that could have come only from the northwest and from localities well within the fold belt.

Triassic alluvial fans are numerous along the marginal fault, and where master streams cut through Reading Prong today, the invariable presence of fans strongly suggests a genetic relationship to ancestral streams that have evolved into the present river systems without displacement or relocation. Much of the evidence lies just outside the area under consideration, hence only a summary statement of the stratigraphic and sedimentologic basis is offered, to support the conclusion that the orientation of eastern New York's topography and drainage is a direct inheritance from the Appalachian Revolution.

The bulk of the clastic material found in the Newark trough in Pennsylvania and New Jersey - perhaps as much as 90% - came from the northwest and demonstrates conclusively that Appalachian master streams had already firmly established southeastern courses to the Atlantic in Triassic time. In Rockland County, New York, lithologic evidence leads to a different conclusion. Here in quarries between Tompkins Cove and Suffern along the Ramapo front, Triassic conglomerates contain pebbles and cobbles from an unknown source, including a porphyry no longer present anywhere in New York or New England. Similar fragments have been identified in Cretaceous strata on Long Island, and this fact, with other evidence, suggests that the fan here at the northeastern end of the trough was deposited by a stream that rose in New England and followed the fault front in a course roughly like the one now used by Peekskill Creek. It is noteworthy that Upper Triassic petrology precludes a pre-Newark course across the Highlands for the Hudson, whereas it supports pre-Newark dating for the routes still followed by the Delaware and Susquehanna.

Lithologic evidence that Appalachian drainage had an Atlantic orientation, it might be added, is also present in coastal plain sediments of Lower Cretaceous age in New Jersey and Maryland. Indeed, the coastal plain sequence from Lower Cretaceous through the Eocene contains grains and fragments of Precambrian, Cambrian, Ordovician, Silurian, and Devonian rocks in such profusion that a theory requiring no merely that the fold belt but even the Piedmont be completely covered at any time by a Cretaceous veneer, is both unnecessary and untenable.

For a much younger Tertiary marginal marine overlap there is evidence. The surface was accurately identified and partly described, but misdated, by W. M. Davis. It extends across Connecticut, following a line that joins Middletown and Nyack, New York. South of this line the interstream areas are marine-planed and streams are unadjusted to the underlying lithology. To the north, the drainage is delicately adjusted to lithology and structure, and the interstream uplands are not planed but exhibit medium- to fine-grained pluvial and fluvial dissection.

#### RELIC TOPOGRAPHY

One other feature, or element, enters into the interpretation of eastern and southern New York's land forms. It may appropriately be named relic topography, which can be defined as topography that was determined by the initial geomorphic configuration of a physiographic province or section but which is now discordant with subsequent land form evolution.

In the hypothesis that has been advanced in the preceding pages, the New England upland was interpreted as a thrust sheet that was moved westward against the Adirondacks and Catskills, both of which were, by preorogenic origin, elevated areas. If this interpretation is valid, the points of impact were also points of maximum elevation in the initial northern Appalachian topography. The zone of contact should initially have been

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the drainage divide between New England and New York, and in fact it still is, despite the discordance produced by the excavation of the Hudson-Champlain trench between the two. Asymmetry of topography and drainage still characterizes the Green Mountains and the Catskills. In the Adirondacks only the topographic asymmetry persists, because the domed structure of the mass was already well defined when deformation occurred. The line of contact was limited in extent by the re-entrant of early Paleozoic rocks from the St. Lawrence lowland to the north and the unaffected wedge of early and middle Paleozoic strata in the Mohawk re-entrant to the south. Mt. Marcy rises to an elevation of 5,344 feet a scant 25 miles west of Lake Champlain, and in Vermont Mount Mansfield, at 4,406 feet, is no farther from the lake. These two mountains and their associated peaks are part of a relic divide that can be traced eastward and northeastward into the White Mountains, thence into Maine and Gaspe. The Catskills reach their highest elevations of 4,000 feet barely 15 miles from the Hudson, which flows at tide level.

The subject of relic topography could be pursued at length, for it provides a diagnostic but neglected clue to geomorphic origins which have undergone profound modifications in the course of time, but which have not lost all of their initial characteristics. In the cases cited, the highest elevations are preserved in wholly dissimilar types of rock, hence any appeal to a lithologic explanation is precluded. Their eminence is a consequence of position - of initial protection from maximum denudation because of their headwater location.

#### CONCLUSIONS

Interpretations of the post-Permian history of the northern Appalachians have persistently been hampered by an assumption that lacks any tangible support - namely, that the Appalachian Revolution raised - or merely heightened - an impenetrable topographic barrier to the Atlantic Ocean. The assumption is based on two premises; first is the evident fact that much of the clastic sediment in the Paleozoic section of the Appalachian geosyncline came from the east, and second is the idea that in orogenic deformation, the highest structural and topographic elements must have been formed along a line, or zone, nearest the orogenic force.

The first of these premises does not follow from the fact, for the simple reason that a comparatively narrow positive element that undergoes recurrent uplift can furnish vast quantities of clastic material. Examples are numerous, notable among them being the 20,000 foot Tertiary section in the Cul de Sac of Hispanola, or the Tertiary section of California. In the northern Appalachians the presence of post-Acadian sediments in Rhode Island, Massachusetts and the Maritime Provinces, is evidence that the oldland that was elevated in the latter part of Devonian time, and was intruded and deformed in the Acadian Disturbance, was relatively narrow. There is no basis for believing that the oldland south of New England in what is now the continental shelf was any broader or any higher, if as high.

The idea that maximum elevation occurs along a line, or zone, close to the orogenic force completely ignores the principle of the transmission of force through competent materials. Maximum deformation and elevation are localized by obstructions to free movement, or by incompetence within the section undergoing compression. Two illustrations of this principle of mechanics have been briefly described in the preceding pages - namely, the Anthracite Basin and the Helderberg escarpment between Kingston and Ravena. The Nittany Arch is another equally striking example, however much it may differ from the other two in form.

It is difficult to understand why adherents of the postulate that post-orogenic drainage in the Appalachians flowed westward attach so much importance to Paleozoic sedimentation and so little to the equally clear Mesozoic and Tertiary record. The Newark



Series attains a maximum thickness of 20,000 feet in New Jersey, and the bulk of the clastic material came from the northwest - mostly from the fold belt. Lower Cretaceous, Upper Cretaceous, and Eocene formations in the coastal plain all contain fossiliferous fragments of Cambrian, Ordovician, and Devonian strata, hence there is no question about a source in the fold belt in any part of the stratigraphic section deposited in post-Middle Triassic time.

Eastern and southern New York State occupies a key structural position in the northern Appalachians, yet relatively little significance has been attached to structures that must have dominated the post-Paleozoic evolution of the entire region because of the pivotal positions they occupy. The Adirondack dome, the Catskill-Pocono prong, and the Champlain-Hudson trench are the principal structural elements. Whether their meaning has been correctly interpreted in this article is not for its author to judge, but it is hoped that the dire need for a reassessment of earlier interpretations has been made abundantly clear.

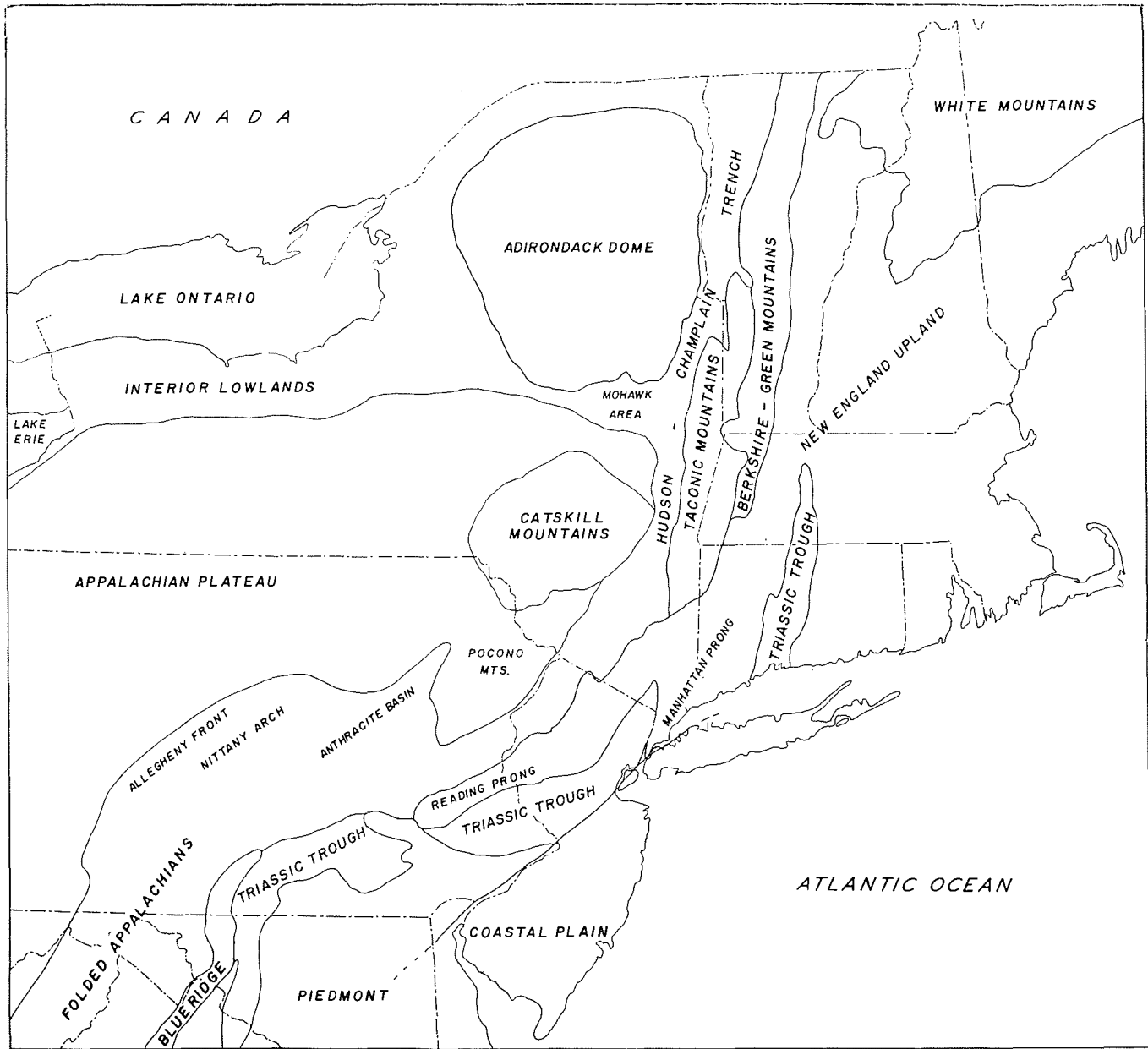
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SCALE IN MILES  
10 0 10 20 30 40 50

TECTONIC ELEMENTS OF NORTH-EAST UNITED STATES

Figure 1.



## GENERAL GEOLOGY OF SOUTH-CENTRAL NEW YORK

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## PHYSICAL SETTING

South-central New York is part of the Appalachian Plateau geomorphic province (Fig. 1), and the Catskill Mountains comprise the more rugged eastern part of the region. The Susquehanna River and Delaware River (Fig. 2) are the master drainage systems. According to textbooks the Appalachian Plateau stereotype is supposed to be characterized by rocks that are essentially horizontal and structureless, are of Paleozoic age, and fall within a Davisonian cycle of being "maturely-dissected" with drainages systems that are largely of dendritic shape. On close examination, many of these ideas need modification.

In New York the Appalachian Plateau is bounded by lowlands of older and more complexly deformed rocks. The Hudson-Mohawk Lowland on the east is part of the Folded Appalachians and exhibit tighter folding and more faulting than the Erie-Ontario Lowland on the north. Summit elevations of the south-central New York region rise to the east and range from 1500'-1700' west of Binghamton, are 1800'-2000' from Binghamton to Windsor, and are 2000'-2300' in the Deposit area (Fig. 3). As the master drainages occur at 800'-1000' elevations, the local relief is generally about 1000'. The Catskills provide a more mountainous appearance owing to topographic slopes that are about twice as steep and flood plain widths that are narrower than those in the western part of the region. The valley gradient of the Delaware River is 2.5 times as steep as the Susquehanna River, as it declines from 1060' at Cannonsville to 960' at the State line a distance of 14 miles whereas the Susquehanna declines from 1000' at Unadilla to 900' at the Pennsylvania border, a 37-mile distance.

## STRATIGRAPHY

The age of rocks in this region is Upper Devonian and the stratigraphy of the units in the central and western part of the region is thoroughly discussed in other articles of this volume. All strata were formed under Catskill deltaic-alluvial plain conditions, but rocks east of Windsor were mostly deposited on land while those to the west formed in the ocean part of the delta. (Fig. 4) A classic example of a regressing shoreline is depicted in Figure 5. The erosional products from the Acadian highlands expanded the terrigenous part of the delta covering to the west the older marine sediments.

The original thickness of the Catskill beds may have been more than 13,000', but thickness of remaining rocks in New York is interpreted to be about 5,000'. The direction of transport of sediments was westward from the Acadian highlands as inferred through study of "lateral grain size diminution, current direction criteria, i.e. cross-bedding, primary current lination, and oriented plant fragments, and 'lensing-out' of the red beds" (Fletcher D-2 in Valentine, 1962).

The degraded materials of the highlands in this region produced clays, muds, silts and sands so that shale and siltstone are the common rocks of the marine facies whereas

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sandstone and some siltstone and shale comprise the non-marine facies. There is a significant absence of limestone with the exception of a few thin coquinite horizons. Conglomerates are rare in the part of the Catskills traversed on the field-trip route. Although some literature offers the impression that the Catskill beds are largely "red beds", less than 10 percent of the beds in this area are "red". The reader is referred to the Explanation in Figure 4 for current nomenclature of the various rock-time units.

The rocks that will be seen on the field trip are mostly fine to medium-grained subgraywackes that range in color from brown and red to gray and blue. The volume of sandstone-type units when compared to finer-grained clastics is about 9 to one for rocks east of Windsor, whereas the sandstones comprise only about 20 percent of the sedimentary volume west of the village.

The mineral composition and fabric of the non-marine sandstones make them particularly valuable in the quarrying and milling of dimension stone. The slightly angular sand grains are tightly bonded by an indurated matrix of materials that include sericite, chlorite, mica, and feldspars. This combination of features make the rock hard and of desirable color. Joints and "reed planes" facilitate commercial operations. The rock is sold under a variety of names as: Hudson River Stone, North River Stone, Railroad Stone, Catskill Stone, Bluestone, and Genesee Standard Dark. The thinner units, generally less than 2", are referred to as "flagstone" and are used for sidewalks, patio walls, floor treads etc. Thicker units have a wide range of uses in buildings, construction, and decoration in the architectural arts. Figure 6a and 6b illustrate the natural setting and commercial production of good quality "bluestone".

#### STRUCTURAL GEOLOGY

The primary or sedimentary structures of the Upper Devonian strata cover a wide range of small-scale features. Ripple marks, rill marks, and flute grooves and casts are common in most south-central New York rocks. Some sequences of the marine facies contain graded bedding, and the sandier horizons show cross lamination. The flow rolls are restricted to marine rocks. Cross bedding is the most important primary structure of the non-marine sandstones. It should be understood that the sedimentary rocks occur in layers with some variation in texture, composition and color. The angularity of bedding planes is so common as to make this a general feature of sediments that formed on a huge system of coalescing alluvial fans and deltaic distributaries. Other features of the non-marine rocks include rain-drop impressions, plant rootlet casts, mud cracks, and occasional fresh-water molluscs.

Certain aspects of the structural history of south-central New York and its relation to other regions in eastern North America are discussed in the Meyerhoff and Woodrow and Nugent articles in this volume. The main properties of the regional structure consist of a slightly flexured south to southwest dipping homocline. Wedel (1932) shows the wave length to be about 10 miles for the gentle east and northeast trending fold axes. More recent work by the University of Rochester group indicates that such structures might more accurately be interpreted as several series of aligned domes. The dip of the rocks is rarely more than 1-2 degrees, but the southern limbs are steeper than their northern counterparts. Wedel uses the following terms from west to east to describe the flexures: Watkins Anticline, Enfield Syncline, Alpine Anticline, Cayuta Syncline, Van Etten Anticline, Horseheads Syncline, Elmira Anticline, Nichols syncline, and Union Center Dome. Table 1 presents data for selected deep wells in south-central New York. An unsuccessful oil test hole was drilled on the Union Center Dome. The regional dip in Broome County is about 11 ft. per mi. in a direction S 30° W.

The main architecture of the Catskill Mountains is a large synclinorium with up-turned nose to the east and plunging gently S 25° W. The eastern rim of this region as it rises majestically over the Hudson-Mohawk region is the classic example of a retreat-

TABLE 1

## DATA FOR SELECTED DEEP WELLS IN SOUTH-CENTRAL NEW YORK

U.S.G.S. Quadrangle 1:24,000	Location		Elevation (feet)	Well Depth (feet) Bottom Formation	Elevation at Top of Tully Limestone (feet)	Depth to Top of Tully Limestone (feet)
	Longitude	Latitude				
Oneonta	3,300' N. of	400' E. of	1457	4,570	-293	1750
	42° 20'	75° 05'		Clinton		
Binghamton West	4,200' N. of	3,550' E. of	940	3,117	-1310	2250
	42° 05'	75° 55'		Tully		
Maine	100' S. of	2,000' E. of	968	3,850	-1038	2006
	42° 10'	76° 05'		Oriskany		
Maine	3,300' N. of	6,750' W. of	830	4,412	--	--
	42° 10'	76° 00'		Oriskany		
Whitney Point	10,000' N. of	2,150' E. of	1300	3,250	-205	1505
	42° 20'	76° 00'		Oriskany		

Kreidler, W. L., 1959, Selected deep wells and areas of gas production in eastern and central New York: N.Y.S. Museum and Science Service Bull. no. 373, p. 243.

ing escarpment in eastern North America, (see Fig. 1 and 5). The structural trends within the Catskills have greatly influenced the thinking of some geologists as they seek explanations of erosional history of the region. Although the dip of major time-rock units rarely exceeds a few degrees, limited localities do contain dips in excess of  $10^{\circ}$ .

Jointing is the predominant manner of rock fracturing. Small faults do occur but they are local and of small extent horizontally and vertically. The region contains a well-developed joint pattern (Parker, 1942) with two sets nearly at right angles, the best developed joints are approximately north-south and this set is intersected by joints that trend east-west. The joint walls contain several features, the most common are plumose markings. Joints are of local importance for wells in bedrock as they provide the only significant avenues of ground-water movement through otherwise very dense and mostly impermeable rocks. Joints also occasionally control the orientation of some post-glacial streams, and as mentioned earlier, can facilitate quarrying operations of commercial-grade stone.

## DRAINAGE HISTORY

### General Statement

The topographic flavor of most landscapes is produced by the interaction of degradational processes acting upon earth materials contained within certain structural forms. The amount of time involved without interruption of the status quo may also play a role in the ultimate appearance of the topography. Running water and its gravity friend have sculptured the great majority of land forms in south-central New York. The work of glacial ice is only of tertiary mention.

Descriptive terms that have usually been used to categorize this region include such phrases as "maturely-dissected plateau". This classification depends on the absence of flat uplands and the presence of floodplains in all the major streams. The prominence of the Catskill Mountains may be attributed to the superior erosion resistance of the hard sandstones as the weaker shales were being selectively removed. Uplift was also higher in the east contributing to elevation differences. Although there are no sizable upland areas, some observers claim that there is a rather uniform accordance of peak elevations and that this gradual eastward rise of elevations into the main Catskills can best be interpreted as a former erosional surface of low relief that has been uplifted one or more times.

### Development of River Systems

Drainage evolution and erosional history of south-central New York is largely the story of the origin of the Susquehanna and Delaware drainage systems and their ancestors, if they were present. The dating and relative importance of the drainage initiation and its development in time is a hotly contested issue\*. Two schools of thought have emerged, namely: 1) The present topography is an inheritance from a more or less continuous erosional history dating from post-Permian times. There is disagreement concerning the mechanics of the drainage development, the nature of uplift renewals, and the importance of drainage reversals and capture. Meyerhoff, Davis, Ashley and Thompson belong in this group. 2) The present landscape is largely post-Cretaceous and all or most of the earlier drainage systems have been obliterated. There is some disagreement concerning the priority of drainage systems. Johnson, Strahler, Mackin, and Ruedemann

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\*As the author has in preparation a manuscript that includes a reevaluation of the drainage history of eastern New York, he believes this is not the time or place to attempt a final solution for the problem.



have supported this idea. Fairchild seems to occupy an intermediate view and in one area has support of Ruedemann.

Table 2 is a chronological presentation of ideas in the geological literature that seek to explain drainage evolution in northeastern United States.

TABLE 2

## Theories of Drainage Evolution in the Appalachians

<u>Name</u>	<u>Theory</u>
1. Davis, 1909	Primitive drainage flowed north and west. Rivers gradually reversed flow to the east in same valleys.
2. Fairchild, 1925	Primitive drainage flowed southwest from rising Catskills. Susquehanna arced to the north and probably only flowed south-east after Pleistocene time.
3. Johnson, 1931	Consequent streams flowed southeast on a Cretaceous coastal plain cover. Evolution of superposed drainage of principal streams with subsequents developing in weak zones with some captures.
4. Ruedemann, 1932	"Ancestral Susquehanna System" flowed southwest as synclinal consequents of Permian age. The more recent subsequent Delaware River has captured important Susquehanna territory.
5. Ashley, 1933, 1935	Development of transverse southeast flowing streams on a peneplain surface, and many subsequent adjustments of drainage orientation as streams were extended and discovered a variety of weaknesses in underlying rocks and structures.
6. Mackin, 1933, 1938	Similar to Johnson. Differs from Ruedemann in western Catskills with the Susquehanna River capturing ancestral Delaware drainage.
7. Meyerhoff, 1936	Primitive drainage occurred in post-Permian tectonic elements. Present drainage patterns are largely inherited from stream migration and capture as structural forms were exhumed. Western Catskill drainage is subsequent.
8. Strahler, 1945	Similar to Johnson.
9. Thompson, 1949	Westward migration of drainage divide owing to asymmetry and structural and compositional weaknesses in rock units.

The question that should be answered is 'what has caused such a wide variety of views in 70 years to explain drainage evolution in eastern North America'? Behind the answer are the interpretations and their relative importance in accessing certain anomalies and facts. A partial listing of such items is presented below but it should be understood that this is only a small sampling of ideas that can be used to test the validity of any drainage theory.

1. The regional drainage fabric. It can be seen in Figure 2 that there are two dominant drainage lineations, the southeast-flowing streams are transverse to the regional structures whereas the southwest and northeast flowing streams strike parallel with the crustal architectural pattern.

2. Barbed tributaries. In the Appalachian Plateau many examples could be cited of stream junctions where the smaller stream joins the master with the V pointing opposite to the present direction of flow.

3. The double drainage divide of the Susquehanna in New York. Although the regional dip is south, hills increase in elevation to the south. Tributaries of the east-west trending Susquehanna are in the awkward position that northern streams are flowing opposite to the summit elevations whereas the southern streams flow opposite to the regional dip.

4. Through-valleys. The headwaters of many tributaries end in valleys that continue in lineation with valleys occupied by streams flowing in the opposite direction. Such rivers as the Chenango, Unadilla, West Branch Delaware River present the puzzling appearance of broader and more mature valleys at the source, instead of becoming more youthful as in the general case.

5. The right angle bend of the West Branch Delaware River. The strange behavior of this river in the Deposit area contributes to one important controversy. Ruedemann's theory holds that the Delaware captured a former tributary of the Susquehanna, whereas Mackin's theory insists the opposite is true (Fig. 7a, 7b, and 8). Stop 5 of the field trip is designed to explore this problem more fully.

6. The drainage reversal bend of the Susquehanna River. The unusual arc of this river as it flows into Pennsylvania and then loops back into New York only to again reverse direction and flow southeast at Elmira. This city is at the heart of a topographic sag.

It is possible to make a second listing of those ideas, many are debatable and conjectural, that may possibly play some part in attempting to derive a reasonable explanation for drainage evolution.

1. Entrenched appearance of East Branch Delaware River (Fig. 3).

2. Migration down the regional dip by the Susquehanna River east of Oneonta, by West Branch Delaware River, and by Ouleout Creek. For example Figure 9 clearly indicates the trellis pattern of the Ouleout drainage so that the master stream appears to be subsequent, the south-flowing longer tributaries might be resequent, and the north-flowing tributaries would be obsequent.

3. Although Figure 3 does not illustrate it very well, on larger scale topographic maps a series of saddles or possible wind gaps can be aligned north of the West Branch Delaware River with decreasing gap elevations to the west. Could this be what Meyerhoff (this volume) terms "relic topography"?

4. What determines the highest elevations? The author is of the opinion that it is not coincidence that high elevations are located where at least one and often all three of the following factors are involved, namely: (1) At or near drainage divides; (2) the cap rock is the most resistant unit in the area, and; (3) the underlying structure is synclinal. A consideration of such features leads to the discussion of "the peneplain problem".

## The Peneplain Problem.

Although the concept of an area being degraded to a plain of low relief was not original with W. M. Davis, he named the concept "peneplain" and carefully enunciated with clarity of deductive reasoning what has served as a denudational model since his papers in the 1890's. The classic area for the study of peneplains and the geomorphic age cycle has been eastern North America, and the clearest expression of the logic is found in the numerous studies of the Folded Appalachians. Perhaps the Appalachian Plateau has not been so exciting a place for regional studies, because the literature is not as voluminous. Contributing to this relative lack of articles and argumentation describing "peneplain" features in the Plateau, is the general absence of such features as water gaps, wind gaps, accordant summits, trellis drainages, etc. that have often been used to count peneplains in the Folded region. Estimates on the number of peneplains in the Folded Appalachians range from 1 to 31. Of course many of these differences can be attributed to variations in interpretation as to what constitutes evidence for peneplains, and/or strath surfaces.

The agreement upon two, possibly three, peneplains by workers in southern New York is remarkable. (Table 3).

TABLE 3

Comparison of Nomenclature for Erosional Surfaces  
in southern New York. (Cole, 1938)

<u>Campbell (1903)</u>	<u>Fridley (1929)</u>	<u>VerSteeg (1930)</u>	<u>Cole (1938)</u>	<u>Approximate Elevation of surface</u>
Schooley	Kitatinny	Schooley (Kitatinny)	Upland	2300' - 2400'
Harrisburg	Schooley	Harrisburg	Allegheny	1700' - 1800'
	Mine Ridge Three erosion surfaces north of Ithaca		Niagara Floors of pre-glacial valleys	

The views of Rich (1915) could also be added to Table 3. He believed in two cycles of erosion with peneplain surfaces. During the second cycle streams in the northern Catskills were entrenched 1,000' and dissected the peneplain to late youth whereas in the central Catskills they excavated steep-sided valleys in the bottoms of the broad, late mature valleys of the previous cycle. This trenching has not yet reached the extreme upper courses of the streams.

The concept of physiographic aging of a land mass ending in a peneplain has dominated American geomorphic thinking from the time of Davis. Although it was periodically debated, only in recent years has this growing disenchantment reached major proportions that seriously challenge the fundamentals of such a teachable and beautiful system. The views of Hack (1960) and Strahler (1958) represent an alternative to the Davisonian aging concept of land-mass degradation. Such landscapes as the "maturely-dissected plateau" of south-central New York are explained by an equilibrium theory that operates in space and time. If summit levels exist they are explained on the basis of stream spacing and positions of drainage divides. The dynamics of the new approach firmly rooted in such ideas as fluid mechanics offers a clearer understanding of the degradation processes. Some of the new tools being developed to test such concepts are in the field of quantitative geomorphology.

TABLE 4  
MORPHOMETRIC COMPARISON OF THIRD-ORDER  
BASINS IN SOUTH-CENTRAL NEW YORK

Locality		A 50 basins north of Binghamton (mean)	B 50 basins Windsor to Oneonta area (mean)	C 50 basins Deposit to Margaretville area (mean)
Basin area (sq. mi.)		0.57	0.99	1.11
Basin perimeter (mi.)		3.18	4.87	4.60
Stream length mean (mi.)	First order	0.17	0.18	0.21
	Second order	0.25	0.27	0.28
	Third order	0.72	0.90	0.89
	Mean all orders	0.29	0.32	0.35
Overland flow (mi.)		0.062	--	--
Stream gradient (percent)	First order	10.9	11.4	25.2
	Second order	8.4	7.3	19.7
	Third order	4.5	4.7	12.3
	Mean all orders	8.5	9.0	22.0
Topographic slope (percent)		13.0	15.3	27.0
Basin relief (ft.)		428	672	1265
Drainage density		8.38	6.30	5.32
Circularity index		.56	.59	.66
Lithology		shale and siltstone (marine)	shale, silt- stone, sand- stone (marine and non-marine)	90% sandstone (non-marine)

## GEOHYDROLOGY

### Geomorphometry Considerations

The most important element of any landscape is slope. The nature of the slopes, whether gentle or steep, long or short, convex, concave, or linear, and their arrangement in space constitutes one important aspect of geomorphometry. Table 4 presents the results of measurements taken within third-order drainage basins along a traverse from Binghamton into the western Catskills. The data were obtained from U.S. Geological Survey topographic maps of 1:24,000 scale. The reader is referred to the many articles by A. N. Strahler and his Columbia University students for a full understanding of procedural methods and nomenclature. For purposes of comparison three different areas were investigated. The areas are dissimilar in appearance and in lithology.

Group C, the Catskill drainages, have basins that are twice as large, the relief is three times as great, and topographic slopes are twice as steep when compared with Group A, the non-Catskill drainages. Furthermore in Group C the streams are longer, gradients are steeper, and there are fewer channels per unit area (drainage density). Group B, the transitional section, occupies a somewhat intermediate step between the measurement extremes. Because the rocks throughout the region are of similar age and structure, their degradational history must have been of similar length. The cause of the differences, therefore, are attributed to lithologic characteristics. Sandstone is a coarser-grained and more permeable rock than the shales and thus is capable of supporting larger channels and longer slopes.

### Hydrologic Considerations

In regions as south-central New York that have been largely sculptured by the many phases of running-water processes, it is necessary to catalog some facets of the hydrologic regime and to offer some assessment of this activity. Table 5 itemizes the amount of streamflow for the principal drainage systems in the region.

TABLE 5

STREAMFLOW DATA FOR MAJOR RIVERS IN SOUTH-CENTRAL NEW YORK

Name of River	Gaging Station Location	Drainage Area (sq.mi.)	Average Discharge (cfs.)	cfs. per sq. mi.
Susquehanna River	Unadilla, N.Y.	984	1,626	1.65
"	Conklin, N.Y.	2,240	3,654	1.63
"	Vestal, N.Y.	3,960	6,451	1.62
Chenango River	Greene, N.Y.	598	932	1.55
"	Chenango Forks, N.Y.	1,492	2,452	1.64
Unadilla River	Rockdale, N.Y.	518	842	1.62
East Branch Delaware River	Fishes Eddy, N.Y.	783	1,673	2.13
West Branch Delaware River	Near Cannonsville, N.Y.	456	844	1.85
Tioughnioga River	Itaska (south of Whitney Point), N.Y.	735	1,250	1.70
Chenango River	Chemung, N.Y.	2,530	2,530	1.00

Data from U. S. Geological Survey Water Supply Papers.

In this short generalized article, it is not possible to offer a balanced treatment of geohydrology or to explore the many important and difficult interlocking relations that exist between topographic development and the various hydrologic cycle components as the character of the storms, nature of water flow, amount and compositional quality of the water etc. Some topographic and hydrologic parameters, however, are indicated in Table 6.

TABLE 6

GEOMORPHIC AND HYDROLOGIC CHARACTERISTICS  
OF THREE RIVERS IN THE CATSKILL MOUNTAINS

	<u>Trout Creek</u>	<u>Oquaga Creek</u>	<u>Ouleout Creek</u>
Drainage area (sq. mi.)	49.5	66.0	102.0
Drainage perimeter (mi.)	33.3	45.2	55.1
Maximum relief (ft.)	1280	1040	1370
Circularity	56	41	42
Topographic slope (percent)	20.5	19.2	15.0
Stream gradient (percent)	10.1	9.2	7.8
Areal extent of valley fill (percent)	7.6	5.2	8.0
Annual discharge (cfs.)	90.6	117	171
Annual discharge (ins.)	24.8	24.2	22.8
Annual discharge (cfs. per sq. mi.)	1.83	1.77	1.67
Annual precipitation (in.)	43.4	43.0	42.0
Water loss (in.)	18.6	18.8	19.2

Geomorphic data from U.S.G.S. 1:62, 500 scale topographic maps  
Discharge data from U.S.G.S. Water Supply Papers  
Precipitation data from Coates manuscript in press.

Precipitation in south-central New York ranges from about 33 inches in the western part of the region to more than 55 inches in the east. The increase of precipitation can be closely correlated with topographic and altitudinal changes. About 50 percent of the precipitation is carried out of a drainage basin as streamflow; it is more than 60 percent in the higher Catskills and less than 50 percent in Chemung drainages. Although such factors as the amount of slope, nature of earth materials, and temperature affect the amount of streamflow, it is water loss through transpiration and evaporation that is the most important determining criterion for the amount of water available to degrade the land mass. The water loss throughout the region has a narrow range of 18-20 inches, and after this requirement has been fulfilled the remainder of the precipitation eventually emerges as streamflow. This is the reason why the Chenango River has only 50 percent the square mile flow of the East Branch Delaware River yet has 70 percent the precipitation. The three rivers that are characterized in Table 6 will be seen on the field trip.

### Ground Water Considerations

For a discussion of ground water in south-central New York the reader should study Brown and Ferris (1946) and Wetterhall (1959). Ground water occurs in the interstices of unconsolidated materials and in the joints and fractures of the bedrock. The best water is obtained from outwash sands and gravels. The wells are shallower, the water has smaller amounts of dissolved solids, and yields of 100's of gallons per minute are

common with range up to 2,000 gpm. Other wells in the valley fill many encounter clay beds and morainic materials that deteriorate ground-water properties. Bedrock wells commonly are more than 100 feet deep. Such depths are necessary in order to incise sufficient numbers of rock fractures that slowly permit recharge in the well bore. The yield of bedrock wells average 5-10 gpm and rarely exceed 30 gpm. The quality of water has a wide range, but would average about 200 parts per million as  $\text{CaCO}_3$  hardness, about 180 ppm alkalinity, 15 ppm chlorine, and 0.1 ppm iron.

#### GLACIAL GEOLOGY

Although Illinoian and Wisconsin ice sheets are known to have travelled at least 40 miles south of the region under discussion in this report, all glacial features and deposits in south-central New York have been given a Wisconsin date in the literature. The youngest ice sheet of Wisconsin time stopped north of the south-central New York region and has been given the name "Valley Heads". This glacier was responsible for many of the features in the Finger Lakes district. The important and debatable question is, however, were there one or two ice sheets that covered southern New York during the Wisconsin prior to Valley Heads time? Although some work has been done on the problem, the writer is unaware of glacial mapping studies that have been done in the area traversed by the field route.

Rich (1935) using topographic and weathering criteria states the case for two separate ice advances in the region of the central Catskills.

"....an outer belt of moraines...seems to separate two unlike areas - one to the north and east, in which moraine loops are abundant, sharp and fresh; and the other to the south and west where few moraines are found, where smooth, thick drift is the prevailing form of glacial deposit, where evidences of the erosive action of the ice are few, and where the topography and the weathering of boulders suggest noticeably greater age of the drift" (Rich, 1935, p. 130).

MacClintock and Apfel (1944) by the use of pebble counts, outwash, and moraine relations in the area west of Binghamton also state there were two ice sheets. The older one is called "Olean" and the younger is termed the "Binghamton".

Flint (1953, p. 904-5) correlated New York and New England till sheets and concluded that Olean drift is of the Tazewell Substage and that Binghamton drift is the same as Rich's younger moraine and is of the Cary Substage.

Denny (1956) working in the Elmira area doubted the presence of the "Binghamton" for that locality and believed it must occur north of the Valley Heads border. Moss and Ritter (1962) using heavy-mineral-suite characteristics and sand-silt-clay ratios deny a separate advance of the "Binghamton". On the basis of previous studies and work done by the author in the preparation of this report, Table 7 is presented as a summation of till characteristics for this region.

Thus, the author believes that a single ice sheet created the morainic materials in this region, and recommends retention of the names "Olean" and "Binghamton" as lithologic facies. The Olean is the upland facies and the Binghamton is the valley facies. In deep excavations the Binghamton grades vertically into the overlying Olean without an intervening soil profile. Along valley walls the Binghamton also grades laterally into the higher Olean lithology. The circumstances that caused facies development is discussed below.

TABLE 7

## Till Facies Characteristics in South-Central New York

		Olean Facies	Binghamton Facies
General appearance		drab and dull	variegated more heterogeneous
Associated land forms		ground moraine, few topographic forms	knobby, irregular
Outwash materials		practically none	some outwash
Lithology of materials larger than gravel size	Local rocks	major constituents	important but rarely more than 80 percent.
	Limestone & chert	generally less than 5 percent	May be as high as 35 percent
	Igneous-metamorphic crystallines		Limestone & chert more than 10 percent
	Degree of round of materials larger than gravel size	poorly-rounded	Bi-Modal, moderately rounded for local rocks, crystallines well rounded.
Heavy Mineral % .149-.317 mm	Coated	Generally more than 65 percent	Generally less than 50 percent
	Opaque	Less than 25 percent	More than 25 percent
Texture Percent	Sand	variable	variable
	Silt	variable	variable
	Clay	variable	variable

Non-Catskill Till

Stream erosion prior to Pleistocene time was vigorous and of long duration. Through-valleys were developed at the points of piracy along the north and east-facing escarpments as obsequent streams with superior kinetics captured south and west-flowing streams with gentle gradients. The drainage divide was continually pushed farther into central New York and the col-like areas are vestiges of the relic topography. Along the northern escarpment that delineates the Appalachian Plateau from the Erie-Ontario Lowlands a series of more than 10 through-valleys were developed. Although the present valley floors at the divides range from 1150' to more than 1400', it is certain that bedrock elevations were considerably lower during the ice ages. In this area Fairchild (1925, p. 51) shows post-glacial uplift of about 300'. The thickness of valley fill in some of these saddles is more than 75'. The relative importance of fluvial erosion in the through-valleys when compared to amount of sculpturing by ice abrasion is an unanswered question. It is clear, however, that by Olean time through-valleys were well developed. Older ice sheets gouging southward traversed the limestone belts incorporating limestone with the erratic-rich igneous-metamorphics from farther north. These lithologies selectively enriched outwash materials owing to their superior cohesiveness and dense fabric. The lower part of the Olean ice in the through-valleys



contained these non-digenous rocks in the basal load. With ice wastage the morainic materials kept their residence in the valleys, and such deposits are not found above 950' elevation in the Binghamton area. Thus the Binghamton facies is restricted to the through-valley areas whereas the Olean facies is commonly found in the uplands.

### Catskill Moraines

The glacial history of morainic deposits in the western Catskills is different than in the region to the north and west. The topographic orientation of the principal valleys is athwart the major direction of ice transport. As a result ice abrasion was weaker in the valleys than in the upland areas. Other differences are discussed in the Description for Field Trip D. The Binghamton facies is absent from the western Catskills. A brief reconnaissance of the region failed to produce positive proof of more than one till sheet. Thus the till is believed to be the Catskill phase of the Olean facies. The topographic development of the till is well developed, and this is illustrated by the field trip route that traverses many of the morainic loops ("choker moraines") and lobate hilly forms of the till. Apparently the history of ice wastage was different than at Binghamton, because ice retreat was periodic with the development of recessional moraines as individual units in many of the valleys.

### Alluvial Plains

A great variety of planar and fan features occur in stream valleys of south-central New York. Many specifics are contained in the report Geomorphology of the Binghamton Area and in the Description for Field Trips B and D. The largest and best-developed plains are found in the Susquehanna River and its major tributaries as the Unadilla and Chenango Rivers. Alluvial features are more subdued in the Delaware drainages and cannot compare in perfection of development.

The planar features range from those that are original surfaces of deposition with little erosional modification, to those erosional forms beveled by lateral stream degradation. All are composed of valley-fill materials as bedrock terraces are unknown in this region. The depth of fill often exceeds 200' in the Susquehanna, Unadilla, and Chenango rivers. In the Delaware drainage system thickness of fill is rarely more than 100' feet. The origin of the materials is largely glacial outwash that ranges from clean sand and gravel to lacustrine clays that are known to be as thick as 150' in the Binghamton area. Although Peltier (1949) studied terraces along the Susquehanna River south of Elmira, very little work has been done on similar features in the southern New York region.

Included in the array of planar features are alluvial fans, deltas, kame terraces, valley trains, erosional plains, flood plains, lake plains etc. Many cities and villages have utilized these features as the following tabulation indicates: (See Table 8).

TABLE 8

## Alluvial Plains in South-Central New York

Name of community	Principal elevation (elevation in feet)	Type of planar feature
Unadilla	1010	Floodplain of Susquehanna River and alluvial fan of Martin Brook
Sidney	980	Floodplain of Susquehanna at junction with Unadilla River
Bainbridge	990	Extension of terrace from Yaleville Brook junction with Susquehanna
Afton	1000+	Kelsey Brook alluvial fan in Susquehanna
Windsor	980	Occanum Creek alluvial fan in Susquehanna
Damascus	970	Tuscarora Creek alluvial fan in Susquehanna
Binghamton area	840	Floodplain of Susquehanna

From such a tabulation it is apparent that when tributaries joined the Susquehanna, plains of alluviation have developed. Other localities that support this generalization can be found in the Binghamton area, such as the terrace in the Willow Point area of Vestal, and the terrace at Hillcrest near Port Dickinson.

The best developed terrace levels along the Susquehanna River between Unadilla and Binghamton are at elevations of 950'-970' and 1050'-1060'. The terrace history is probably similar to that of other glaciated regions. Lands marginal to the glacier were aggraded during the ice ages, and are currently being degraded by entrenchment of river systems.

## SYNTHESIS

South-central New York is the gift of the Devonian Acadian Highlands and the Pleistocene Laurentide glaciers. Clastic, fine-grained, marine units constitute bedrock in the west, and in the east the sediments are coarser grained and terrigenous. Surficial deposits of glacial materials, alluvium, colluvium, and soil show a wide range of composition and texture.

Although the architectural pattern of the Appalachian Plateau is structurally less complicated than surrounding geomorphic provinces, the region has suffered through a long, vigorous, and complex erosional history. Important controversies have arisen not only concerning the details of the denudational life of the Plateau, but over the fundamental principles as well. Problems that must be listed, therefore, as unsolved include: Direction of flow and erosion intensity of primitive drainage systems; presence of a coastal plain cover through which rivers could become superimposed; the nature of stream captures and drainage reversals, and; the verity and/or perfection of peneplain development. Susquehanna drainage is largely limited to the marine bedrock area and Delaware drainage is restricted to sandstone lithologies of land derivation. These factors help account for steeper and longer slopes in the Catskill Mountains.

The ice age was instrumental in causing important topographic alterations. The deposits assume a variety of small morainic knolls and loops, and larger outwash and lacustrine terraces and plains. Numerous drainage diversions have resulted from deposition of till, and choker moraines. This caused abandonment of some channels necessitating their relocation. The variety of new channels includes syn-glacial, pene-glacial and post-glacial phenomena such as high level notches and overflow areas, and youthful bedrock gorges superimposed in valleys. It seems probable that the region of this study was profoundly affected by only one major Wisconsin ice sheet - the Olean Substage.

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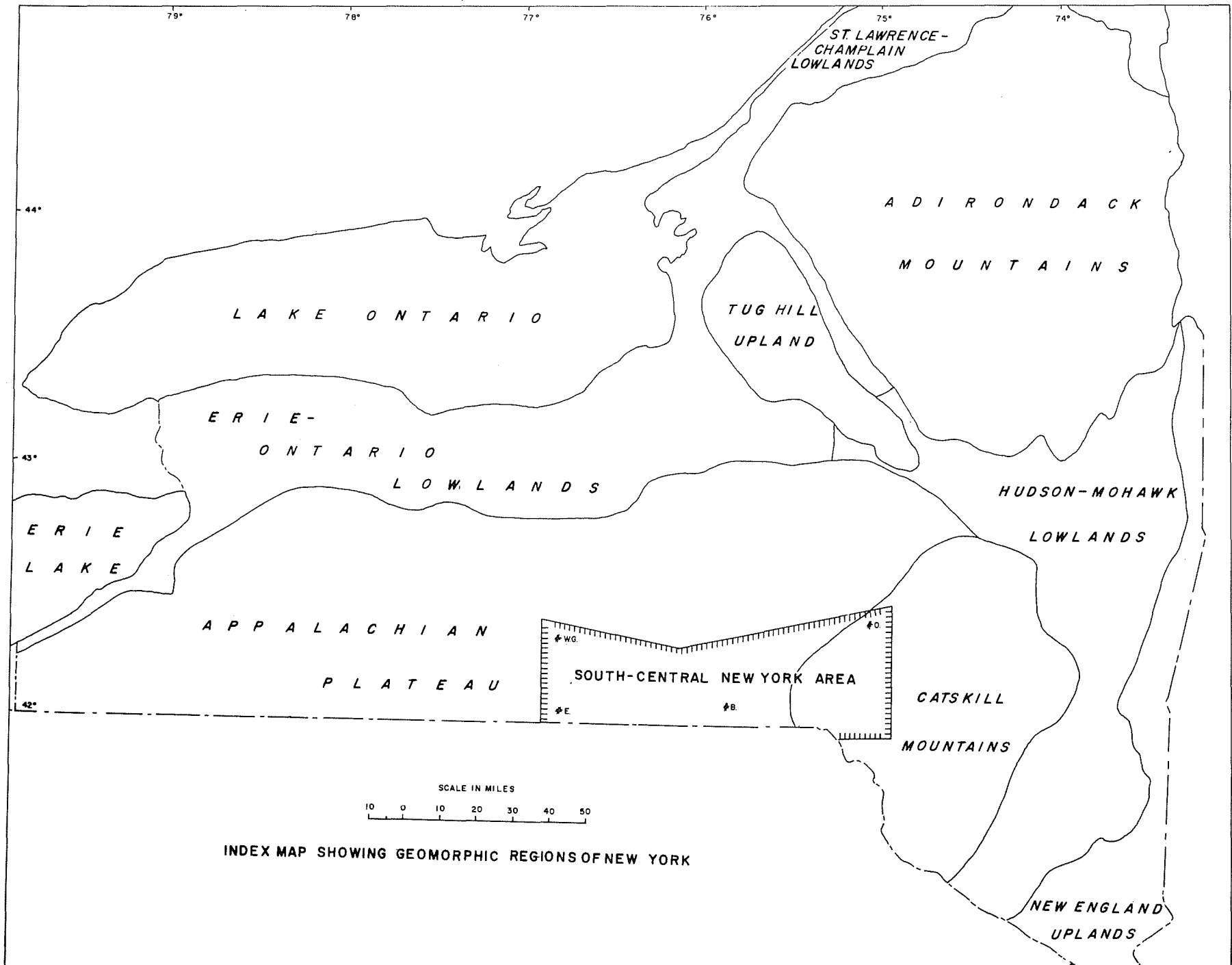


Figure 1.





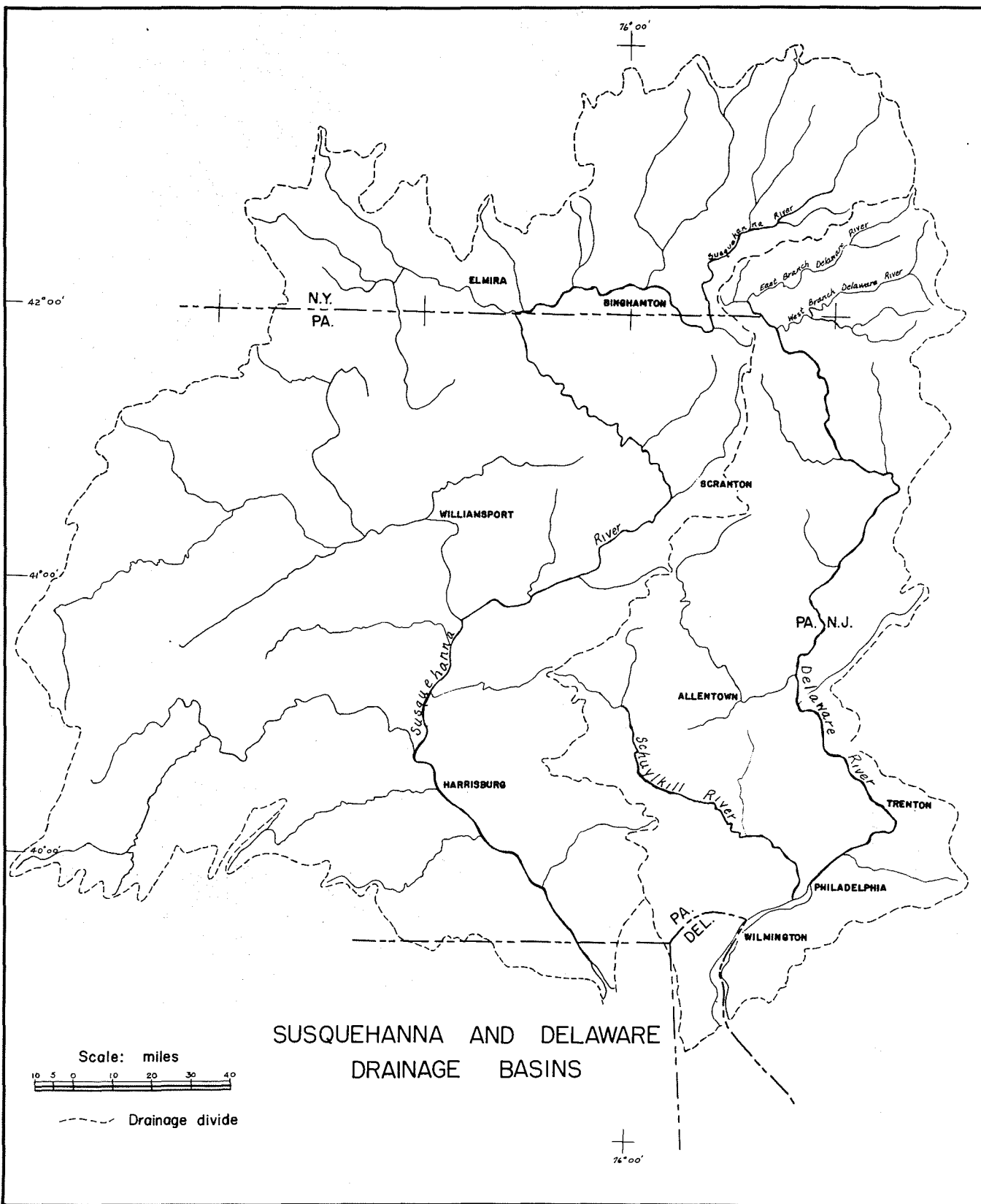


Figure 2.

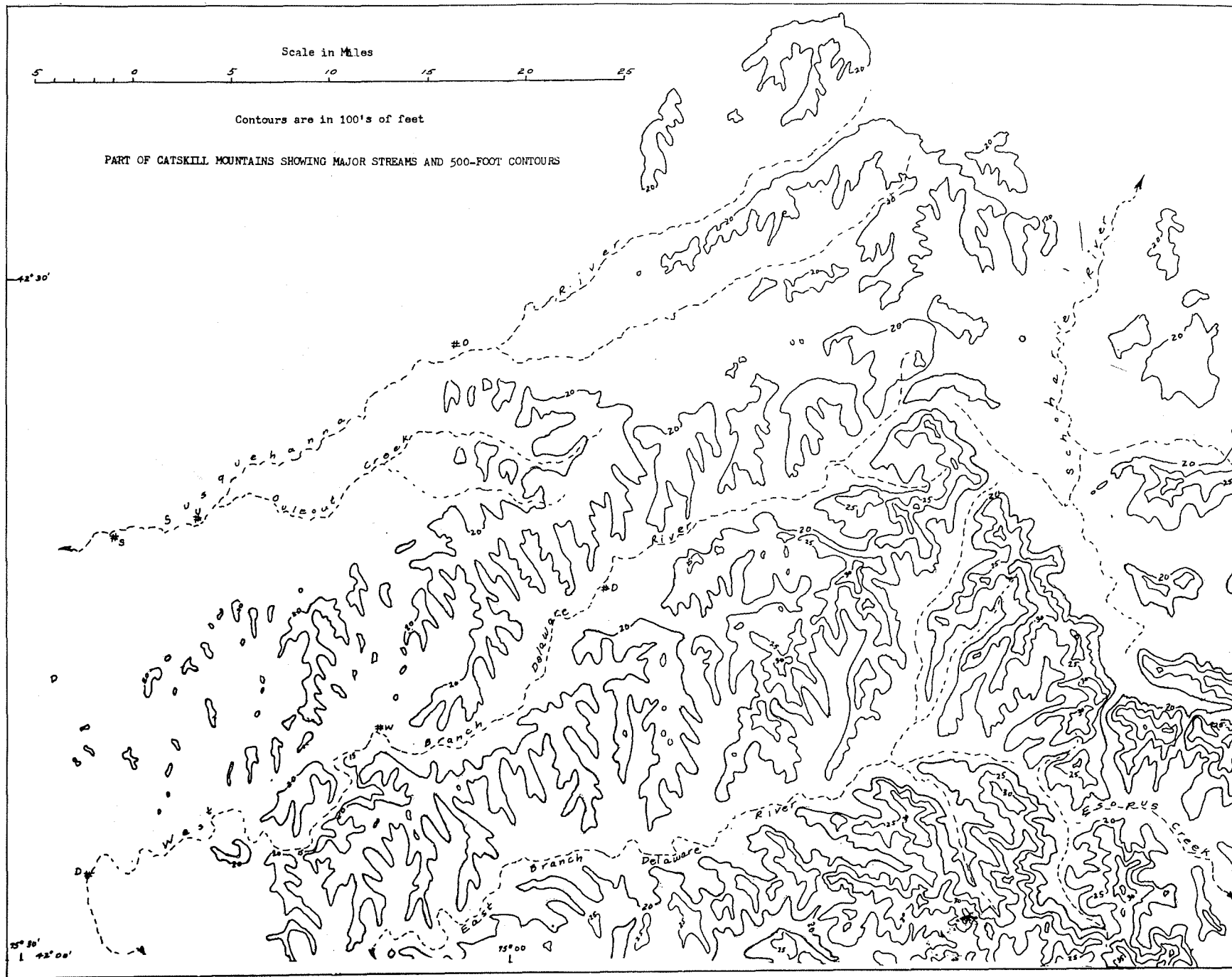
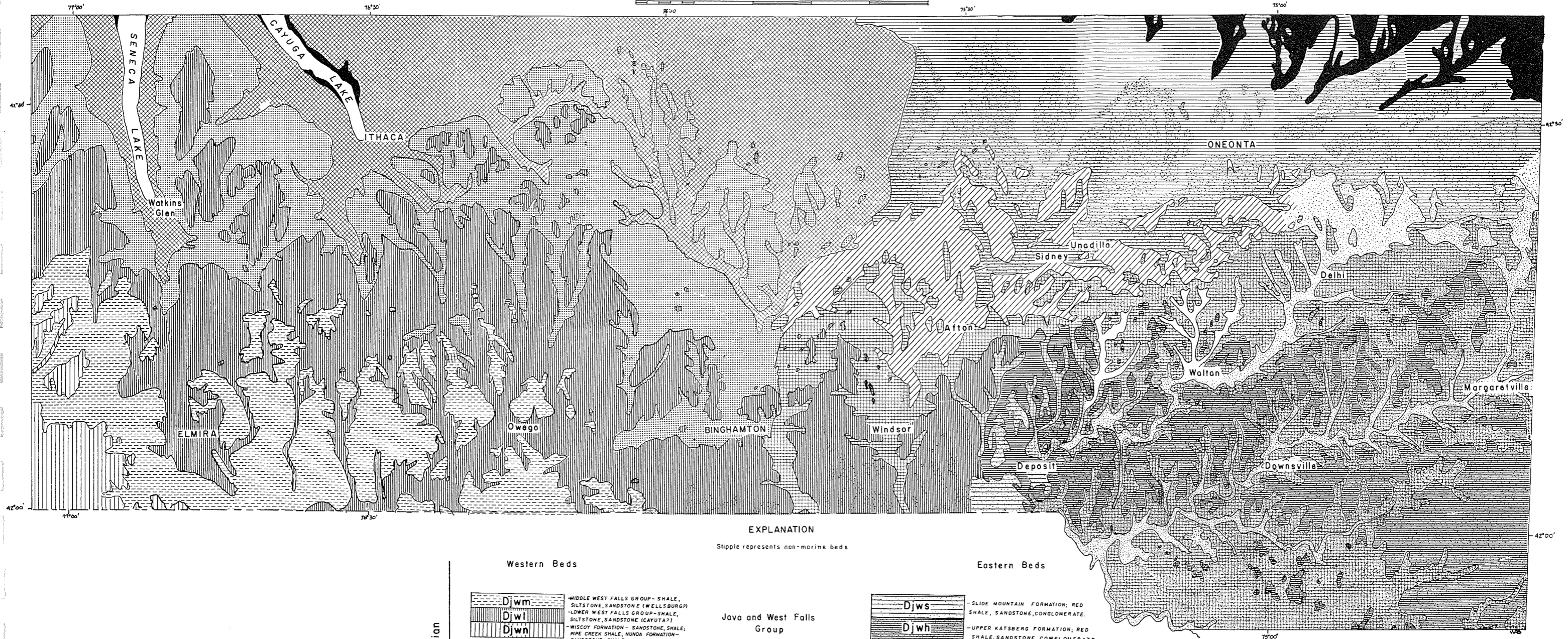


Figure 3.

REDRAWN FROM GEOLOGICAL MAP OF NEW YORK 1961  
**GEOLOGIC MAP OF SOUTHERN NEW YORK**



**EXPLANATION**

Stipple represents non-marine beds

Upper Devonian

**Western Beds**

Djwm	MIDDLE WEST FALLS GROUP - SHALE, SILTSTONE, SANDSTONE (WELLSBURG?)
Djwl	LOWER WEST FALLS GROUP - SHALE, SILTSTONE, SANDSTONE (CAYUTA?)
Djwn	WISCOY FORMATION - SANDSTONE, SHALE; PIPE CREEK SHALE; NUNDA FORMATION - SANDSTONE, SHALE
Ds	CASHAQUA SHALE REPLACED EASTWARDLY BY ENFIELD FORMATION SHALE, SILTSTONE, SANDSTONE; MIDDLESEX SHALE.
Dg	WEST RIVER SHALE; GUNDEWA LIMESTONE; PENN YAN AND GENESEE SHALES; ALL EXCEPT GENESEE REPLACED EASTWARDLY BY ITHACA FORMATION SHALE, SILTSTONE AND SHERBURNE SANDSTONE.

NOTE: BLACK REPRESENTS MIDDLE DEVONIAN GRANITE

**Java and West Falls Group**

Djws	SLIDE MOUNTAIN FORMATION; RED SHALE, SANDSTONE, CONGLOMERATE.
Djwh	UPPER KATSBERG FORMATION; RED SHALE, SANDSTONE, CONGLOMERATE.

**Sonyea Group**

Dsu	DSU - UPPER SONYEA GROUP, SHALE SILTSTONE, SANDSTONE
Dsd	DSK - KATTEL FORMATION - SHALE SILTSTONE, SANDSTONE
Dsk	DSK - LOWER KATSBERG FORMATION, SANDSTONE, RED SHALE, SILTSTONE.
Dss	DSS - STONY CLOVE FORMATION SANDSTONE, CONGLOMERATE, SHALE

**Genesee Group**

Dgou	ONEONTA AND UNADILLA FORMATION RED SHALE, SILTSTONE, SANDSTONE.
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Figure 4.

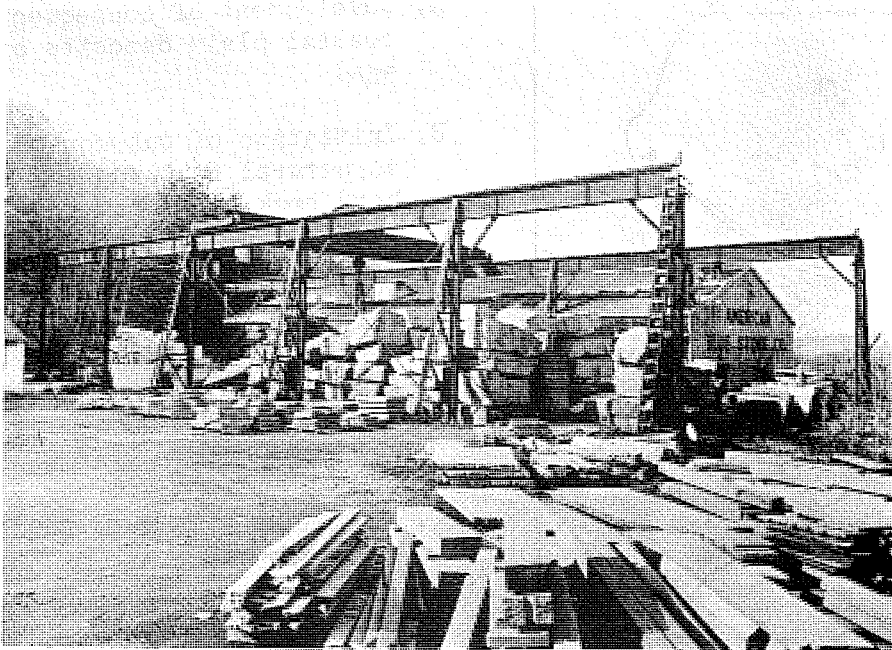






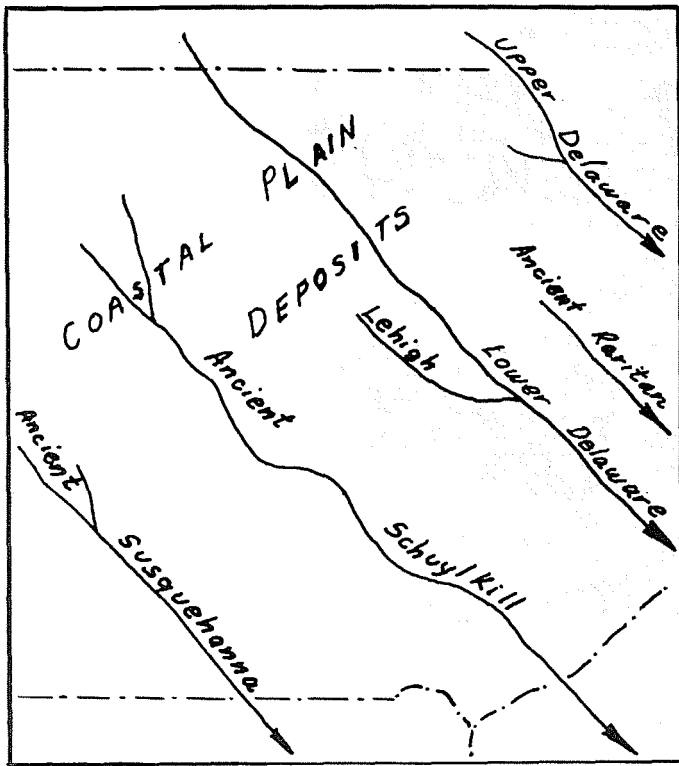


- A. Catskill "Bluestone" Quarry South of Sidney, N.Y. These massive non-marine sandstone units yield dimension stone of excellent quality. Photographs taken on the property of American Bluestone Company by courtesy of J. J. Newbery

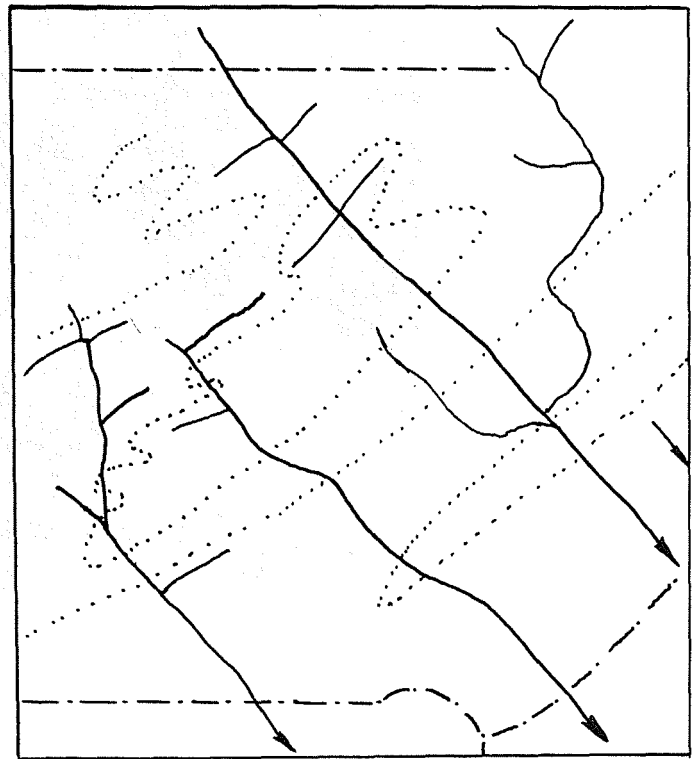


- B. Mill Operation of "Bluestone" at South Unadilla, N.Y. At this site rock from the Sidney quarry is cut and prepared for sale.

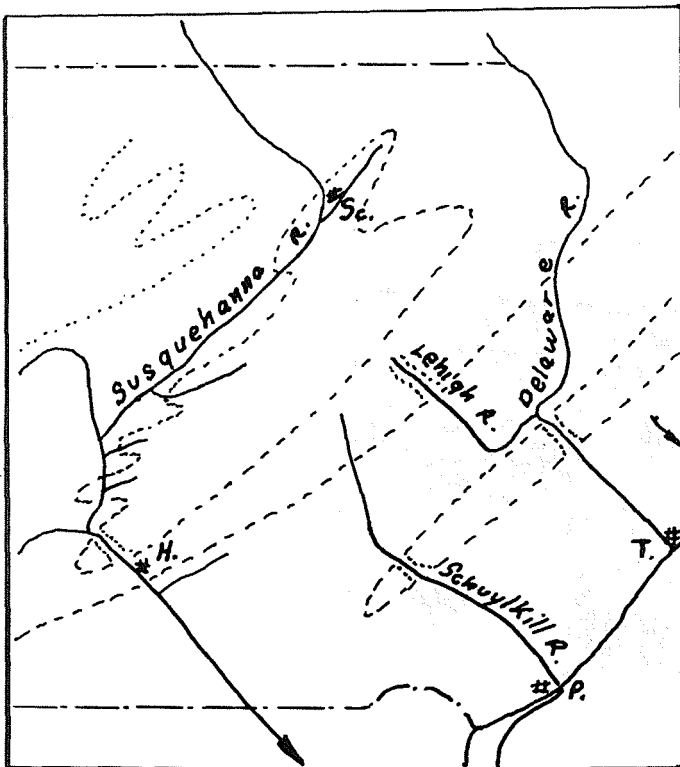
Figure 6.



A.



B.



C.

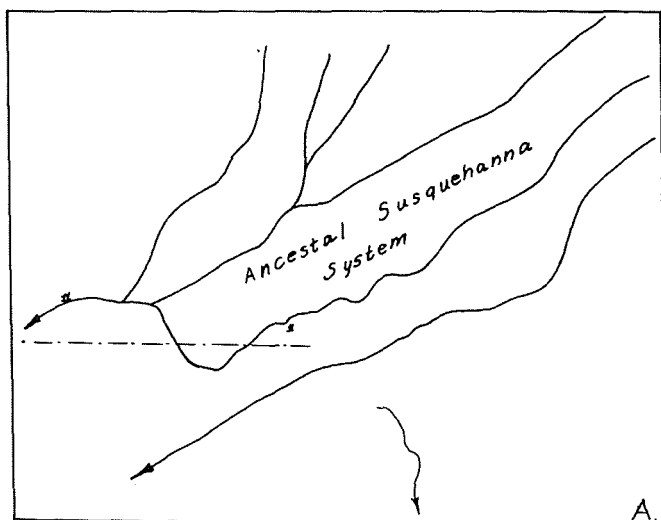
- A. Development of consequent stream on coastal plain deposits of Cretaceous age.
- B. Initiation of subsequent streams as structural features and belts of hard rock are encountered.
- C. Present drainage in eastern Pennsylvania with water gaps, wind gaps, and compound stream systems.

(After D. Johnson (1931))

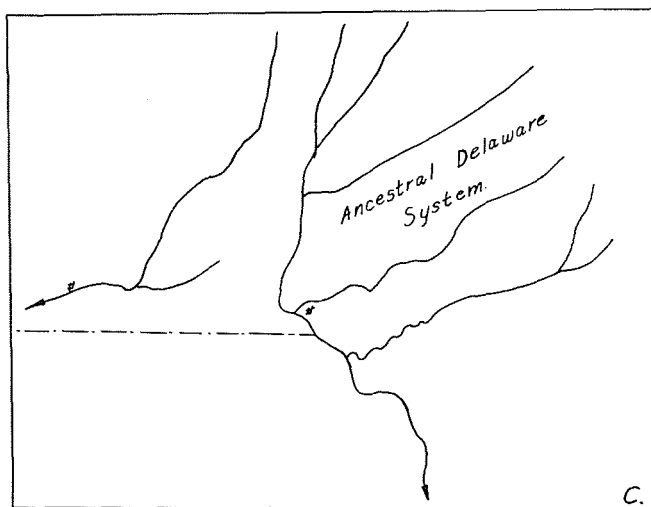
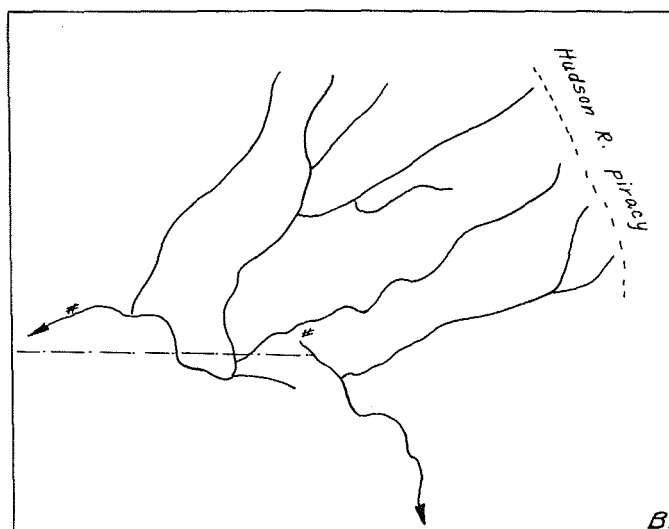
SUPERPOSITION THEORY OF DRAINAGE EVOLUTION

Figure 7a

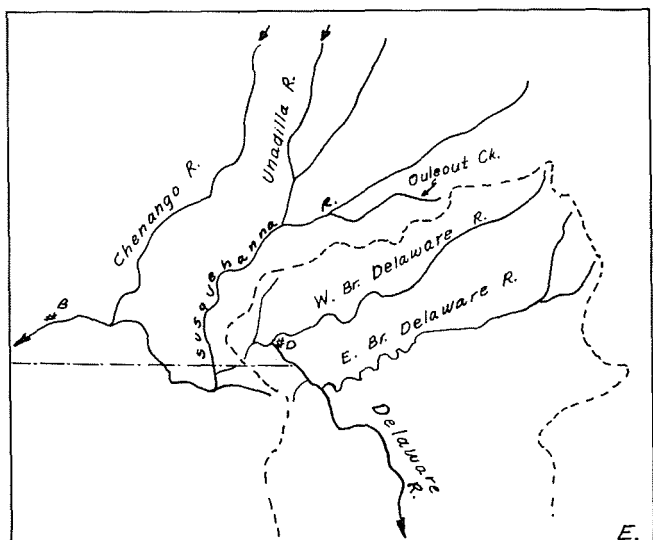
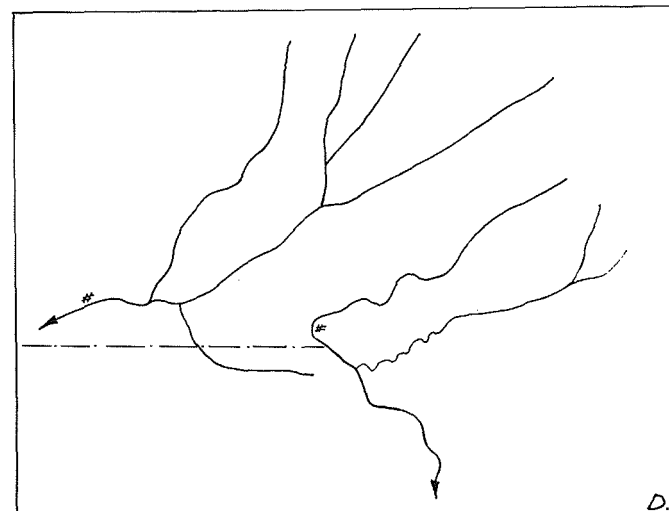




Ruedemann  
Theory



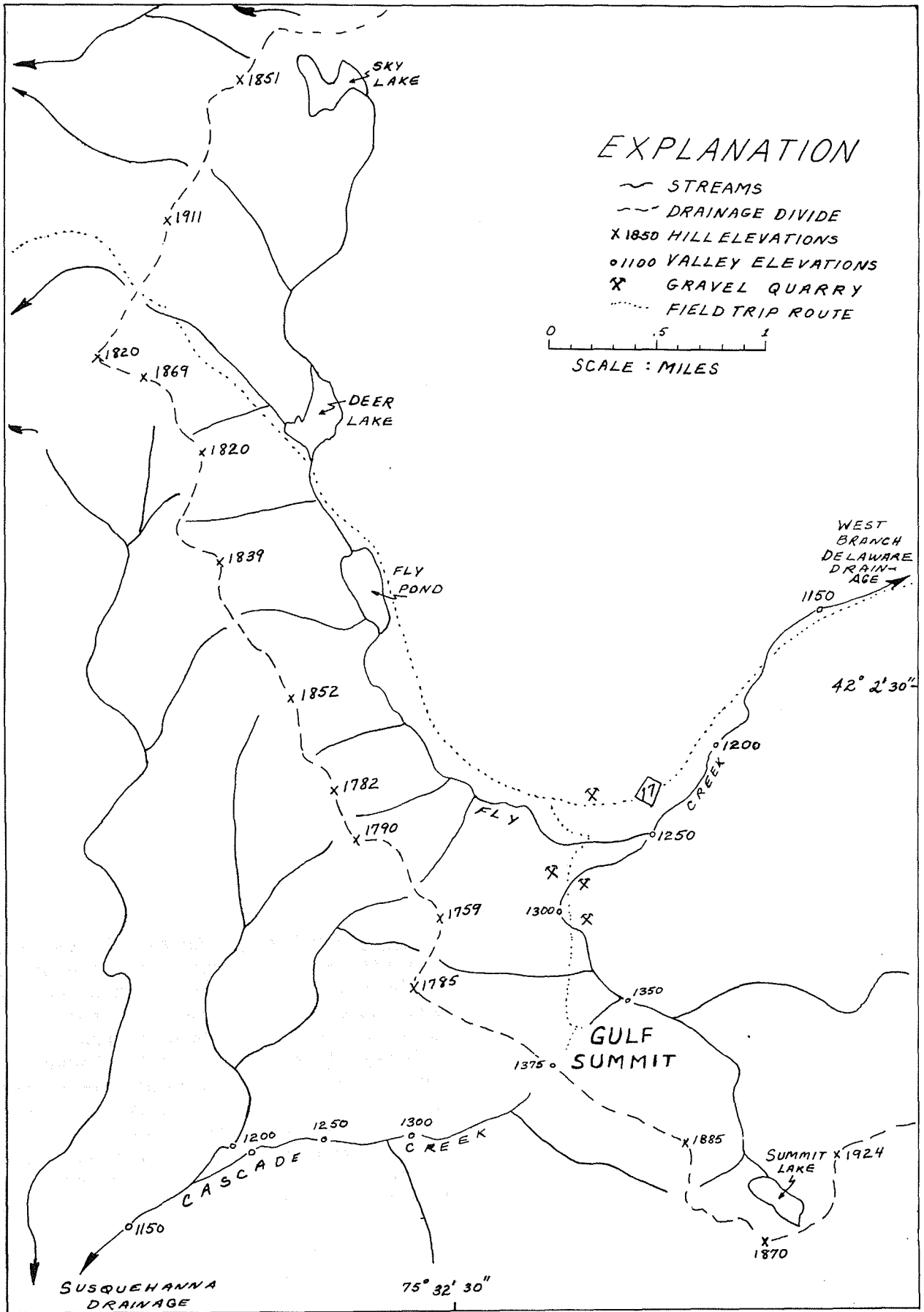
Mackin  
Theory



- A. Ruedemann Theory. Ancestral Susquehanna is master system of primitive drainage.  
 B. The Delaware as subsequent stream has made one capture and is ready for a second piracy of the Susquehanna.  
 C. Mackin Theory. Ancestral Delaware is the original stream of primitive system.  
 D. The Susquehanna by headward growth has captured northern headwaters of the Delaware and is ready for a second capture.  
 E. Present relation of Susquehanna and Delaware drainages in the western Catskills.

THEORIES OF DRAINAGE DEVELOPMENT IN  
WESTERN CATSKILLS

Figure 7b.



DRAINAGE PATTERN OF THE GULF SUMMIT VICINITY

Figure 8.

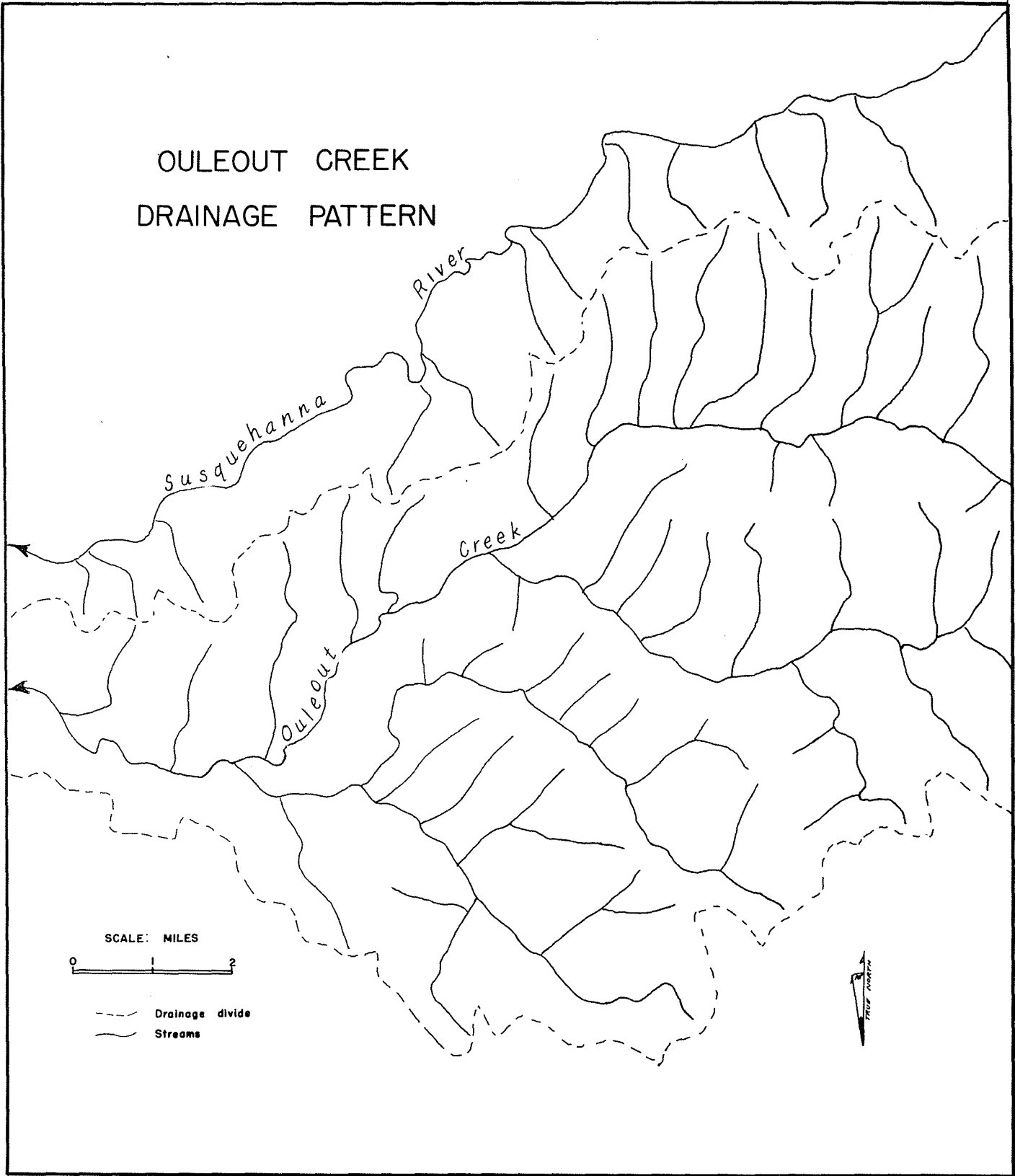
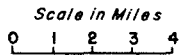
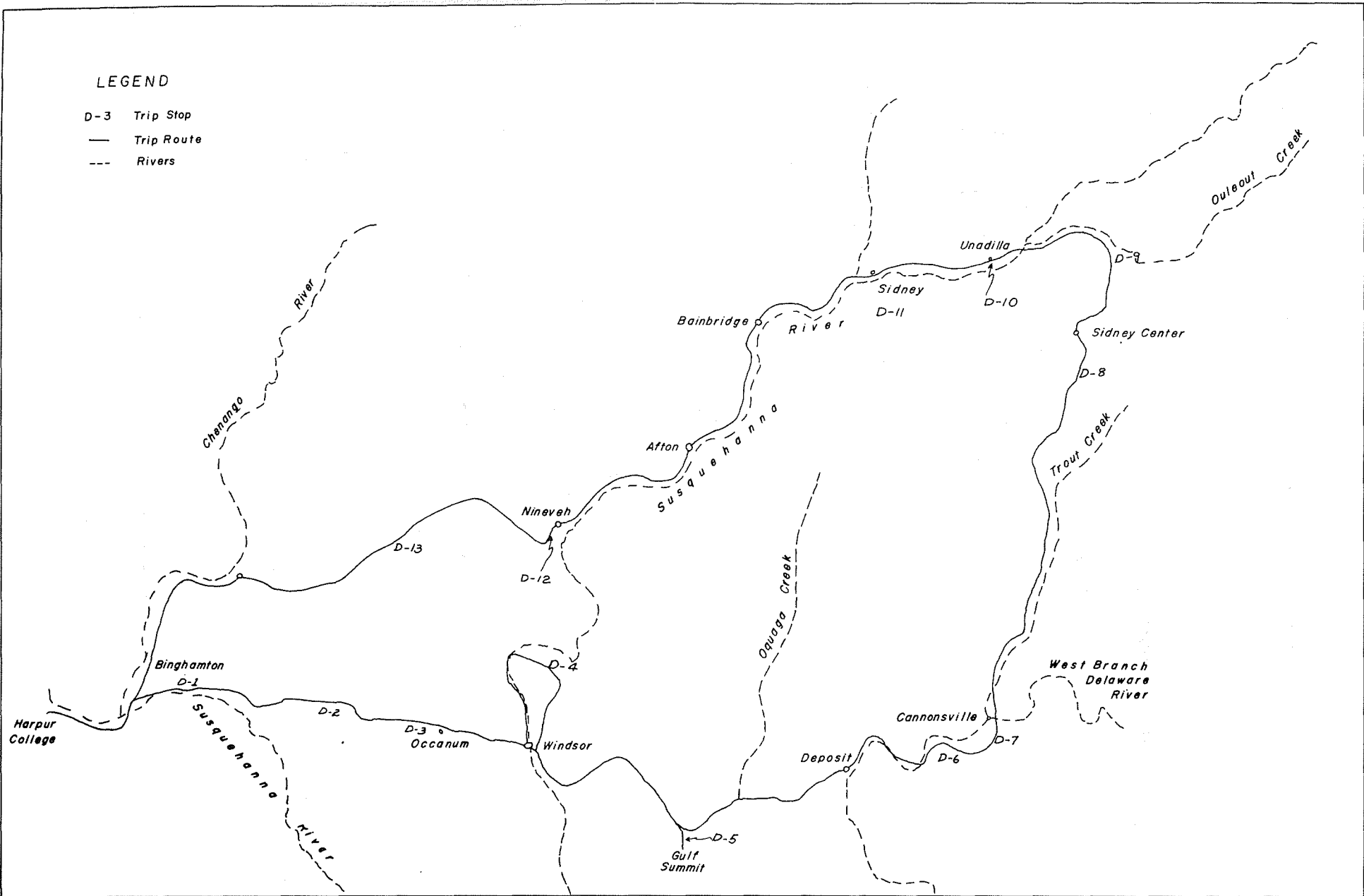


Figure 9

LEGEND

- D-3 Trip Stop
- Trip Route
- Rivers



TRIP D FIELD TRIP ROUTE

## TRIP D ROAD LOG AND ROUTE DESCRIPTION

## GENERAL GEOLOGY OF THE WESTERN CATSKILLS

Donald R. Coates

Total miles	Miles	ROUTE DESCRIPTION
0.0	0.0	Harpur College entrance. East on Rt. 17. Will turn off 14.8 mi. at Occanum.
6.6	6.6	<u>STOP 1.</u> Outcrop of glacio-fluviatile and glacio-lacustrine beds intermixed with till and a deltaic complex. Lithology of the larger rocks includes red sandstone, local siltstone, and coquinite, and some igneous-metamorphic crystallines. Limestone is rare. The Susquehanna River is 810' and adjacent hills are 1500'-1600'.
7.7	1.1	Stay on Rt. 17 as Rt. 11 turns south. The wide area of unconsolidated materials was produced by junction of the west-flowing Park Creek and south-flowing Stanley Hollow. The latter stream was a major overflow channel of glacial waters when the ice front was north of the area.
8.4	.7	Stay on Rt. 17 at Penn-Can turnoff. Climbing out of the Susquehanna valley. Will see Susquehanna again at Windsor.
10.4	2.0	<u>STOP 2.</u> West Falls Group. Lithology is largely shale and siltstone with some fine-grained sandstone. A few thin coquinite beds are present containing brachiopods and crinoid columnals. The original limestone has been removed. Several excellent horizons of flow rolls occur. The lack of parallelism of flow rolls and bedding planes is seen in the easternmost part of the outcrop. Radiographs done at Harpur (Greene and Coates, 1963) of sections cut at different orientation of the flow rolls indicate some interior structures of small-scale folding and gravity faulting. An angular unconformity occurs at this stop. Rocks also contain many other structures, both primary and secondary in origin. Next to the bedding characteristics in rock importance is the universality of the joint patterns. Two sets are well-developed throughout the Catskill region.
11.5	1.1	West Falls Group on south side of road. Similar to Stop 2. Throughout this area the hills are capped by sandstones of the continental facies of the Catskill delta-alluvial plain complex, but only marine facies rocks are visible along the road at the lower elevations.
14.8	3.3	Take Exit 78. Right to Occanum, and in .2 mi. take another right (east).
16.1	1.3	<u>STOP 3.</u> Walk on the west side of house down to flood plain of Occanum creek about 500 feet. On south side of creek is 50' high outcrop of Olean till (Catskill phase). The bedrock that occurs upstream indicates that in places Occanum Creek occupies a post-glacial channel.
16.3	.2	Excellent terrace development at the community of Occanum. The origin of this type feature will be discussed later.
17.3	1.0	Thick till "choker moraine". This feature is also common along the route that will be travelled and it will be discussed later.
18.0	.7	Windsor. Turn left (north) at red light on Rt. 79 to Ouaquaga 4.0 mi.

## TRIP D

The Susquehanna River, elevation 920', flows south. The hills are 1700'-1900'. Occanum Creek forms an alluvial fan and the village of Windsor is built on the junction of the alluvial fan and the 980' level of outwash developed by the Susquehanna River in glacial times during ice recession. This terrace extends to Sage Brook and Rt. 79 utilizes it. Well-developed flood plain occurs in the present Susquehanna channel area.

- 21.0 3.0 Sage Brook. Top of alluvial fan is 1000'. Olean till (Catskill phase) is exposed on north side of stream. This is the southern edge of the morainic barrier that extends northward around the river meander.
- 22.0 1.0 Turn right (east) at Guaquaga over Susquehanna River and keep left at road Y .2 mi. Good view of present channel, plains and terraces on this west-flowing stretch of river.
- 24.4 2.4 STOP 4. This is a .25 sq. mi. area of stratified glacial deposits. Materials have a wide range of size, composition, and structural forms. The history of this area originated with blockage of the river by ice and morainic deposits in the channel to the west. The glacial meltwaters were diverted to a low pass east of the former valley, causing incisement of the former divide. Further recession of the ice front occurred with the abandonment of stagnant blocks that melted more slowly owing to favorable positions of insulation. These conditions account for the complex bedding, size, and sorting of material relations. Much evidence of ice-contact deposits, lacustrine conditions, deltaic sedimentation, and valley train outwash is visible. Disconformities occur indicating an erosional interval separating deposition of older and coarser materials from younger sands. In some of the outwash sands there are veinlike structures composed of "bridged" grains. Normal faulting is also present. Travel in and out of quarry is .6 mi.
- 25.3 .3 From the quarry take the road south to East Windsor, pass under the tracks and turn right (south) at the T. This valley is the former overflow channel of the Susquehanna that was in turn abandoned when the drift dam was breached in the older channel to the west. Elevation of the pass is 1000'.
- 28.6 3.3 Intersection of old Rt. 17, turn left (east) and stay on road until Gulf Summit, 7.7 mi.
- 30.2 1.6 Damascus. To this point the route elevation has been 900'-1050' and at this level all bedrock is marine. Rock exposures in the new Rt. 17 road-cuts at Damascus indicate this is the strand line at road level. There are many interfingerings of marine and non-marine beds at this locality. Eastward the rocks are mostly non-marine. Damascus is on an incised alluvial fan of Tuscarora Creek. The road now climbs what is locally called "Tuscarora Mountain", and hill elevations are over 1900'.
- 32.9 2.7 South of the road is the first visible exposure of the non-marine strata of the Catskill delta-alluvial plain complex. Formations are still in the West Falls Group and are continuous for more than one mile.
- 33.9 1.0 Deer Lake. This lake along with Sky Lake one mile north and Fly Lake one mile south occur in the drainage of Fly Creek. The amphitheater-like basins all contain constrictions on the south suggesting their glacial origin of impoundment of south-flowing Fly Creek behind morainic loop

## TRIP D

dams. This pattern is repeated throughout the Catskill area.

- 36.3 2.4 STOP 5. Turn right (south) to Gulf Summit. This area contains a great variety of glacial deposits, many are stratified. This is a topographic hollow with slopes rising on all sides, and thus was the locus for a large stagnant ice mass. The meltwater drainage was southwest and a deep notch was incised southwest of the village. This is now the divide, elevation 1375', between Cascade Creek flowing west to the Susquehanna River and a tributary of Fly Creek flowing east to the West Branch Delaware River. (see Fig.7 and 8) Cascade Creek with greater gradient is capturing drainage that formerly went eastward. 2.2 mi. round trip to Gulf Summit and return to Rt. 17.
- 39.0 2.7 North of road is sand and gravel quarry developed in materials that indicate deltaic and glacio-fluviatile origin. These deposits are typical of the Otisville gravelly loam that occurs as a terrace-band through this area at elevations that reach 1410'. Thus, at a minimum there has been more than 35' of post-glacial incisement through the pass at Gulf Summit.
- 40.8 1.8 Junction of Rts. 17 and 41. At this location on north side of road was a well-developed esker, recently demolished during construction of the new road. From this point to Deposit in the Oquaga Creek valley are many glacial deposits, including high-level hanging deltas. See text for data on Oquaga Creek.
- 44.3 3.5 Deposit. LUNCH STOP at the Jordan House. This town is often given as the western boundary of the Catskill Mountains. Eastward the rocks are all continental, (Fig.4) and the stratigraphy for the general area is the Sonyea Group, with the Stony Clove and Lower Katsberg formation in the valley and lower slopes and the Upper Katsberg formation of the West Falls Group on the higher slopes and capping the mountains.
- 45.5 1.2 Turn on Rt. 10 left (east) at stop light. Stay on Rt. 10 to Cannonsville, 9.2 mi. The route parallels the west-flowing West Branch Delaware River. Upper Katsberg beds will be seen on left, with cross bedding, typical of many non-marine sandstones. Large outwash area is present on south side of river.
- 47.2 1.7 Old Rt. 10 has been abandoned east of intersection of Rt. 8 and Cold Spring Creek. This is new bridge over the river and all the new construction was necessitated by development of Cannonsville dam and area as a reservoir for New York City. Work is done through the office of the Board of Water Supply.
- 48.6 1.4 Massive continental sandstones. This is near contact of Upper Katsberg and Slide Mountain formations. Good exposures for .8 mi.
- 50.2 1.6 STOP 6. Picture stop for Cannonsville dam area. The Board of Water Supply, City of New York was created in 1905. Since that time water use in New York City has risen from 400,000,000 gallons per day to 1,200,000,000 gpd in 1955. Estimated usage for the year 2000 is more than 1,900,000,000 gpd. The Catskill system of reservoirs was started in 1907 for eastern drainages. When these supplies appeared inadequate for continued growth of the City, enabling interstate legislation was undertaken to use Catskill drainages of the west-draining Delaware

## TRIP D

River. In 1931 by court action 440,000,000 gpd could be used by the City and this was increased to total usage of 800,000,000 gpd in 1954. Total cost for the present Catskill reservoir system is well over \$1 billion.

The Cannonsville Reservoir will impound 97.4 billion gallons in the 450 square mile drainage area of the West Branch Delaware River. The dam is an earth embankment about 1,500' long and 175' high. The water supply will move by gravity through the West Branch Tunnel to the collecting Rondout Reservoir. The tunnel will be 44 miles long and 11.3 feet in diameter. Estimated cost of the dam and reservoir construction is about \$60 million and the tunnel at \$81 million. (Source: 50th Anniversary Report of the Board of Water Supply).

- 53.6 3.4 STOP 7. Catskill-type red beds. View of the village of Cannonsville that will be inundated when construction of area has been completed. (see Cover page for picture taken prior to construction).
- 54.7 1.1 Pass over West Branch Delaware River and at Cannonsville turn right .2 mi. then left (north) up Trout Creek. (see text for Trout Creek data) Cannonsville was built on materials that developed a small alluvial fan and terrace. Soil classification is Tunkhannock gravelly loam. It is 114' to bedrock.  
A variety of phenomena can be seen during ascent of Trout Creek. The valley slopes are in places bedrock (lower Katsberg Formation), and in others show unconsolidated materials some till, some stratified outwash and kame terrace deposits, and probably some of the large blocky rocks are in the range of congeliturbites. In places the road is on a terrace and there are constructional hills, mostly kames, developed in a valley-choker type of morainic complex. North of the kame and terrace area are flat plains of lake deposits impounded by the stagnant ice.
- 57.8 3.1 Lacustrine sands were uncovered during construction of the new bridge and another well-developed lake plain occurs upstream from this locality.
- 60.0 2.2 Rock Royal. Sherruck Brook has developed an alluvial fan and associated with it is glacial outwash. On east side of Trout Creek are more exposures of stratified outwash. Lake plain occurs north of this area.
- 63.4 3.4 Village of Trout Creek and intersection of Rt. 206. Continue north. Valley fill is 60' thick.
- 64.0 .6 Glacial constructional topography of knobby-morainic hills, incised by a post-glacial, V-shaped gorge. This pattern will be seen many times on the trip.
- 65.4 1.4 Turn right, stay on blacktop.
- 65.9 .5 Bedrock and morairic loop.
- 67.9 2.0 STOP 8. Stone net in lower Katsberg Formation. This was first noticed by E.H. Muller. Open meadows as this, throughout the Catskills, often show similar features. The slabs develop polygonal shapes, and constantly change in attitude from the center of a net. There is also some tendency for size-sorting of slabs. The original spacing of joints



## TRIP D

seems to influence the location and development of the nets. Frost heaving and ice wedging aid in detritation and movement of the slabs.

- 68.2 .3 Drainage divide for Susquehanna and Delaware systems.
- 69.9 1.7 Turn left at T to Sidney Center.
- 71.0 1.1 Turn right in Sidney Center on blacktop at Flying A sign.
- 72.0 1.0 Keep to left at Y in the road. Morainic loop on left side of road with post-glacial gorge.
- 73.0 1.0 Man-made lake.
- 73.5 .5 This is site on right side of road of Gulf Oil Company test well drilled by Delta 29. On March 16, 1963, 3800' of rock had been drilled in about a month. Apparently the hope is that Oriskany sandstone when encountered will contain oil or gas of commercial value. From this position the road descends to Ouleout Creek drainage area.
- 74.8 1.0 STOP 9. Rt. 7B, East Sidney Dam and Ouleout Creek drainage area. See manuscript for data on Ouleout Creek and Figure 9. Turn right .3 mi. to dam. Oneonta formation red beds occur at base of dam.

East Sidney Dam built by Department of Army, Corps of Engineers. Completed 1950.

Dam characteristics:

Quantity of concrete	156,000 cu. yd.
Height above Ouleout Ck.	130'
Length of Spillway crest	240'
Total length of concrete dam	750'

Embankment

Length	2,010'
Rock Fill	113,000 cu. yd.
Earth Fill	194,000 cu. yd.

Excavation

Earth	323,000 cu. yd.
Rock	113,000 cu. yd.

Take Rt. 7B from the dam going east until intersection with Rt. 7. This part of road traverses excellent kame and kettle topography. There are two well-developed lower terraces before Ouleout Creek unites with the Susquehanna River. Sands and gravels are Tunkhannock gravelly loam, the upper terrace is Tioga silt loam and lower terrace is Chenango silt loam.

- 79.1 4.3 Rt. 7 turn left (south) to Unadilla. Oneonta formation crops out along railway cut. Susquehanna River flows south, elevation 1000'. Hills rise to 1900'.
- 81.0 1.9 STOP 10. Quarry southwest side of Unadilla. This area is kame and kettle topography within a morainic complex that impounded meltwaters during glacial recession. Extensive lake plains and terraces levels and remnants of levels occur from this position upstream several miles. This pattern is repeated several times downstream in the Susquehanna valley. See text for description of lithology.

## TRIP D

- 84.4 3.4 Rt. 8 intersection and Sidney. If time permits a left turn will be made, to quarry site 3.3 mi. south of Rt. 8 and .4 mi. east off of main road.
- 88.1 3.7 STOP 11. The Masonville Quarry owned and operated by The American Blue Stone Company, New York, N.Y.: has been in operation since 1945. (See Fig.6) Current level working area is about 250' x 100' and production is confined to mill blocks. The processing plant is in South Unadilla. The quarry is flooded during the winter months to a height five feet above the lower bench to protect the stone from ice and frost damage. Mr. James J. Newberry has kindly given information about the quarry and has given permission to visit it. The mill processes 16,000 cu. ft. of stone from this quarry.
- 91.8 3.7 Back to Sidney and intersection with Rt. 7. This is near the confluence of the Susquehanna and Unadilla Rivers. Streamflow of these rivers in this area are: Susquehanna River at Unadilla, N.Y., 1,626 cfs for 984 sq. mi. drainage area, and Unadilla River at Rockdale, N.Y., 842 cfs for 518 sq. mi. drainage area. Although the Susquehanna has two times the flow today owing to the larger drainage area, it is probable that the Unadilla carried more water during the ice ages. The headwaters of the Unadilla are at lower elevations than most Susquehanna tributaries and the major tributaries of the Unadilla occur in through-valleys. Overflow of the glacial lakes in the Mohawk Valley Region therefore found ready-made outlets in such rivers as the Unadilla and Chenango, and turned these valleys into giant sluiceways for the impounded glacial waters.
- There is a high-level drainage channel of the Unadilla in the saddle that occurs just east of Mt. Moses, the hill that rises north of the intersection of Rts. 7 and 8. Throughout the Sidney area are outwash sand and gravel quarries. Terrace development is common and a good view of the 1010' level occurs on the south side of river.
- 94.6 2.8 Quarry outwash materials, coarse and rubbly at the bottom and finer sands and gravels at the top. The road is built on the 1010' terrace level.
- 97.0 2.4 Bainbridge stoplight intersection of Rt. 206. Bainbridge is built on the 1010' terrace. Susquehanna River is 975'
- 97.7 .7 Olean till on right side of road. (See text for description).
- 100.5 2.8 Sand and gravel area. Ice contact features are present. The Susquehanna is incised through the outwash plain.
- 101.9 1.4 Afton Lake, a kettle hole lake. This is kame and kettle topography, created in part by a morainic complex. The locale is characteristic of many others in the Susquehanna valley, in which the constructional topography occurs near the junction of the Susquehanna and a tributary. The south-flowing Kelsey Brook is an underfit stream and the morainic areas are upstream in the Susquehanna valley.
- 102.7 .8 Afton and Rt. 41 intersection. More kame and kettle topography near the mouth of the north-flowing Cornell Creek on the south side of the Susquehanna valley.

## TRIP D

- 107.8 5.1 STOP 12. near Nineveh. The Susquehanna River 950' elevation has incised more than 100' through a broad and exceptionally well-preserved 1060' terrace level, called "The Plains". Remnants of this level can be found several miles along the Susquehanna.
- 108.8 1.0 Wylie Brook and Rt. 235. Continue west on Rt. 7 to Binghamton. We are now leaving the Susquehanna River which turns south. The road ascends Belden Brook up to Belden Hill.
- 110.0 4.8 STOP 13. Parking area, elevation 1650'. Near the Chenango-Susquehanna drainage divide. View to the south provides appearance of accordant summit levels. The summits actually range between 1600' and 1850'. Westward the road follows a tributary of Osborne Creek, an underfit stream. There are a series of at least four different morainic loops in this tributary system of the Chenango. These choker moraines occur at intervals from the parking area of 1.6 mi., 1.6 mi., .5 mi., and .9 mi. Notice the flat topography that is always upstream of these constructional areas.
- 122.2 7.4 Intersection of Rt. 369. (See Trip B Road Log and Route Description for remainder of the route, although the writeup is in reverse order).  
Travel back to Harpur College via Rt. 7 and then Rt. 17.
- 132.5 10.3 Harpur College entrance.



## FACIES AND THE RHINESTREET FORMATION IN SOUTH CENTRAL NEW YORK

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## INTRODUCTION

The purpose of this field trip is twofold: 1. Outline stratigraphic relationships in a part of the Catskill delta complex, and 2. Describe and compare the techniques used in solving problems presented by this stratigraphy. The writer's discussion and the field trip proper are concerned with the Rhinestreet Formation (see below) as it is developed between Elmira and Binghamton, New York. During the trip stops will be made at exposures displaying typical lithologic and paleontologic features of the Rhinestreet Formation and the facies units with which it is associated. These exposures are accessible and of sufficient size to give the viewer a representative sample of the sequence involved. It is hoped the accessibility and size of these sections will encourage more detailed examination at a later date by interested parties.

To outline the nomenclature used in this discussion, the Rhinestreet Formation and its members are summarized briefly. Detailed descriptions of the stratigraphic limits and areal extent of these units are given elsewhere (Sutton and others, 1962; Sutton, 1963). The history of the term "Chemung", long associated with most of the strata to be examined on the trip, is reviewed. Facies relationships within the Rhinestreet are discussed with particular attention given the Chemung magnafacies. Finally, the discussion concludes with a review of the techniques used by previous workers and a detailed description of the techniques employed by the writers in solving some of the stratigraphic problems presented by this sequence.

This report may serve as an introduction to the problems involved when working in the North American Upper Devonian standard section. For historical perspective, those interested should read Hall's "Report of the Fourth Geological District" and then proceed, preferably in chronologic order, through the publications referred to here. In itself, the lengthy list of publications is an indication of the intriguing nature of the problems faced by geologists who have concerned themselves with this classic sequence.

## THE RHINESTREET FORMATION IN THE FIELD TRIP AREA

The Rhinestreet Formation and its members have been defined by Sutton and others (1962). The members are Moreland (bottom), Millport, Dunn Hill, Beers Hill, and Roricks Glen (top). The Moreland, Dunn Hill, and Roricks Glen members are black and dark gray shale units with black shales making up 75 percent of the Moreland, 50 percent of the Dunn Hill, and less than 30 percent of the Roricks Glen. The remaining strata of these members are comprised of dark gray shales and gray, thin, calcareous siltstones. The intervening Millport and Beers Hill members are lithologically similar. They consist of gray shales and mudstones, gray, calcareous siltstones, black and very dark gray shales. Both members are fossiliferous at their type sections.

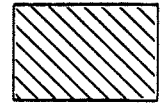
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Acknowledgments: The Harpur College geology staff aided in drafting the illustrations.

Figure 1. Index to Map Symbols

Formations and Members ShownMap Symbols

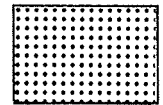
Post - Rhinestreet Strata (undifferentiated)



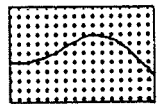
Corning Member of the Gardeau Formation



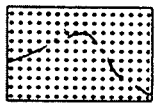
Rhinestreet Formation



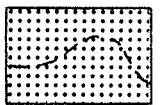
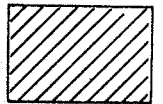
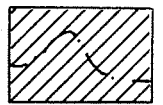
Roricks Glen Member



Dunn Hill Member



Moreland Member

Pre - Rhinestreet Units (Including the Sonyea,  
Middlesex, and Ithaca For-  
mations; See: Figure 2.)Sawmill Creek Member of the Middlesex  
Formation (Shown near Montour Falls, West  
Danby, and Binghamton.)

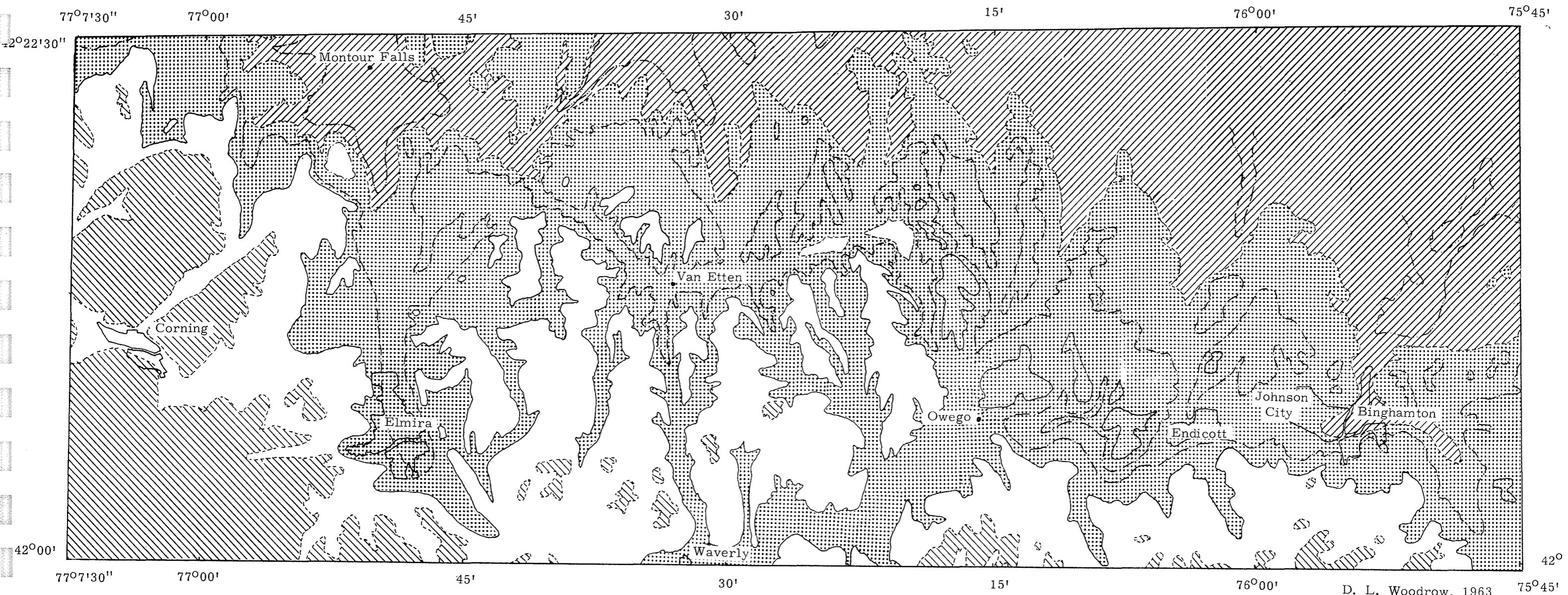


FIGURE 1. RECONNAISSANCE GEOLOGIC MAP SHOWING DISTRIBUTION OF KEY UNITS  
IN THE FIELD TRIP AREA

SCALE : MILES  
4 0 4

Compiled from Humes, 1960, Nugent, 1960  
Twigg, 1961 and Sutton, 1963

D. L. Woodrow, 1963

Figure 1

In 1960, when the writers ended field work, it was felt the key black shale members of the Rhinestreet could not be traced beyond a line trending S 30° W through Van Etten. Southeast of this line the Chemung Formation was recognized. Further reconnaissance by Sutton (1963) and Woodrow (1963) has indicated that dark gray shale equivalents of the black shale members may be traced much further east and southeast than had been supposed previously (Stops 1 and 2). Although the lithologic character of these members differs from the type section lithologies, their equivalency appears to be well established. Extension of the Rhinestreet through recognition of its easterly equivalents eliminates the need for a Chemung Formation. The Moreland, Dunn Hill and Roricks Glen members of the Rhinestreet Formation and the Corning Member (new, see Appendix A) of the overlying Gardeau Formation (redefined, see Appendix A) are continuous from Corning to Binghamton (see Fig. 1 and 6.).

Here, Chemung is restricted to the name of an informal magnafacies unit with its well-known lithologic and paleontologic components. Limiting its use to informal magnafacies terminology provides consistency with correlations as determined by the writers and represents a more accurate understanding of this classic sequence. Retention of the term in a formal rock-stratigraphic terminology would perpetuate the confusion of poorly defined terms that has characterized New York Upper Devonian stratigraphy in the past.

#### OLDER STRATIGRAPHIC TERMINOLOGY

Chemung has had a long and varied history in the geologic literature of New York beginning with the first formal usage in James Hall's 1839 "Report of the Geological Survey" in which he described lithologies and fauna of the Chemung Group (p. 322-324). The name was derived from the town of Chemung, Chemung County, New York, because some of the rocks could be examined at the "...Chemung Upper Narrows, about 11 miles below Elmira". The sequence of units in the type area was outlined in 1840 by Hall (p. 389-395, 402-405). Modifications of what should be recognized within the unit were made by various writers between 1840 and 1906 (Summarized in Wilmarth, 1938, p. 411). The accuracy of Hall's early observations and his growing stature in geology probably inhibited more detailed examination of these strata during the latter part of the nineteenth century.

H. S. Williams (1906, 1909) first referred to the Chemung Formation which was composed of the Cayuta Shale Member (bottom) and the Wellsburg Sandstone Member with a thin conglomerate lentil at the top. Williams's definition was that adopted by the United States Geological Survey and no major modifications were suggested until Chadwick offered a new interpretation of Upper Devonian stratigraphy in the thirties. In Chadwick's scheme, the Chemung Group was again recognized although it contained many more units than that proposed by Hall. Chadwick's group was composed of the Cayuta and Wellsburg Formations with three members in each (1932, p. 352).

Cooper and others (1942) produced a Devonian correlation chart illustrating the use of the term as it was accepted at that time. In this report, a Chemung State was defined, "...because of the widespread and distinctive character of the fauna. The Stage has the same limits that Chadwick gave to the Group" (p. 1734).

Since the late 1940's the United States Geological Survey has been very active in the study of Upper Devonian stratigraphy in west and central New York. De Witt and Colton (1959) published a partial summary of this work in which they proposed revised correlations of the lower Upper Devonian rocks to the west of Elmira and Watkins Glen. They mention the Chemung Formation with its basal member, the Cayuta Shale, which corresponds in a general way to the definition proposed by Sutton and others (1962) who defined the Chemung Formation as being "...restricted geographically to the strata lying southeast of a S 30° W line passing through Van Etten and stratigraphically above the Moreland Member below and including, at its top, the Fall Creek Conglomerate. The



Watkins Glen - Elmira		Binghamton	
Formations	Members	Formations	Members
New Milford		New Milford	
Gardeau	Corning	Gardeau	Corning
Rhonestreet	Roricks Glen Beers Hill Dunn Hill Millport Moreland	Rhonestreet	Roricks Glen Beers Hill Dunn Hill Millport Moreland
Sonyea	Rye Point Rock Stream Pulteney	Sonyea	West Danby
Middlesex	Sawmill Creek Johns Creek Montour	Middlesex	Sawmill Creek Kattell Montour
Ithaca	West River Genundewa Penn Yan	Ithaca	
Geneseo		Geneseo	

Figure 2. Nomenclature for Upper Devonian Units Recognized in the Field Trip Area.

formation is approximately 1500 feet thick; a small part of which is displayed at Chemung Narrows, the type section" (1962, p. 393).

This summary, though not comprehensive, does show Chemung used in both the rock and time-stratigraphic sense. The term has additional, less formal lithologic and faunal connotations that are discussed below. No attempt has been made to show the effect of these numerous revisions on the work of stratigraphers who have studied correlative rocks in neighboring states.

## MAGNAFACIES

### The Concept, Its Applications and Limitations

The magnafacies concept (Caster, 1934) is of great value in understanding broad lithologic and faunal relationships of the Catskill delta complex. Caster described magnafacies as "facies zones" that are given the dimension of time, making them complete lithic units, or magnafacies (p. 21). Caster also notes (p. 22) that "...a magnafacies is made up of varitemporaneous parvafacies of like lithology and closely related (mutated) faunas" (Fig.3) Caster's description of larger facies units that transgress "planes of contemporaneity" (p. 19-29) in the Upper Devonian of northwest Pennsylvania implies facies migration through large spans of time. A strikingly similar situation is encountered in the field trip area where facies migration is evidenced throughout the sequence. Similarities between the two regions make possible application of the magnafacies concept.

Although other magnafacies, all having characteristic lithologies (lithofacies) and faunas (biofacies), are recognized by the writers in the Catskill delta complex, only the Chemung magnafacies is well exposed in the Binghamton-Elmira area. A small part of the Portage magnafacies is exposed here, but this part is not typical of the entire unit. Sufficiently detailed descriptions of Caster's magnafacies are not available for accurate comparison with those developed in the Binghamton-Elmira area, therefore, the names used here are not those defined by Caster. However, this does not detract from the applicability of the concept.

Other workers such as Chadwick (1933), Ashley (1938), and Fisher (1956) have used similar ideas in describing Catskill delta stratigraphy. Chadwick's rather complex diagram is given below (Fig.3).

Unlike Caster the writers have utilized the persistent, black and dark gray shale units as marker beds for differentiation of stratigraphic units that cut through the magnafacies. The black shales and their easterly dark gray shale equivalents are lithologically distinct, stratigraphically limited, and laterally persistent making them excellent marker beds. Faunal zones of the type region were found to be inadequate for accurate correlation over distances greater than a few miles. Indeed, their restriction to specific lithologies indicates they are facies faunas, a feature Caster pointed out as typical of magnafacies development (1934, p. 31-36). Therefore, it is to be expected that regional correlations based on these facies fauna will define magnafacies.

The magnafacies concept has been found useful only on a regional basis owing to complex small scale facies relationships not amenable to such simple explanation. The wide areal extent of red and black tongues of the Catskill and Cleveland magnafacies is the only well-defined indication of the degree of interbedding of the magnafacies. Relationships between other magnafacies are known to a much lesser degree, and further work is necessary to clarify the picture.

Changes in lithofacies and biofacies occur within each magnafacies. However, the

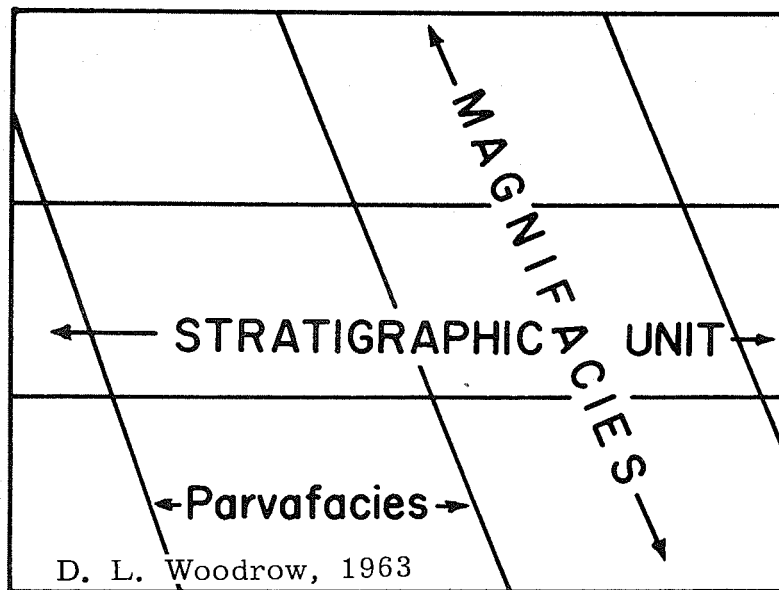
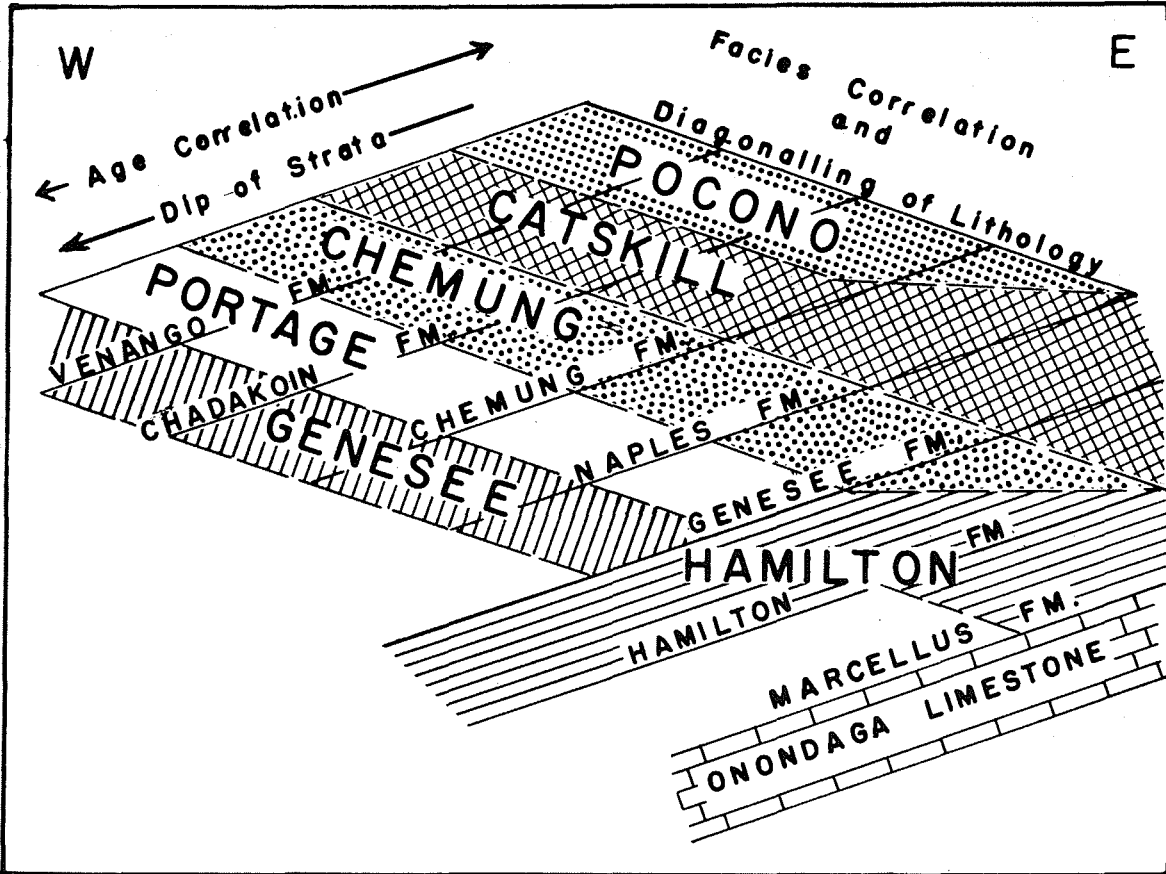


Figure 3. Relation of Formal Stratigraphic Units and Magnafacies (Modified from Caster, 1934, p. 20).



D. L. Woodrow, 1963

Figure 4. Diagram illustrating the relationships of facies and Formations in the Middle and Upper Devonian of New York and Northern Pennsylvania as interpreted by G. H. Chadwick (1933, p. 92; slightly modified by the writers.)

use of such terms implies a comparison of the most typical features of each, ignoring the more intimate, small scale changes. In no way does this affect the value of the concept provided the limitations are clearly understood.

### Chemung Lithofacies

Chemung lithology and Chemung fauna bring to mind a rather clear picture of lithologies and fauna, especially to stratigraphers who have concerned themselves with problems of the New York Upper Devonian sequence. Even so, these distinctions are not specific because of the scarcity of detailed published data. James Hall first described the lithologies as being different than those lower in the sequence: "...in the absence of argillaceous matter in most of the layers, these being of a porous texture; while still a large portion of the mass consists of compact shales and argillaceous sandstones of a softer texture than those below. The surface of the sandstone is rough..." (1839, p. 322). The distinctive sedimentary structures displayed at Chemung Narrows did not escape Hall. He noted: "At the Chemung Upper Narrows, and at several other localities there occurs in this group a stratum of concretionary sandstone of a peculiar character. In a few instances only are the concretions perfectly formed, but generally they have one side imperfect, with a solid nucleus partially surrounded with concentric laminae, which easily separate from each other..." (1839, p. 323-324). These "concretions" (flow rolls) are prominent features of the exposures at Smithboro and Chemung Narrows (Stops 4 and 5) and at many other exposures of the Chemung lithofacies.

A slightly more detailed description is given by Williams and others who describe the Chemung formation as being "...composed almost entirely of sandy shales and thin-bedded sandstone of drab or very light gray color. Some heavy bedded sandstone and fine pebble conglomerates were noted as were the flow rolls described by Hall. Williams also refers to "...blocky argillaceous shales..." as being diagnostic of the Chemung rocks (1909, p. 9, 10).

A more detailed description of the lithologies, based on the writers' studies in the type region follow:

#### Sandstone and Siltstone

Grain size variable: medium silt to fine or medium sand  
 Light gray to tan to buff when fresh, weathers white or dull brown  
 Bedding thickness variable: two inches to six feet, some beds apparently lenticular; bedding surfaces uneven and hummocky  
 Slightly to very calcareous; fossils common to rare  
 Sedimentary structures include: cross laminations and cross bedding, flow rolls, ripple marks; sole markings very rare

#### Mudstone

Silty to very silty; chunky fracture  
 Brown to olive to blue gray when fresh, weathers purplish brown to blue gray  
 Calcareous to non-calcareous, often profusely fossiliferous; fossils occur in all orientations with respect to bedding.  
 Generally appears structureless, petrographic examination often reveals minute laminae strongly distorted.

#### Shale

Silty to very silty; hackly, rarely fissile; soft  
 Gray to olive when fresh, weathers to tan or buff; dark gray shales very rare  
 Slightly calcareous, fossils may be profuse  
 Laminae noted in most shales, cross laminae noted in siltier beds.

### Coquinite

Composed of size-sorted shells or shell fragments

Matrix of fine sand or shell fragments

Thickness variable: One or two inches to two or three feet; very lenticular

Massive, stylolites well developed; enclosed quartz grains often partially or totally replaced by carbonate.

The amount of each rock type will vary considerably from exposure to exposure; it is uncommon to find large exposures composed entirely of a single lithology. Petrographic studies of the sandstones show them to be subgraywackes of variable composition. Siltstones are compositionally similar. In the more calcareous, fossiliferous rocks, quartz grains are often etched and replaced by interstitial carbonate. Silica is not a common cementing agent.

Conglomerates form a very small part of the sequence, but their presence has great significance for the interpretation of depositional environment. Two types of rock containing quartz pebbles have been noted in the field trip area. The most familiar consists of granules and pebbles of milky quartz and gray and green shales (rare). Pebbles are somewhat discoid and are well rounded. A matrix of fine- to coarse-grained quartz sand cemented by carbonate or silica fills and interstices. Carbonate-rich layers are quite friable when weathered. The conglomerates occur as scattered lenses, with a dimension along strike of several miles, a mile or two across strike, and never over 20 feet thick. The second rock type containing pebbles and granules is little more than a "conglomeratic mudstone". Pebbles and granules of milky quartz are widely scattered in thin beds of dense, greenish-gray mudstone.

Apparently these lithologies occur a few hundred feet below the oldest red-beds in the field trip area. Outcrops in which conglomerates are displayed do not contain the "conglomeratic mudstones", that is, both rock types have never been observed in a single outcrop.

### Chemung Biofacies

Fossils are common in rocks of the Chemung magnafacies. Although found in all lithologies, the fossils are generally concentrated in the mudstones. Brachiopods and pelecypods predominate, but gastropods, cephalopods, coelentrates, echinoderms, and bryozoa also have been reported. At some localities forms are found with no indication of movement after death while at other locations disarticulation of valves is complete and their alignment indicates transport and sorting after death of the organism. Other indications of movement of the hard parts after death of the organism are the coquinities scattered throughout the sequence and fossils forming a significant part of the sediments filling groove casts wherever these sole markings are developed.

Perhaps the best known fossil of the Chemung biofacies is the ubiquitous Cyrtospirifer chemungensis ("Spirifer disjunctus"). The lowest stratigraphic occurrence of this form has been used as a zone marking the base of the Chemung State throughout the Appalachian basin. Greiner (1957) has demonstrated very clearly the variety and stratigraphic distribution of the closely related Cyrtospirifer species in the Upper Devonian and Lower Mississippian rocks of New York and northern Pennsylvania. Other zones based on the brachiopods (Thiemella danbyi, Tropidoleptus carinatus, and Nervostrophia nervosa) have been used as the basis for correlation within the Cayuta Shale Member in New York. Lengthy lists of fossils reported from Chemung biofacies are given by Chadwick (1935) and Williams and others (1909). These publications should be consulted for detailed information about the species included in the Chemung biofacies. When compared with fauna in the older Ithaca Formation and Hamilton Group the close faunal relationship that exists between these and the Upper Devonian units becomes apparent.

## THE STRATIGRAPHIC PROBLEM

### Preliminary Statement

Throughout the field trip area, complex interfingering and intimately interbedded facies repeat in a cyclic fashion and occur with varying degrees of completeness on all scales from a few inches to several hundred feet. In addition, interbedded parts of magnafacies have a wedge-like form in cross section, thickening toward source and none occupy fixed geographic positions throughout time, but are offset with respect to the facies units above and below. Therefore, the basic problem is: To make accurate, reproducible correlations through the shifting magnafacies and thereby outline the stratigraphic framework of this part of the delta complex.

We will now examine some procedures that have been used in attempting to resolve this problem.

### Techniques Applied by Previous Workers

Most of the stratigraphic work carried out in the field trip area has involved the use of paleontologic or lithologic criteria or some combination of both. Generally, paleontologic criteria have been considered most reliable. The earliest work (Hall, 1843) had as its purpose little more than description of the rocks and demonstration of the gross lithologic relationships in the western part of New York. Not until Clarke and Luther (1905) mapped the Elmira and Watkins Quadrangles was detailed work undertaken. Their approach was based on tracing key beds and on paleontology. However, the difficulty of distinguishing between similar lithologic bodies stratigraphically hundreds of feet apart resulted in correlation errors.

H. S. Williams and others (1909) mapped the Watkins Glen-Catatonk Quadrangles. Lithologic sequence and variations were noted but paleontologic relationships were strongly emphasized; in fact, it is Williams who compiled a great deal of what we presently know of the Chemung biofacies and its variations. Although the faunal zones established by Williams have present day applications, they are somewhat elusive and can be distinguished one from another only with difficulty.

Apparently Chadwick (1933) relied on lithologic criteria for correlation, at least until 1935 when paleontology was called upon to corroborate his previous findings. (Chadwick's reasons for relying on paleontology for verification of his work, already nearly completed, make interesting reading and are indicative of the philosophy of the times. See: Chadwick, 1935, p. 306). The sheer bulk of his work and multitude of stratigraphic unit names Chadwick employed illustrate the magnitude of the problems involved in correlating throughout the Catskill delta.

Another approach, employed by De Witt and Colton, was based almost entirely on lithologic relations. Use was made of the very precise techniques described below.

"During the course of the field study more than 400 closely spaced stratigraphic sections were measured by plane table and the lithologic character of the rocks was recorded in detail. Other sections were measured with steel tape, and the elevations of key beds were determined by plane-table survey or with an altimeter. Regional correlations were established by comparing the lithologic sequence in adjacent sections and by mapping key beds and other stratigraphic units across the study area. In several places fossils were used to check the lithologic correlations". (1959, p. 2820)

These correlations were discussed by Sutton and others (1962) who pointed out that certain key beds either had been misidentified or not recognized.

Studies undertaken without an understanding of the facies relations are similar in that errors of correlation resulted from misidentification of key beds or faunal zones. In addition, work based solely on paleontologic criteria eventually results in the mapping of magnafacies, especially if correlation is based on benthonic fauna and extended over many miles. The species of the Chemung biofacies illustrate this problem. In the main, they are facies fossils. That is, they are restricted to specific lithologies which may be taken to indicate the living organisms had adapted to specific environments. When a particular environment shifted (as happened during the gradual filling-in of the Catskill basin) organisms adapted to an ecologic niche within the environment, in effect, "shifted" with it. "Migrations" of this type result in biofacies being offset from those occurring above and below.

Nugent (1960) demonstrated that Cyrtospirifer chemungensis, used to mark the base of Williams' Cayuta Shale Member in the field trip area, occurs throughout several hundred feet of strata. Moreover, the stratigraphic position of the lowest occurrence of this guide fossil varies significantly in outcrops separated by only a few miles. Williams (1913) defined other zones based on multiple occurrences of Tropidoleptus carinatus which he employed in further defining the Cayuta Shale Member of the field trip area. However, the writers, after locating very few of these brachiopods while working in five fifteen quadrangles felt differentiation of these zones necessitated an inordinate amount of field work in their reconnaissance studies. In addition, T. carinatus is a member of the benthonic fauna noted in these rocks and can be expected to reflect magnafacies migrations. Therefore, although mapping of these zones is valid, the geographic limitations of the method must be realized.

In the same manner, regional study of the lithologic sequence alone will result in correlation of magnafacies. Here, the major problem occurs when comparing widely separated sections. Sequences are easily confused and units separated hundreds of feet stratigraphically may be inaccurately correlated. Thus, the most challenging problem in such areas is the tracing of key beds through magnafacies. To achieve this goal, the writers employed a variety of criteria for correlation. as explained below.

#### Techniques Employed By The Writers

As graduate research at the University of Rochester under the supervision of Dr. Robert G. Sutton, the writers and E. C. Humes studied the stratigraphy of the Upper Devonian strata in the Watkins Glen-Owego region. During this study the necessity of employing several criteria for correlation became apparent. A partial explanation of these criteria and the correlations resulting from their application are given by Sutton and others (1962). A more detailed explanation is offered here.

Exposures were located and at selected localities stratigraphic measurements were made with Jacob Staff and Brunton Compass. Every effort was made to observe detailed relationships in the exposures. Black or very dark shales were known to be most significant; thus their presence or absence was carefully noted. The orientation of sedimentary structures and the presence or absence of fossils, especially Cyrtospirifer chemungensis, were noted. Most of this work was carried out by Nugent (1960) and Humes (1960). Woodrow (1960) studied fossil relations of the lowest Cyrtospirifer zone in the Spencer-Alpine-Montour Falls region to define its persistence and to determine the paleoecology of this faunal zone.

Key black shales were correlated across the area using lithologic sequence, paleontology, and variations in orientation of sedimentary structures. At all times it was necessary to take into account subtle complications caused by low domal structures developed in this region. Exposures were isolated and structural data often was lacking, however, making assignment of the black shales to their proper stratigraphic positions difficult. A similar situation confronted Sutton (1959) when working in the Harford and Dryden quadrangles northeast of the field trip area. Using subsurface data, Sutton noted



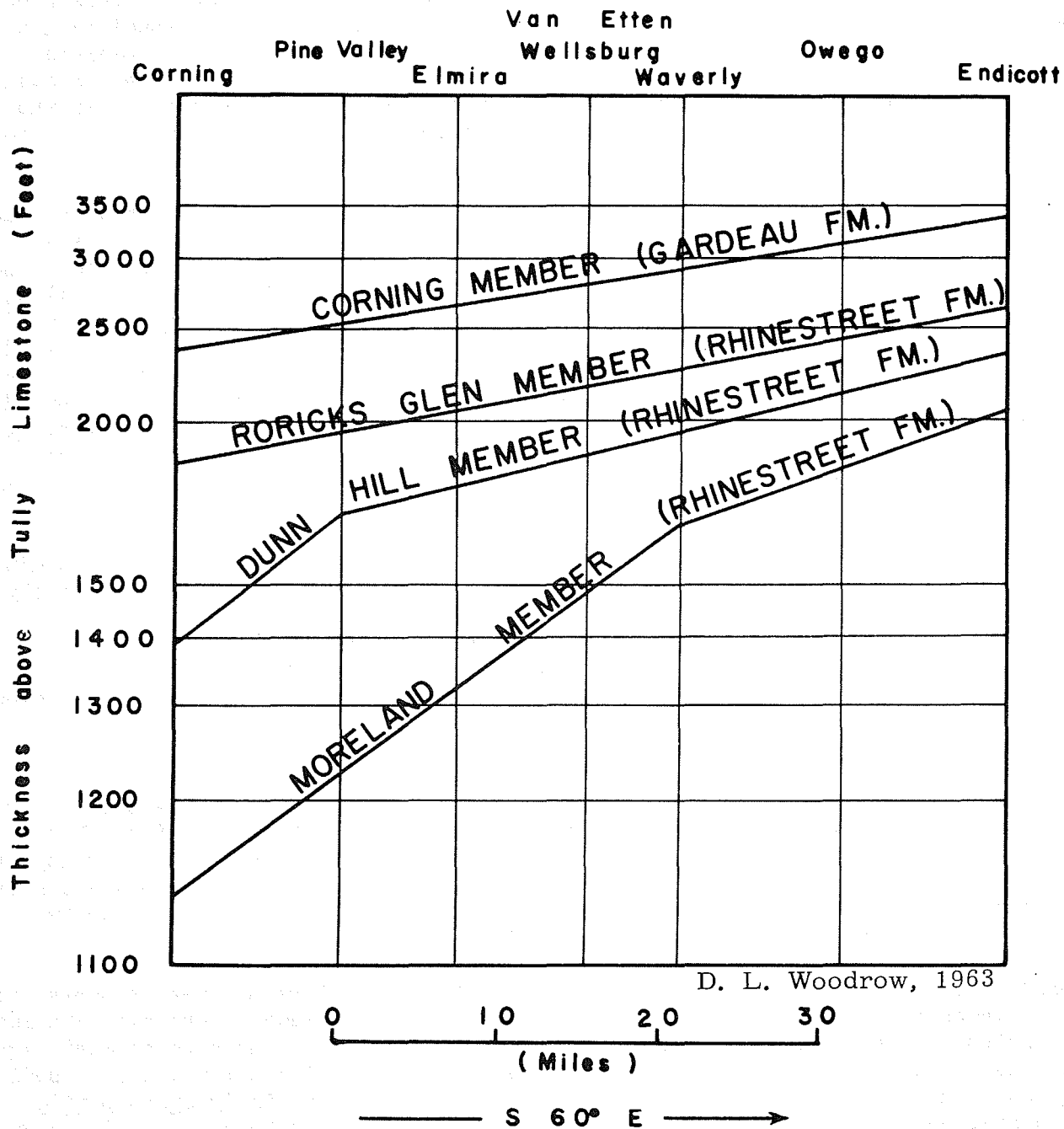


Figure 5. Post-Tully Thickening Rates

an exponential increase in thickening of the post-Tully pre-Enfield strata towards S 60° E (p. 12). He determined the direction and rate of maximum thickening by plotting thickness of strata between the Tully limestone and the base of "Zone A" (later designated the Sawmill Creek Member of the Middlesex Formation). Thus, using the thickening rate chart, Sutton was able to predict the location of Zone A wherever subsurface data was available. The Tully limestone was selected as the reference unit because of its distinctive lithology and stratigraphic position directly beneath the Genesee Formation. These two features make the Tully easily recognizable in well samples.

Following Sutton's example, Nugent and Humes determined the maximum thickening rates of the strata between the Tully limestone and the key black shales of the study area. Again, maximum thickening was found to occur in a S 60° E direction (Fig.5). Next, using subsurface data from Kreidler (1957), structure contour maps were constructed illustrating the top of the Tully in the study area. However, in some parts of the area no wells had been drilled, thus control was lacking. In these instances, it was possible to predict the location of the Tully from the combined use of the thickening rate chart and elevations of previously located shale units occurring in small, scattered outcrops by utilizing the thickening rate chart and the Tully structure maps. Thus, the top of the Tully limestone was used as datum throughout the field trip area.

Establishment of the datum does not exclude the use of other criteria for accurate correlation, therefore substantiation of these results was sought using other stratigraphic methods. For example, a black shale unit north of Van Etten, in Langsford Creek, at 1180 feet elevation, was originally interpreted as the Moreland Member of the Rhinestreet Formation. This identification was made on the basis of subsurface data and projections of surface data from nearby exposures. However, massive fine-grained sandstones containing many large forms of Cyrtospirifer chemungensis were located less than 150 feet above the black shale. Approximately 50 feet below the black shale in the same stream, diminutive forms of Cyrtospirifer were noted. This field evidence made the original correlation appear questionable, for in other exposures nearby it had been determined previously that massive sandstones were a robust fauna overlies the stratigraphically higher Dunn Hill Member of the Rhinestreet and the diminutive forms of Cyrtospirifer occur just below it. This lithology and fauna is not associated with the Moreland Member in the Van Etten region, instead, it occurs 200-300 feet higher stratigraphically. Additional field checks indicated northerly dips which explain the low position of the Dunn Hill Member. This evidence indicated a small dome at Van Etten. Subsequent drilling has proved this interpretation correct and some natural gas has been produced from the dome.

Special correlation problems concerned with the dark gray shales in the East Church Street quarries at Elmira (Stop 7), the shales exposed near Owego (Stop 3), and the dark gray shales that extend into northern Pennsylvania have been resolved through the use of Post-Tully thickening rates, and lithologic and paleontologic relationships.

The writers' studies, although largely of a reconnaissance nature, did include detailed work in many localities in order to develop reliable criteria for correlation of key beds. When this sequence has been studied in greater detail the correlations discussed in this report may require modification, but refinements of correlation should not invalidate the procedures developed. Experience here has shown that problems in stratigraphy of the Catskill delta complex must be solved by application of many correlative techniques. The use of a single technique has led to errors in the past and can be expected to do so in the future.

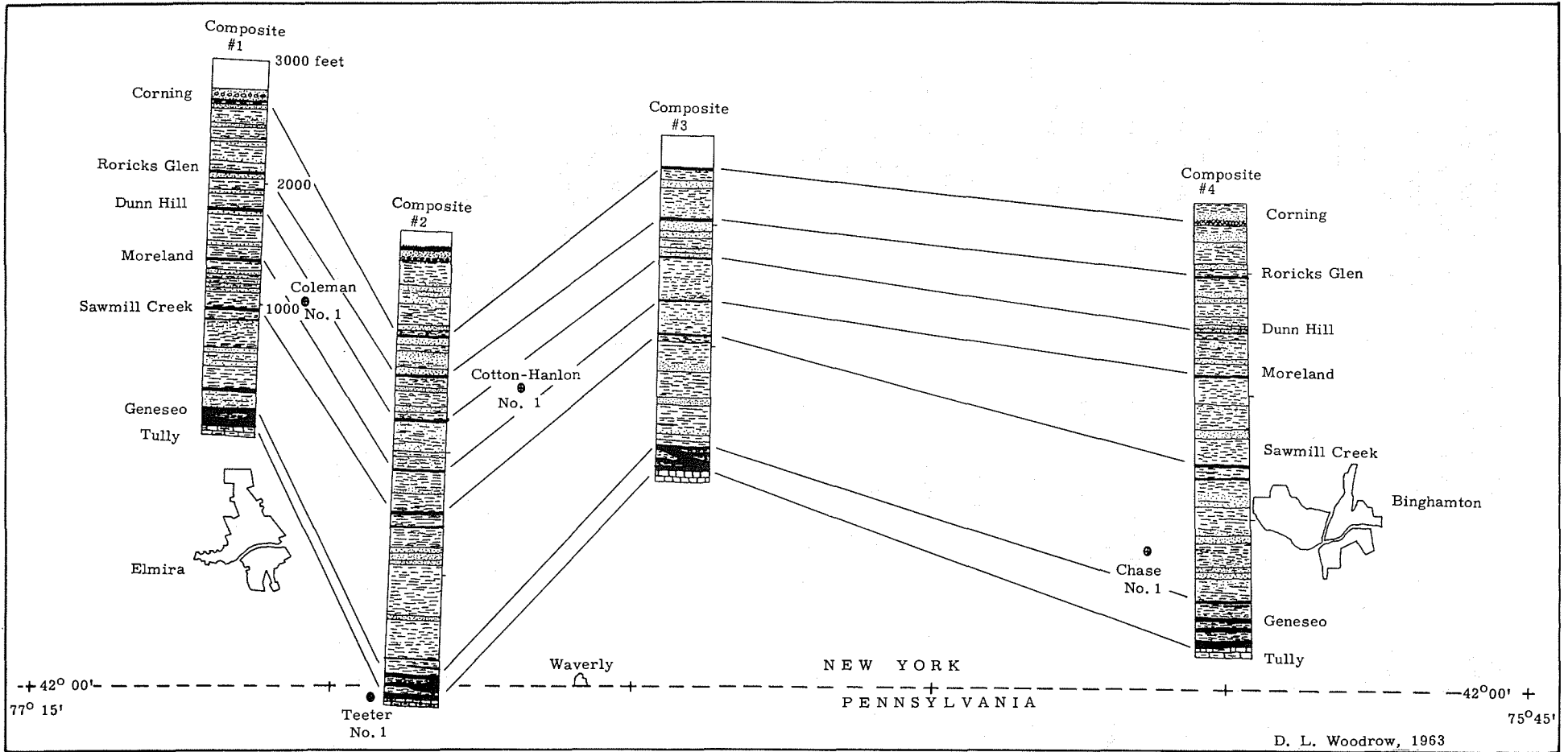
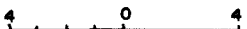


FIGURE 6. COMPOSITE SECTIONS COMPILED FROM SURFACE AND SUBSURFACE DATA

THE STRATIGRAPHIC POSITION OF KEY UNITS AND INTERVENING LITHOLOGIES ARE SHOWN ACROSS THE FIELD TRIP AREA.

Map Scale: FEET   
 Sections are marked at intervals of one thousand feet.

SUBSURFACE DATA USED IN COMPILATION OF COMPOSITE SECTIONS  
 (Specific Well Information May Be Found in Appendix C)

Composite	Interval	Well
1	Tully-1140'	Coleman #1
2	Tully-3000'	Teeter #1
3	Tully-1650'	Cotton-Hanlon #1
4	Tully-1740'	Chase #1

Figure 6.

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## APPENDIX A

## STRATIGRAPHY IN THE APALACHIN AND BINGHAMTON QUADRANGLES

Robert G. Sutton<sup>1</sup>

Reconnaissance studies provide the following generalized stratigraphic section:

"New Milford"	lower 100 feet only
West Falls Group	
West Hill-Nunda	130-0 feet
Gardeau	400-620 feet
Rhinestreet	600-800 feet
Naples Group	
Sonyea	800 feet
Middlesex	250 feet
Genesee Group	1200 feet (subsurface only)

Given below is a summary of post-Rhinestreet strata. More detailed information will be presented in papers being prepared for publication (Sutton, 1963 and Woodrow, 1963). The Rhinestreet and pre-Rhinestreet formations and members have been discussed elsewhere (Sutton and others, 1962).

The Gardeau Formation as described by Twigg (1961) is comprised of all the strata between the top of the Roricks Glen Member of the Rhinestreet and the base of the overlying West Hill Formation. Recognized at the top of the Gardeau and included in it is the Corning Member, a sequence of very dark gray shales and thin-bedded gray siltstones approximately forty feet thick. The type section of the Corning is the cliff, south of New York 17 at the west edge of Corning, New York (elevation 975 feet) where 17 bridges the railroad.

Strata above the Gardeau and below the oldest red-beds in the area are recognized as occupying a stratigraphic position correlative with the West Hill and Nunda Formations west of the field trip area. Strata of this interval decrease in thickness between Elmira and Binghamton as the red-beds are encountered lower in the sequence, until, at the Corbisello Quarry on Ingraham Hill south of Binghamton, sandstones of the "New Milford" Formation are found directly above the dark gray shales of the Corning.

Assignment of the youngest units to the "New Milford" is tentative and is based on the appearance in the section of red-beds. "Mansfield" is used in the same manner west of the Waverly quadrangle.

Within the Apalachin and Binghamton quadrangles strata dip S 60° W at approximately 90 feet per mile. Middlesex outcrops are confined to the Chenango valley. The Sonyea and Rhinestreet may be found in the Susquehanna valley and on the hills to the north. The Gardeau-"New Milford" strata are restricted to the hills south of the Susquehanna.

The Moreland Member of the Rhinestreet occurs at Union Center, at Dickenson and in Acre Creek; the Dunn Hill on New York 17 southwest of Twin Orchard and in Doubleday Glen; the Roricks Glen on Pennsylvania (1500 feet); the Corning Member of the Gardeau at Ingraham Hill.

The Portage lithofacies occurs in the Middlesex and in portions of the Sonyea.

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<sup>1</sup>University of Rochester (Temporary Address: Lamont Geological Observatory, Palisades, New York).

The Chemung magnafacies is present in the Sonyea, Rhinestreet, and Gardeau. Seven of Nugent's Cyrtospirifer chemungensis zones were identified in the Apalachin quadrangle but only the lower four persist as far east as Binghamton. Two zones were traced to the east of Binghamton and were identified by the abundant and associated form Platyrachella mesistrialis. The Catskill lithofacies is represented by the "New Milford" and marked by thick-bedded, gray-green subgraywackes, red mudstones and shales as well as a few scattered quartz-pebble conglomerates.

The Portage, Chemung, and Catskill magnafacies are interpreted as representing basin-slope, shelf, and non-marine environments, respectively. Thus the bulk of the strata in this area are interpreted as shelf deposits with a paleoslope toward the northwest and an interface at a depth of less than 600 feet. Various faunas coexisted on the shelf, each occupying separate ecologic niches. The cyrtospirifer zones represent the repeated northwestward migration of this form and its associates as conditions on the shelf permitted. The dark muds now represented by the Moreland, Dunn Hill, Roricks Glen, and Corning are explained by periodic restrictions of surface currents and closely approximate time planes. The persistence of the Chemung magnafacies both geographically and stratigraphically is cited as evidence of the tectonic stability of this area. Subsidence rate equalled or nearly equalled sediment supply throughout much of Senecan time.

## APPENDIX B

## WELL DATA

Sample logs of cuttings taken from wells drilled in the field trip area have provided an invaluable source of data (Figure 6). The writers wish to acknowledge the courtesies extended them by Art Van Tyne and Ross Sangster of the New York Geological Survey and Walter R. Wagner of the Pennsylvania Geological Survey in making available for examination cuttings from numerous key wells. Information concerning wells of particular interest to this report is listed below.

<u>Well Name and Number</u>	<u>State, County</u>	<u>Elevation</u>	<u>Year Completed</u>	<u>Location</u>
Chase-Troy Chemical Company #1	New York Broome	830'	1933	3300' N of 42°00' 6750' W of 76°00'
Cotton-Hanlon #1	New York Chemung	1552'	1962	23,400' S of 42°15' 2900' W of 76°35'
E.R. Coleman #1	New York Chemung	1115'	1961	10,900' S of 42°15' 5400' W of 76°45'
C.V. Teeter #1	Penna. Bradford	1520'	1952	.10 mile S of 42°00' 2.20 mile E of 76°45'



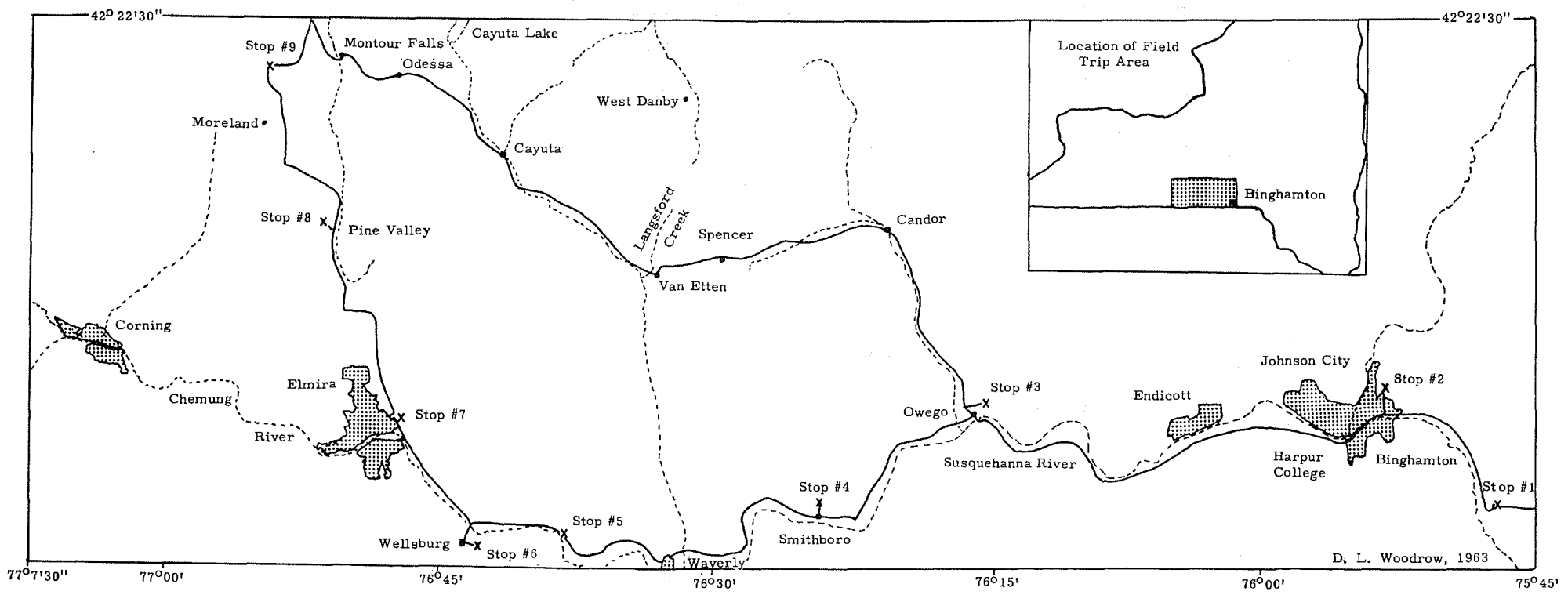


FIGURE 7. INDEX MAP SHOWING ROUTE OF FIELD TRIP AND LOCATION OF STOPS

SCALE : MILES

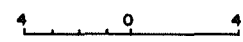


Figure 7.

## APPENDIX C

## ROAD LOG

<u>Mileage</u>	<u>Description</u>
0.0	Harpur College Gate; turn right (east) on New York 17. Proceed through Binghamton on 17.
9.2	Leave 17; turn right (south) to Interstate route 81; Proceed toward Scranton, Pennsylvania.
13.8	Leave 81; turn right (west) toward Kirkwood, New York.
13.9	Yield sign; turn left (east); proceed up hill on paved road.
14.2	<u>Stop 1.</u> Doubleday Glen.  Exposures of the Dunn Hill and Beers Hill Members of the Rhinestreet Formation. Elevation of exposure: 975'.  After leaving the busses, walk up the hill to the terraced exposure where the dark gray shales of the Dunn Hill Member may be seen. Small flow rolls are exposed here and many additional flow roll zones are visible in the stream bed of the Glen. Excellent view to the southwest, across the Susquehanna River. Red sandstones and shales of the "New Milford Formation" cap the hills visible across the river.
14.6	Turn right (north) on Interstate 81.
20.0	Leave Interstate 81; turn right (west) on New York 17 and then proceed into Binghamton.
24.3	Turn right (north) to Broad Avenue; proceed north on Broad until road ends at the base of the Binghamton Brick Company Quarry.
25.6	<u>Stop 2.</u> Binghamton Brick Company Quarry  Exposures of Moreland and Millport Members of the Rhinestreet. Elevation of the quarry floor: 900'.  The very dark gray shales exposed at the base of the quarry are the easterly equivalent of the Moreland Member. No other dark gray shales such as these have been found at higher elevations in the quarry.  Proceed south on Broad to New York 17.

<u>Mileage</u>	<u>Description</u>
26.9	Turn right (west) on Court Street (N. Y. 17); proceed through Binghamton on 17.
32.8	Harpur College.
36.4	Prominent cut on south side of 17 with dark gray shales of the Dunn Hill Member exposed at the base.
43.0	Apalachin, New York.
51.0	Intersection with New York 283, bear right across the bridge; enter Owego; proceed north, through town, on New York 96 and 38.
51.8	Railroad underpass; After underpass, take first possible right turn (east), then bear left to East Beecher Hill Road.
52.3-52.8	<u>Stop 3.</u> East Beecher Hill Road.  Exposures of Beers Hill and Roricks Glen Members of the Rhinestreet. Elevation at bottom of exposure: 950'.  The Roricks Glen is represented by scattered, very dark gray shales at the upper end of the exposure. Flow rolls are well developed here. <u>Cyrtospirifer</u> sp. have been reported from strata at bottom and top of exposure.  Proceed down hill to New York 96 and 38; Turn left (south) and proceed through the town to N. Y. 17;
54.1	Turn right (west) on 17 toward Waverly and Elmira.
64.2	Smithboro, New York; turn right (North), follow paved road to first fork, keep left on paved road.
64.9	<u>Stop 4.</u> Smithboro Section.  Exposure in Beers Hill Member of Rhinestreet. Elevation: 1000'.  This is an excellent, although small, exposure of Chemung lithofacies and biofacies. Massive sandstones and underlying mudstones are highly contorted in large flow rolls. Numerous brachiopods, pelecypods, and rugose corals may be collected.
65.6	Proceed back to Smithboro; turn right (West) on 17.
66.2	Exposure in Beers Hill Member, approximately 75 feet above the Dunn Hill member: lithologies Portage-like with rare, diminutive forms of <u>Cyrtospirifer</u> sp. reported.

<u>Mileage</u>	<u>Description</u>
74.6	Waverly, New York. (Lunch in this area.)
77.8-78.2	Sandstones of the Gardeau Formation exposed on north side of road.
80.4	Chemung, New York
82.7-83.1	<u>STOP 5.</u> Chemung Narrows.  Exposure in the Gardeau Formation. Elevation: 800'.  This exposure is one of the most famous Upper Devonian sections in North America. Here, the typical features of the Chemung magnafacies are developed and well exposed. Notice the well-formed flow rolls and prolific fauna. The proximity of this exposure to the highway makes it unsuitable as a place for discussion; therefore, we will move a short distance west and cross the Chemung River to a similar exposure, stratigraphically higher.  Proceed west on 17 until reaching the road to Wellsburg. Turn left (south) with caution.
88.5	Turn left on paved road to Wellsburg; Cross the Chemung River; This road crosses the main-line of the Erie-Lackawanna Railroad less than 100 feet south of the bridge; <u>Be careful at this crossing.</u>
89.2	Turn left (east) on New York 427; proceed to the east end of the outcrop.
89.8	<u>STOP 6.</u> Wellsburg Section.  Exposure in the Gardeau Formation. Elevation: 840'.  This is a fresh (1962) exposure of lithologies similar to those seen at Stop 5. Flow rolls are rare, but fossils may be collected readily. This road-cut and the section exposed along the railroad below the road served as the type section of Williams, Tarr, and Kindles "Wellsburg Sandstone Member of the Chemung Formation" (1909).
90.9	Proceed back across the Chemung River to 17; turn left (west) toward Elmira.
93.1	Newton Battlefield State Park on the right (north) side of the highway.
96.9	Leave 17 for Elmira via East Church exit (extensive cuts in the Millport Member of the Rhinestreet Formation on the north side of the exit ramp.)
112.0	Turn left (north) on 14; proceed toward Watkins Glen

<u>Mileage</u>	<u>Description</u>
97.3	Turn right (north) to Sullivan Street.
97.17	Turn right (east) to Watercure Hill Road.
98.0	Cross bridge over 17.
98.1	Leave busses at first dirt road to right after crossing bridge. Walk to quarries.
	<u>Stop 7.</u> East Church Street Quarries.
	Exposure of the Millport and Dunn Hill Members of the Rhinestreet. Elevation 910'.
	A comparison of the lithologies displayed here with the lithologies seen in the Millport of the Binghamton region illustrates the facies changes that have occurred. At the top of this quarry may be seen the heavier-bedded siltstones and fine-grained sandstones of the upper Millport. The quarry floor and lower faces are cut into the black and very dark gray shales of the Dunn Hill Member.
	Return to the busses and drive back through Elmira to route 17.
99.3	Proceed north on 17.
103.1	Intersection with New York 13; proceed west on 17.
105.0	Intersection with New York 14; turn right (north) to 14.
106.8	Stop light; turn left (north) on 14.
107.4	"Bluestone" quarry on left side (west) of road.
110.0	Village of Pine Valley; turn left (west) at paved road.
110.6	Leave busses at first dirt road to the right (north); walk to stream exposure.
111.0	<u>Stop 8.</u> Type Section of Dunn Hill Member.
	Elevation: 1070'.
	In this stream, the Dunn Hill Member is 22 feet thick and is composed of gray, silty shales and mudstones with nearly eight feet of black and very dark gray shales of which the majority is concentrated in the basal ten feet of the member. A tributary of this stream draining the hill to the south is the type section of the overlying Beers Hill Member of the Rhinestreet.

<u>Mileage</u>	<u>Description</u>
114.7	Turn left (west) to paved road just before railroad underpass. This turn must be made with caution.
120.9	Turn left on New York 414.
121.2	Turn right (north) on first dirt road to right, proceed up hill to first intersection.
122.9	Turn right (east) on dirt road, cross small bridge; leave busses, cross to north side of road and move off the road into the stream bed.
123.0	<p><u>STOP 9.</u> Reference Section for Moreland Member</p> <p>Black shales of the basal Moreland are exposed. Elevation: 1380'.</p> <p>Owing to time limitations, the type section of the Moreland Member (in Hamilton Creek, one mile north of this stop, elevation: 1370') will not be visited, however, the black shales may be observed here. In addition, the limey mudstones and shales of the underlying Rye Point Member of the Sonyea Formation are well exposed in this stream.</p> <p>After leaving this stream section, proceed east on dirt road to New York 414.</p>
124.4	Intersection with 414; turn left (north) to Watkins Glen.
126.8	<p>Intersection with New York 14 in Watkins Glen; turn right (south) to Montour Falls.</p> <p>On the right (west) side of 14, exposures of the evenly bedded siltstones and shales of the Ithaca Formation are continuous from Watkins Glen to Montour Falls.</p>
128.4	Montour Falls, New York
128.9	Intersection with New York 224; turn left (east) on 224 toward Owego.
130.6-130.9	Road cuts on north side of road; excellent exposure of siltstones in upper part of the Ithaca Formation.
134.9	Odessa, New York. Exposure of Montour Member (Middlesex Formation) under bridge in center of town.
135.2	Intersection with New York 228; proceed east on 224.
140.7	Intersection with New York 13; proceed east on 224.

<u>Mileage</u>	<u>Description</u>
142.1	Cayuta, New York.
144.0	Exposures of Millport Member on right (south) side of road.
152.2	Van Etten, New York. Langsford Creek occupies valley on the left (north).
152.5	Intersection with New York 34; proceed east on 224 and 34.
155.5	Spencer, New York. Intersection with New York 96, 34 turns left to Ithaca; proceed straight ahead (east) toward Owego on 96.
163.4	Candor, New York. Intersection with New York 96B; turn right (south) on 96 toward Owego.
172.8	Intersection with New York 38; turn right (south) to Owego. <u>Be very careful at this intersection.</u> Excellent exposures of the Beers Hill Member of the Rhinestreet in the hillside directly across the intersection from the bridge. Other exposures may be seen along 38 to the left (north).
174.5	Owego, New York.
174.8	Intersection with New York 17C; turn right (west) to 17 and return to Harpur College via New York 17.
	End of Trip

## UPPER DEVONIAN STRATIGRAPHY AND SEDIMENTOLOGY IN THE BINGHAMTON AREA

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### INTRODUCTION

The purpose of this half-day field trip is to illustrate the prominent stratigraphic and sedimentologic features of the Upper Devonian rocks of the Binghamton area. The trip will introduce the participants to the stratigraphic units and some of the stratigraphic problems of the Upper Devonian strata of south-central New York, thus enabling them to appreciate more fully the longer field trip conducted by Woodrow and Nugent.

This report contains a summary of the stratigraphic nomenclature applied to the rock sequence in the Binghamton area and a brief discussion of some sedimentary features of these rocks. The location of each stop is shown on the index map (Fig.1), and the rock sequence at each stop is summarized in a generalized stratigraphic section (Fig. 2,3, and 4).

### STRATIGRAPHY

The Upper Devonian sequence is composed of alternating very fine-grained sandstones, siltstones, and blocky shales. Interbedded with these units are beds of dark, fissile shale representing tongues extending eastward from a predominantly shale sequence in western New York. The presence of the dark shale tongues provides marker beds in an otherwise monotonous series of deltaic sediments, the Chemung facies.

A system of stratigraphic nomenclature based on the recognition of these marker beds has been developed by stratigraphers at the University of Rochester under the leadership of R. G. Sutton. This group is actively engaged in field studies of the Upper Devonian rock units in south-central New York. As these studies represent the most recent work on these strata, terminology proposed by the group (Sutton, *et.al.*, 1962, Sutton, 1963) is used in this report. For further discussion of stratigraphic nomenclature, and of problems that have arisen during study of this rock sequence, see the article by Woodrow and Nugent.

Rock strata belonging to several formations are present around Binghamton. The oldest exposed rocks are in the Sonyea Formation (Colton and deWitt, 1958). The Sonyea beds occur in the lower parts of the Susquehanna River valley near the city of Binghamton, and in the Chenango River valley north of Binghamton. The Sonyea Formation will not be observed on this field trip. Stop A-1 at Twist Run (north of Endicott, N.Y.) and stop A-2 at the Binghamton Brick Company quarry will provide opportunities to examine exposures of several members of the Rhinestreet Formation (Sutton, *et.al.*, 1962) which overlies the the Sonyea Formation. Stop A-3 is in the Corbisello Quarry, just south of the city of Binghamton, where beds younger than Rhinestreet are exposed. These are classified as the Gardeau Formation and the overlying New Milford Formation (Sutton, 1963), and are the youngest Devonian strata exposed in the area.

For purposes of small-scale mapping, it is useful to employ the procedure illustrated on the State Geologic Map of New York (1962). On this map strata above the Sonyea are not subdivided, but are included in the lower West Falls Group.

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Acknowledgments: J. Harrison and D. Patchen assisted in preparation of the illustrations.



## SEDIMENTARY FEATURES

A casual inspection of the Upper Devonian rocks in the Binghamton area may lead one to the conclusion that the lithologic sequence is devoid of significant or interesting sedimentary features. However, more detailed examination reveals several features and sedimentary structures worthy of discussion and investigation.

A striking characteristic of this rock sequence is a cyclicity of sedimentation that appears to be generally present, although in varying degrees. At two stops (A-1 and A-2), a cyclic pattern may be observed in the shale and siltstone alternations.

At stops A-1 and A-2, sedimentary features will be seen that have been named "flow rolls" by Pepper, de Witt, and Demarest (1954) to describe bulbous, somewhat nodular, lens-shaped siltstone or sandstone masses that frequently occur in the Devonian rocks of this area. The flow rolls generally rest upon shale and give the appearance of having been rolled or curled. Dunbar and Rogers (1957, p. 192) state that early in this century such phenomena were interpreted as the result of violent storms that churned the bottom of the sea floor and rolled up masses of the surface sandy layers. This is not a likely explanation because storm waves sublevate the sand on a sandy sea floor, moving the grains individually. It is not reasonable to conclude that the sand (or silt) would have had sufficient cohesion to permit rolling in this fashion. Thus the structures represent small landslides formed where the bottom had been aggraded to an instable slope. In such an environment, soft mud layers would have formed a lubricant over which thick sand layers could slide.

Preliminary radiographic studies of thin slices of flow roll matrix, employing the technique described by Hamblin (1962, p. 201), have been conducted at Harpur College, and the results have been somewhat surprising. Some laminations within these flow rolls are quite regular and, for the most part, little disturbed. There are some minor flow-age features at the periphery of the masses, but not within the central portion.

There is little evidence that flow rolls formed on the surface of the sea floor, and in fact, where shales immediately underlie and overlie the flow rolls, the shale layers appear to "wrap around" these lens-shaped masses from above and below. Observations suggest that some, if not most, of these masses formed as a result of differential compaction and are more closely related to load casts.

Cross-stratification commonly occurs in the siltstones and sandstones. The sets of cross-strata range in thickness from a fraction of an inch to several feet. The sets of cross-strata in the siltstones are usually tabular and the individual cross-laminae are only fractions of an inch thick. Lenticular cross-stratification may be present in thick or massive sandstone beds. Tabular cross-stratification can be observed in siltstone beds at stops A-1 and A-2. Lenticular cross-stratification is seen in the sandstones of the Catskill facies at stop A-3.

Ripple marks have been preserved on the bedding surfaces of many sandstones and siltstones in the Upper Devonian strata. They are generally small-scale symmetrical features; thus they are thought to be oscillation ripples. Ripple marks will be seen at stop A-3.

At various levels within the alternating siltstone, shale, and very fine-grained sandstone sequence of the Chemung facies, thin beds of coquina or coquinoid siltstone are noted. These beds have a matrix of calcareous siltstone and weather to prominent pitted surfaces on the outcrop as a result of leaching of the calcareous material of the fossil shells. Some of the beds appear to be fairly persistent at a given outcrop, but it has not been established that they are persistent enough to be of any use as stratigraphic marker beds, even within a very limited area.

At stop A-1 of this trip, in Twist Run, typical coquinas will be seen. They contain an abundance of crinoid columnals, a majority are small (less than 1/10" in diameter), but with sizes ranging to 1/2" in diameter. The proportions of the various sizes of debris vary from place to place within a single bed. Associated with the columnals are many rhynchonellid and spiriferid brachiopods and pelecypods, all of relatively small size. There does not seem to be any size sorting of the fossil material which could be taken as an indication of current action on the debris.

A different type of coquina will be seen at stop A-2, at the Binghamton Brick Co. quarry. This coquina contains disarticulated valves of Platyrachella mesastrialis in profusion, with many crinoid columnals forming the bulk of the rock matrix.

#### FIELD TRIP STOPS

Stop A-1, Twist Run (Lat. 42° 08' 45" N., Long. 76° 03' W.)

The road cuts in Twist Run (Fig.2), expose beds of the Rhinestreet Formation. Near the top of the hill is a 7-foot interval of dark gray, fissile shale, the Dunn Hill Member of the Rhinestreet Formation. Above the Dunn Hill shales are the basal beds of the overlying Beers Hill Member of the Rhinestreet. Approximately 12 to 15 feet of strata of the Beers Hill Member are composed of siltstones, generally quite massive where fresh, but weather into thin and irregular units. The basal 4-foot unit exhibits minute cross-lamination.

Below the Dunn Hill Member is the Millport Member of the Rhinestreet, comprising the largest amount of the exposed beds. It is composed of a series of units which are somewhat cyclic in nature. Ideally the unit grades from massive, very fine-grained sandstone at the base, through massive siltstones into siltstones progressively thinner bedded and more argillaceous upwards, with a thin bed of dark shale at the top. At the base of each massive unit are flow rolls. Few if any of the units show the complete range of lithologies listed above, and each unit is extremely lenticular. Thus the measured thicknesses of each bed shown on Figure 2 must be regarded as true only for the exact place of measurement. Several of the massive beds of very fine-grained sandstone can be seen pinching out laterally within the confines of the outcrop.

Faunal elements are present within the sequence, either interspersed along bedding planes within the siltstone layers, or in definite beds of coquina. Both brachiopods (orthids, productids, and spiriferids) and pelecypods are abundant at several levels. At least three thin beds of coquina are present within this sequence. At this locality, each bed is very thin; the thickest observed being less than 6 inches.

The lowest outcrops in Twist Run are still within the Millport Member, which is underlain by the basal or Moreland Member of the Rhinestreet Formation. The Moreland is a dark shale unit similar in lithology and thickness to the Dunn Hill Member seen at this locality.

Stop A-2, Binghamton Brick Co. Quarry (Lat. 42° 07' 30" N., Long. 75° 54' W.)

The quarry of the Binghamton Brick Company is developed in the Millport Member of the Rhinestreet Formation. The Moreland Member is exposed at the entrance to the quarry below the level of the main floor. The quarry floor and walls, developed as a series of steps carved from the hill, are composed of beds of the Millport Member.

As in Figure 3, the Millport Member in this locality consists of a series of alternating gray to green siltstone and shale. The shale units range from 10 to 15 feet in thickness, and are generally thin-bedded and fissile, especially where weathering has occurred. Medium-bedded siltstones occur in a somewhat cyclic pattern throughout the

section. In the upper part of the sequence, the siltstones are more thickly bedded, and correspondingly the cyclical pattern is not as regular.

Smooth, continuous bedding planes between shale beds and also between shale and siltstone beds predominate; there appears to be little lensing. Small-scale cross-laminations may be observed in the siltstones.

Two prominent flow roll zones may be observed. The first occurs about 100 feet above the floor of the quarry, and the next about 20 feet higher. The flow rolls of the latter unit are numerous, and range greatly in size, shape, and degree of development. Beds of coquina are seen in place and in slump in the upper part of the section.

Stop A-3, Corbisello Quarry (Lat. 42° 03' 45" N., Long. 75° 57' W.)

The Corning Member of the Gardeau Formation and the overlying New Milford Formation are exposed in this quarry. The Corning Member at this locality is a gray, fissile shale, of which approximately 5 feet are exposed.

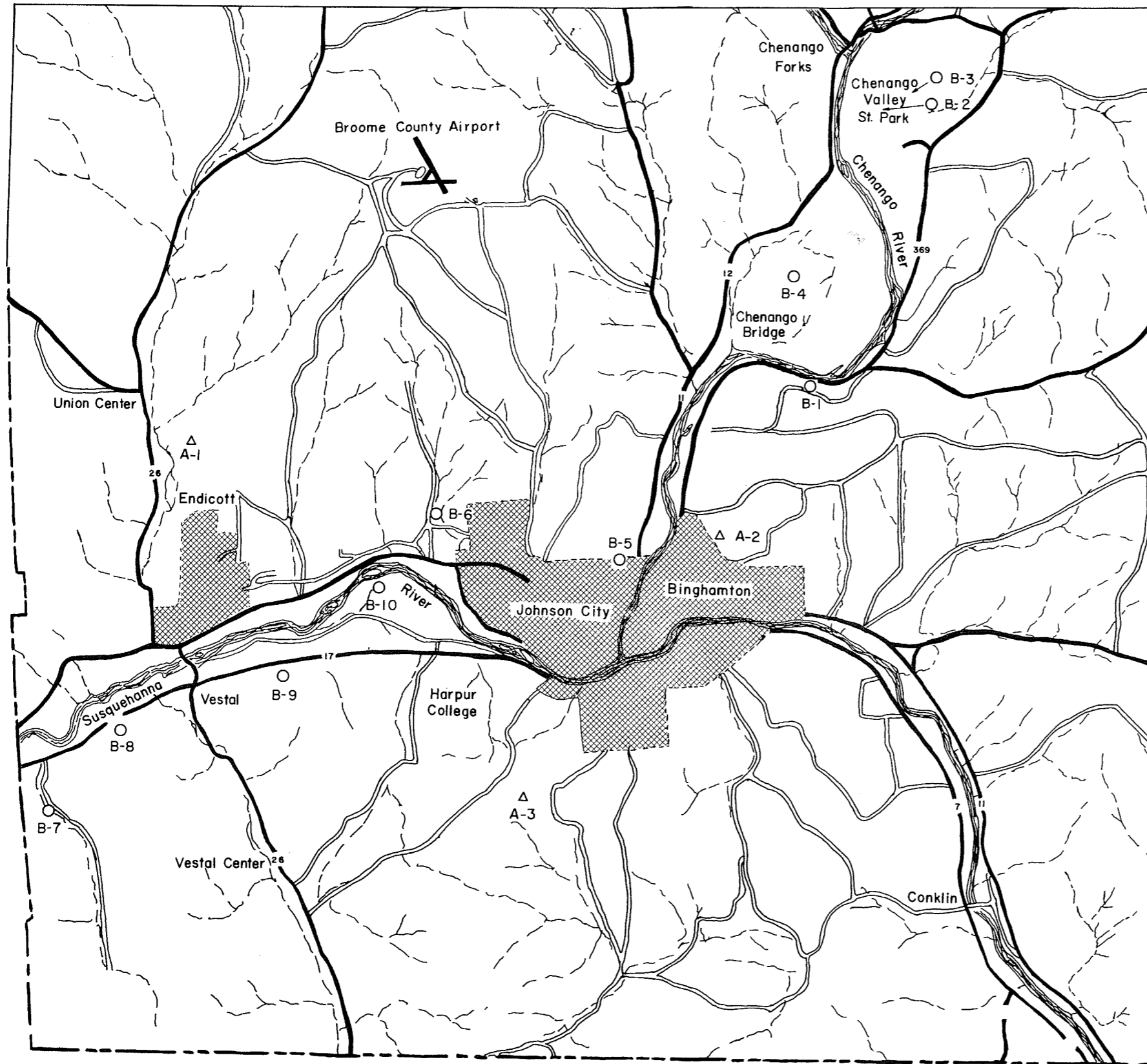
The New Milford Formation contains a tongue of the Catskill facies at the base. This tongue is composed of massive, interbedded, thick lenses of sandstone. Lenticular cross-lamination is present in the thick lenses. There is a thin disrupted coal seam in the middle part of this sandstone unit. Ripple marking has been preserved on the upper surface of this sandstone tongue. This is probably a fluvial deposit deposited near the strand line of the Upper Devonian sea.

Overlying the massive sandstone is a thick sequence of shale and interbedded siltstone. These fine-grained rocks are thought to be near-shore deposits, possibly lagoonal muds. Above the unit of shale and interbedded siltstone is another sequence of massive lenses of sandstone with interbedded siltstone and shale. These beds are similar to the basal sandstone in lithology, but are extremely lenticular.

This is the only stop on this trip, or on the trip led by Woodrow and Nugent, where the Catskill non-marine facies may be observed. Several miles to the south the New Milford is entirely composed of beds belonging to the Catskill facies.

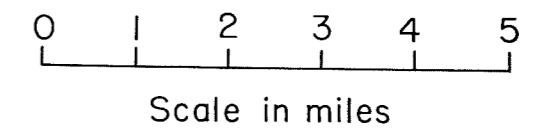
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LEGEND

- △ - Stop-Trip A
- - Stop-Trip B
- Streams
- Highways
- = Secondary Roads



Location Map Showing Field Trip Routes, Binghamton, N. Y., Area.  
FIGURE I

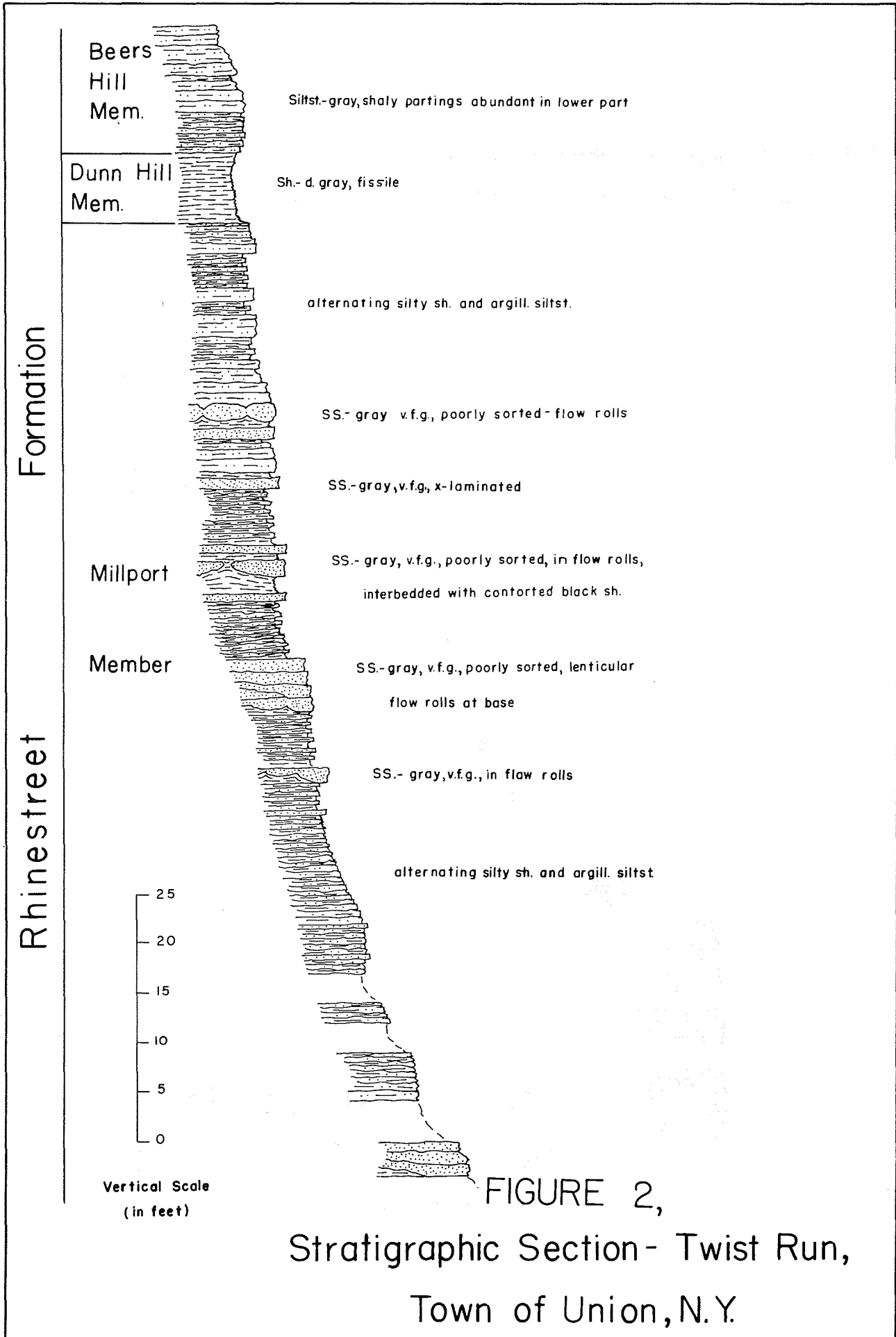


FIGURE 2,  
Stratigraphic Section- Twist Run,  
Town of Union, N.Y.



# Generalized Stratigraphic Section Corbisello Quarry, Binghamton

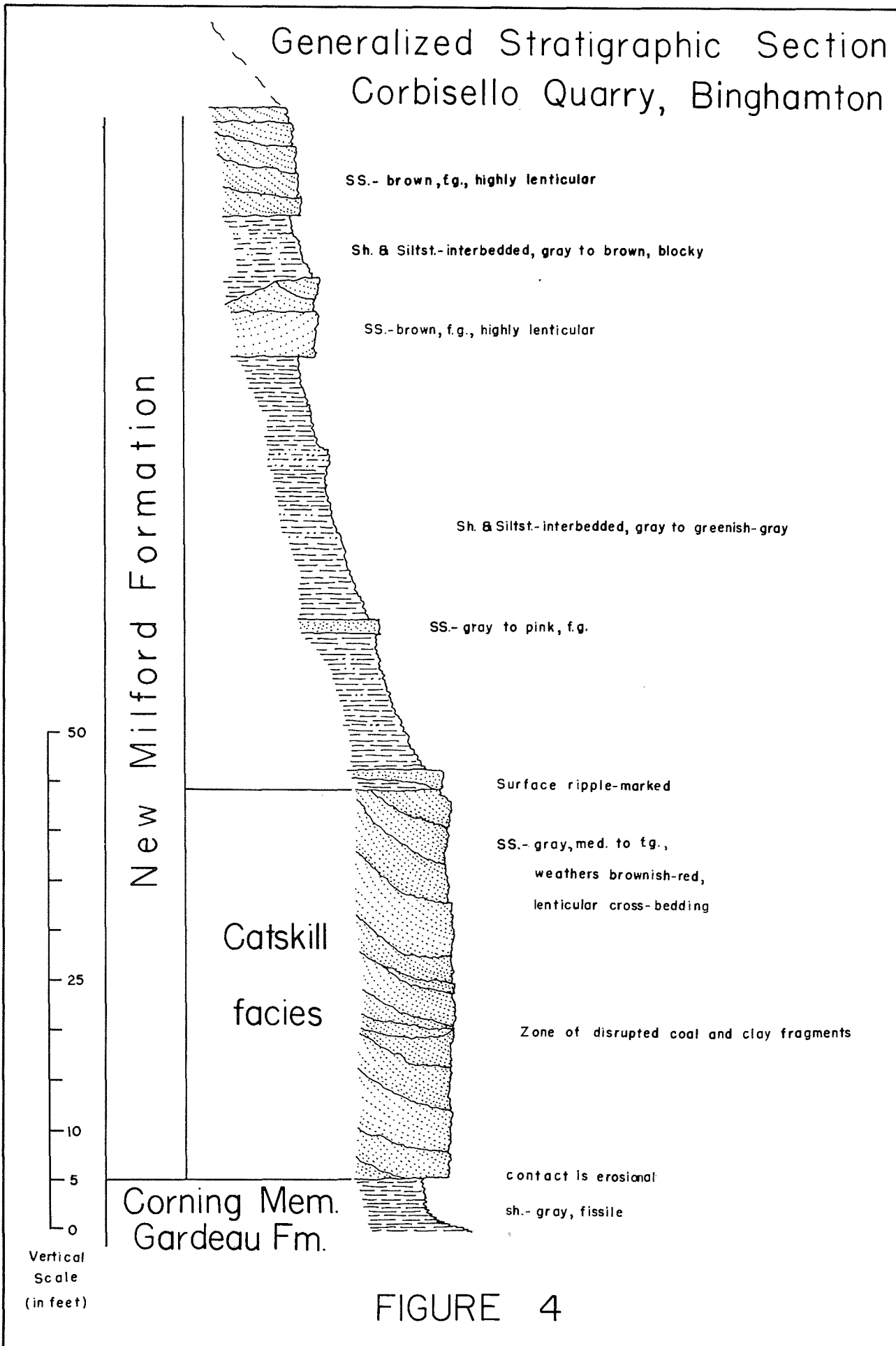


FIGURE 4





## GEOMORPHOLOGY OF THE BINGHAMTON AREA

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The Binghamton area, also known as "The Triple Cities", is located in Broome County, immediately north of the Pennsylvania State line. The 200,000 population of the metropolitan area is largely confined to the flood plain-terrace area, often two miles wide, of the Chenango and Susquehanna Rivers. Until recent years the Endicott-Johnson Corporation was the only important large industry of the area. Attracted by excellent water resources, and other factors, however, there are now more than 100 industries in the area the largest being: International Business Machines, Inc., Ansco-Ozalid, Link Division of General Precision, Inc., and General Electric Co. Such a setting provides an ideal environment for Harpur College and Broome Technical Community College.

The purpose of this report is to focus attention on the specific topographic, hydrologic, and glacial features that typify the area. The general geologic setting is discussed in other articles of this volume. Additional information may be found in the text of the Description for Field Trip B. The route of the trip (Fig. 1) was designed to cover the maximum area in the time provided. The trip stops are at convenient and accessible localities but are representative of the geomorphology of the Triple Cities.

### TOPOGRAPHY

The flavor of any topography is largely the result of the intensity and nature of the interaction of internal earth forces and the external degradational processes. The Binghamton landscape has been sculptured from shale and siltstone of Upper Devonian age by the action of running water and gravity. These processes continued for millions of years until molested and interrupted by the challenge of Pleistocene glaciation.

The topography of the area ranges from 810' in the Susquehanna River to 1877' south of Ingraham Hill (Fig. 2). The total relief is less today than it was during pre-glacial time, owing to aggradation of till on upland and valley sides and deposition of outwash and alluvial materials in river channels. The valley bedrock floors of the major drainages were 200' deeper and hill summits were probably 10'-20' higher. Glacial ice was not an important erosional factor in the area.

Three important slope elements compose the topography, namely those slopes produced by, (1) Sheet wash and gravity - "equilibrium-type slopes", (2) direct river incisement and oversteepening by lateral corrasion, and (3) aggradational processes. Some of the quantitative slope and drainage relations are presented in Tables 1 and 2. Slopes of the first category usually range from 13-15 percent grade, whereas second category slopes may be vertical and third category slopes horizontal. Less than one-fourth of the slopes are more than 15 percent. The wide flood plain-terrace areas reduce the overall ruggedness of the region.

At least three interesting aspects of slopes and drainage are worthy of special mention: (1) With the exception of direct stream corrasion the, steepest topography occurs on north-facing slopes; (2) Many stream junctions in the southern part of the

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Acknowledgments: W. Bothner and W. Cook aided in drafting the illustrations. W. Cook, J. Conners, and R. Teifke aided in assembling some of the statistical data.

DRAINAGE BASIN	BASIN AREA (Sq. mi.)	TOPOGRAPHIC SLOPE				SOILS					
		More than 15%		Less than 15%		Pervious		Partly Pervious		Impervious	
		Sq. mi.	% at basin	Sq. mi.	% at basin	Sq. mi.	%	Sq. mi.	%	Sq. mi.	%
North of Susquehanna River including Patterson Creek Finch Hollow Creek	52.1 12.1	7.8	15	44.2	85	12.9	25	2.9	5	36.2	70
South of Susquehanna River	37.6	9.0	24	28.6	76	8.6	23	2.6	7	26.4	70
Chenango River Valley (including Castle and Thomas Creeks)	41.3	8.8	21	32.6	79	10.3	25	1.7	4	29.5	71
TOTAL	131.0	25.6	20	105.4	80	31.8	24	7.2	6	92.1	70
Nanticoke Creek	29.3	4.6	16	24.7	84	4.7	16	1.5	5	23.1	79
Little Choconut Creek	11.7	2.4	20	9.3	80	.4	3	.1	2	11.3	95
Tracy Creek	10.0	1.1	11	8.9	89	.6	5	.1	2	9.3	93
Big Choconut Creek	19.0	5.3	28	13.7	72	1.9	10	.3	2	18.7	88
Pierce Creek	5.5	1.1	20	4.4	80	0	0	0	0	5.5	100
Little Snake Creek	22.8	7.2	32	15.6	68	1.3	6	0	0	21.4	94
TOTAL	98.3	21.7	22	76.5	78	8.9	9	2.0	2	89.3	89
Potato Creek Brooks Creek	6.9	1.4	20	5.5	80	0		0		6.8	100
Page Brook Ballyhack Brook Osborne Creek	23.1	4.7	20	18.3	80	1.7	7	.2	1	21.2	92
Bradley Creek	7.4	.8	11	6.6	89	.7	9	.1	1	6.7	90
Stratton Mill Creek Stanley Hollow Creek Sherwood Hollow Creek Trim Street Creek Doubleday Creek Unnamed Creek	19.2	6.9	35	12.3	65	.6	3	0	0	18.5	97
Sugar Creek	6.4	1.9	30	4.5	70	.3	5	0	0	6.1	95
TOTAL	63.0	15.7	25	47.2	75	3.3	5	.3	0	59.3	95
GRAND TOTAL All Drainage Areas	292.0	62.5	22	229.0	78	43.9	15	9.5	3	238.8	82

TOPOGRAPHIC SLOPE AND SOIL CHARACTERISTICS OF  
DRAINAGE BASINS IN THE BINGHAMTON AREA

TABLE 1

TABLE 2

Morphometric Summary of Third-Order  
Basins in the Binghamton Area

		50 basins north of Susquehanna River (mean)	50 basins south of Susquehanna River (mean)
Basin area (sq. mi.)		0.573	0.482
Basin perimeter (mi.)		3.179	2.780
Stream length total (mi.)	First order	3.16	2.32
	Second order	0.79	0.81
	Third order	0.80	0.56
	Total all orders	4.75	3.69
Stream length mean (mi.)	First order	0.167	0.151
	Second order	0.250	0.236
	Third order	0.722	0.506
	Mean all orders	0.291	0.253
Overland flow (mi.)		0.062	0.058
Stream Gradient (percent)	First order	10.9	10.7
	Second order	8.4	8.6
	Third order	4.6	6.4
	Mean all orders	9.3	9.5
Topographic slope (percent)		13.1	15.2
Basin relief (ft.)		428	506
Drainage density		8.38	8.90
Circularity index		0.563	0.621

All data obtained from U.S.G.S. 1:24,000 scale Topographic Maps.

area are "barbed", and; (3) The presence of youthful-type valleys superimposed upon the "maturely-dissected" land forms.

The author believes that by use of such data as found in Tables 1 and 2 important deductions can be made and theories for erosional history can be tested. For example some geologists believe the area south of the Susquehanna has had a somewhat different history than the area to the north. An interpretation of the data shows, however, that in general the erosion is of similar magnitude. The statistical level of significant differences are attributed to the slightly higher sandstone ratio and circularity index of the southern basins.

## HYDROLOGY

### Drainage Considerations

The major streams in the area are the Susquehanna, Chenargo, and Tioughnioga Rivers. As the combined discharge of these rivers entering the Binghamton area is 6,106 cfs. and is 6,451 cfs. when it leaves the area, the 228 square miles of the region have added 345 cfs., a yield of 1.51 cfs/sq.mi.

There are many unusual drainage relations in this area, such as the Susquehanna River entering the area from the south and then making a right angle bend and flowing west out of the area. The relic channels and erosional history of these rivers is discussed elsewhere in this volume.

### Water Resources

Water is a basic ingredient of the economy of the Binghamton area. Table 3 itemizes water use for the year 1962. The reader should study the publication by Brown and Ferris (1946) for a complete analysis of ground-water characteristics in the area. In 25 years, ground water use has increased 170 percent, from 5.3 billion gallons in 1937, to 7.6 bg. in 1944, to 8.9 bg in 1962. Brown and Ferris (p. 40) gave this note of caution:

"Thus, under the present localization of ground-water development in the southwestern part of Broome County, it is possible that appreciably more than 50 percent of the total available supply is being utilized".

Some water users, such as Ansco, have major programs of water reversal in which they have developed some wells that are periodically used as recharge wells.

Rock wells in the area are generally more than 100' deep and yield only small amounts of water that is of poor quality owing to hardness and occasional chlorine, iron, sulfur etc. All public and industrial wells are developed in the outwash sand and gravel. The water is of excellent quality and may produce yields considerably more than 1,000 gpm with transmissibility of 70,000 gallons per day per foot of draw down. Several wells and test borings have encountered large thicknesses of lacustrine clays, one reported as much as 200'.

## GLACIAL GEOLOGY

The Wisconsin ice sheet covered the Binghamton area and spread 40 miles south into Pennsylvania. As it covered hills in Pennsylvania as high as 2,800' and by an interpretation of modern ice sheet slopes, it is probable that the total thickness of ice over Binghamton may have approached 3,000'. The part of the sheet confined to the major

TABLE 3

## Water Use in 1962 by Major Districts in the Triple Cities

District Location	Water use <sup>1</sup> 1962 (gal.)	Water Source
Binghamton	3,700,000,000	Susquehanna River
Endicott	3,600,000,000	Ground water wells
Johnson City	4,500,000,000	Ground water wells
Vestal	310,000,000	Ground water wells
Chenango Bridge	73,000,000	Ground water wells
Fenton	146,000,000	Ground water wells
Others	250,000,000	Ground water wells
Total	12,579,000,000	

<sup>1</sup>Data obtained from official records and by personal interviews of major facilities.

valleys would be 1,000' thicker than ice over the uplands. The amount of ice erosion of bedrock features would be dependent on orientation. For example north and south-trending valleys probably were over-steepened owing to parallel direction with major alignment of ice transport. The Finger Lake district is a perfect example of what happened when a newer ice sheet invaded that area slicing 1000' of bedrock in the troughs. In the Binghamton area drainages that were athwart glacial movement received little erosion except on the north-facing upper slopes, and instead were largely filled with a great assemblage of glacial debris. The burial of such pre-glacial channels has attributed to many of the V-shaped post-glacial gorges in the Triple Cities area. Glacial deposits and outwash along with drainage modifications is discussed in separate sections.

#### Number of Wisconsin Glaciations

According to MacClintock and Apfel this area is the type locality for the Binghamton till sheet, a later glacial stage than the Olean till sheet. It would be good propaganda and serve local pride if this could be verified. There is serious doubt, however, concerning a two-cycle advance and retreat of major scope in this part of south-central New York (Denny, Muller, Moss and Ritter etc.). The author has found a few additional nails to hammer in the coffin of a "Binghamton till sheet" (Table 4). The Binghamton till lithology is always found below 950' elevation, it has been found with Olean separated by a transitional phase, both vertically and laterally, and only one weathering profile is developed in the till. Geomorphometry studies of small drainage systems (Table 2, Fig. 3) indicate the two areas, one south and one north of the Susquehanna River, have had a similar drainage history. This would not be the case if there had been a separate Binghamton till sheet, because the area south of the river would have had a longer and different type of erosion history. Thus the idea of a separate ice advance during Binghamton time should be abandoned and instead the term should be retained only as the valley facies of the Olean drift. It is only found in the through-valleys or in regions in communication with such valley systems. Its somewhat characteristic lithology of a high limestone content often enriched with igneous-metamorphic erratics, is attributed to transport by basal ice in the through-valleys as they incorporated formerly reworked stream gravels.

Table 4 contains data analysis of till samples compiled at Harpur College and at Franklin and Marshall College. The author is very surprised that all Olean samples of Moss and Ritter show coated heavy minerals greater than 74 percent. In their article

no mention is made of a possible transitional lithology. Studies in the Binghamton area for this report indicate there are morainic hybrids and that there was mixture of the two end-members of the series. This can also be noted in the sand-silt-clay ratios. The nature of ice flow in this region and the wastage of ice blocks contribute to this heterogeneity. Furthermore, whereas significant exposures of Binghamton facies are unknown higher than 950' in this area, Olean facies can occur at all elevations, viz. Oakdale area (Samples #12,13, 14, taken at elevations from 850'-875'). Much work remains to be done on the intertonguing of the till lithologies.

### Landforms Resulting From Glaciation

1. Plains. The character of glacial deposits, with some exceptions, indicates that the end of the ice age was not marked by general recession of the ice margin. Instead, much of the ice withered in place without support of fresh increments from Canada. The thinner ice on the hills left a general ground moraine that ranges from a few feet to more than 75 feet thick, but averages about 10 feet. Table 2 provides data on soil that has developed from the till and other materials. In the valleys the ice blocks were thicker and the valley walls offered some protection from the sun. This resulted in a longer residence time for such stagnant masses: These relations are spectacularly displayed by the range of deposits and land forms in the Chenango Valley State Park area, and will be seen on Field Trip B. (see Figure 4 and 2 for orientation and interpretation of the vicinity) The pre-glacial channel of the Chenango River was located north and west of Chenango Bridge. Owing to the unique topographic configuration and protection in the area the ice margin remained static in this locale and even received moderate nourishment from a tongue of ice that extended north to upper Chenango River area. The great flood of deposits that issued from this source are still visible in the valley train and terrace deposits that extend from this spot to west of Vestal and decline 100' in slope from Chenango Bridge (940') to Castle Gardens (840'), in Vestal. Thus, this huge aggradational plain compounded by the meltwaters in this natural sluiceway in addition to lacustrine clays covered the former bedrock channel to depths greater than 200' in places (Fig. 5).

2. Diversion channels. The ice blocks also forced drainage from its former channel, causing incisement in other areas. Many changes occurred in the Chenango Bridge vicinity, for example, as the Chenango had to abandon its old channel at Kattelville and east of the State Park and cut a new channel west of the Park and south of Chenango Bridge. Confirming evidence for these events are found in well logs, kame terraces at Hillcrest, and glacio-fluviatile gravels plastered 140' high on bedrock walls south of Route 7. Another sure sign of post-glacial channeling is the cutting of bedrock in the stream bed as occurs west of Lilly Lake.

The 950' elevation was local base level for much of the Binghamton area in the post-glacial cycle of erosion. This is the elevation at which, many features are truncated; many valley walls steepen (exclusive of under-cut bends), and; alluvial fans from tributaries spread their debris in the major valleys. Fairchild erroneously interpreted these forms as deltas thus giving him the picture that during Wisconsin time a huge lake was impounded behind a morainic barrier at Towanda, Pa, that extended upstream in the Susquehanna and tributaries to Great Bend, Pa., a distance of 75 miles. He named it "Glacial Lake Binghamton" and infers a 915' strand line at Towanda is equivalent to the 940' level at Binghamton, thus necessitating a 25' isostatic rise. Unfortunately, the author's work in the area does not substantiate this conclusion, so once again he performs a nomenclatural disservice to the name "Binghamton". It is true that outcrops of some deltaic clays and sands occur and that well logs indicate blue clays at many sites. Such exposures are not correlative, however, but instead emphasize that during the life cycle of the ice age there were many local blockages of impounded waters. The Field Trip will visit some of the lakebed outcrops and show their occurrence at many different elevations.



The Susquehanna River, like the Chenango, has also had its share of drainage diversions (Fig. 5). Good examples are at Rock Bottom Dam (located at point D in Fig. 4), at Roundtop Hill, (west of Harpur College), and at Roundtop (in Endicott). A slightly different pattern of diversions can be seen at the mouth of the Tioughnioga River and Tracy Creek, both streams were forced to cut through bedrock gorges in order to reach their local base level.

3. Cols. In addition to the low-level drainage diversions, there are many high-level saddles and cols that indicate drainage modifications in drainage divide areas. The region between Chenango Bridge and Greene (Fig. 4) probably has at least 10 of these overflow saddles and the position of several of the best ones are indicated on the map. In a modest way these are through-valleys but they had a different history than those along the Appalachian Plateau escarpment to the north. The notches show a wide range in perfection of development and size and a smaller range in elevation.

4. Kettle Holes. The kettle hole swarm in the Chenango Valley State Park vicinity is one of the finest displays of this ice stagnation feature in New York State. Many are more than 60' deep with side walls that show a wide range in steepness. The largest single kettle hole is immediately south of Roundtop Hill in Vestal.

5. Additional Forms and Deposits. There are additional glacial deposits in the region, some with form and some are formless. Morainic loops occur with imperfect hill and lobate form, and are largely restricted to the area south of the Susquehanna River. Varve clays are found in Tracy Creek, and several small hanging deltas are in the Binghamton area. Some hillside slopes near the State line appear to be of the form produced by congeliturbation processes. Although kame hills and eskers are unknown in the metropolitan region both forms are present to the west of the area near Apalachin.



## SYNTHESIS

The Binghamton metropolitan area is located on a variety of fluvial planar features at the confluence of the Susquehanna and Chenango Rivers. The Upper Devonian marine shales and siltstone were sculptured by running water into rolling hills of about 13 per cent gradient. The original relief of more than 1000' had been somewhat modified and subdued by glaciation.

Water is an important commodity and is found in good abundance in the interstices of the sand and gravel outwash deposits. Small amounts are obtained in some bedrock wells provided the bore has intersected sufficient numbers of water-bearing fractures.

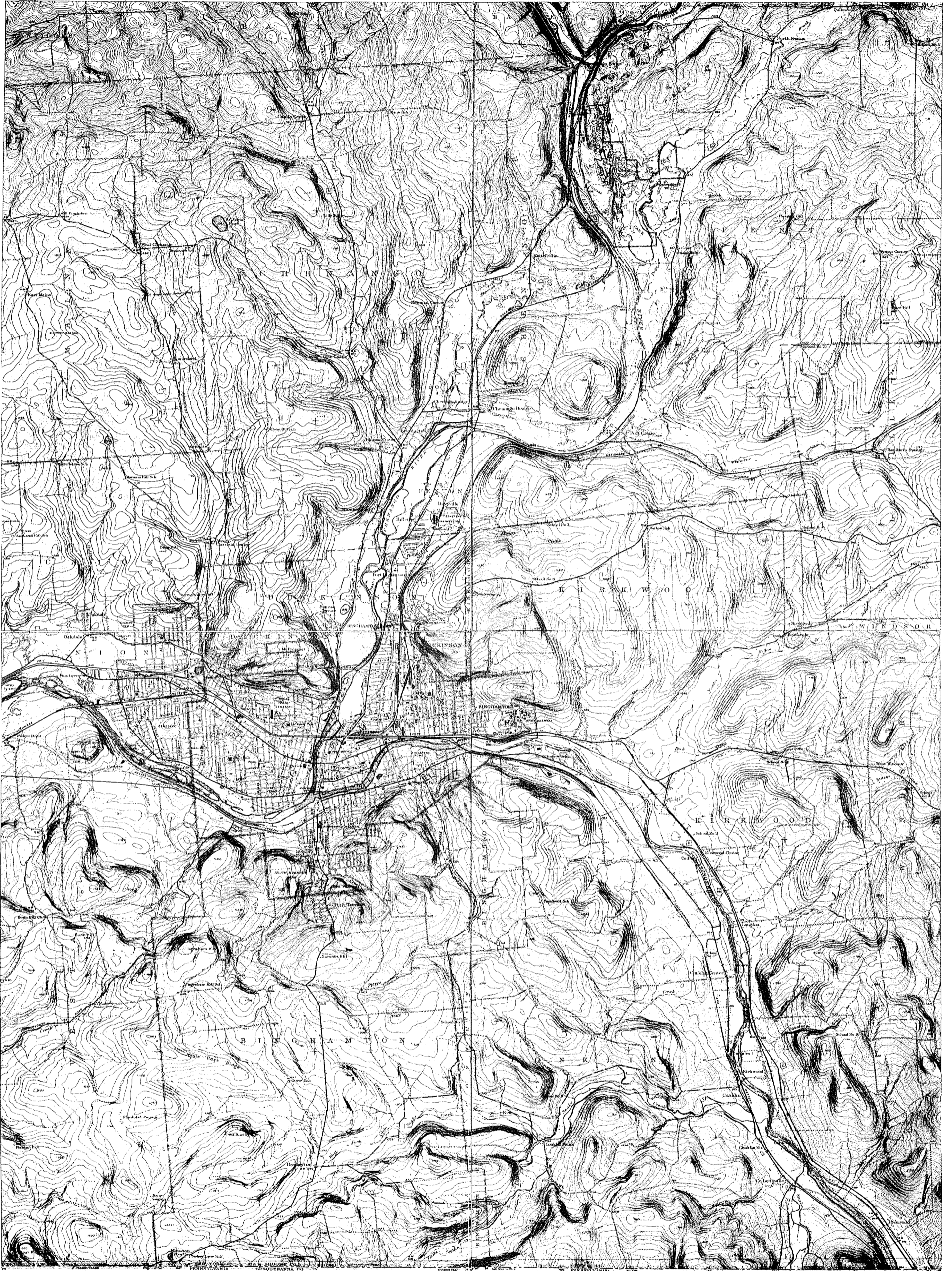
There was one major Wisconsin ice sheet that covered the area, and it left a rich geomorphic heritage. A partial chronology of glacial events would include the following:

1. Glacial erosion of a small degree on upland areas increasing in magnitude in north and south-trending valleys.
2. Ice stagnation and melting with development of ground moraine on uplands and hillsides, and valley moraines with "choker" deposits in the lowlands.
3. Impounding of water forming lakes between morainic masses with formation of lacustrine clays and deltaic deposits.
4. Diversion and breaching of the stagnation areas with formation of outwash areas, valley trains, and kame terraces.
5. Alluvial fan development by tributary streams.
6. Present period of degradation of the valley fill materials.

## REFERENCES

References are listed in the article General Geology of South-Central New York.





Oriskany	Oriskany East
Oriskany West	Oriskany

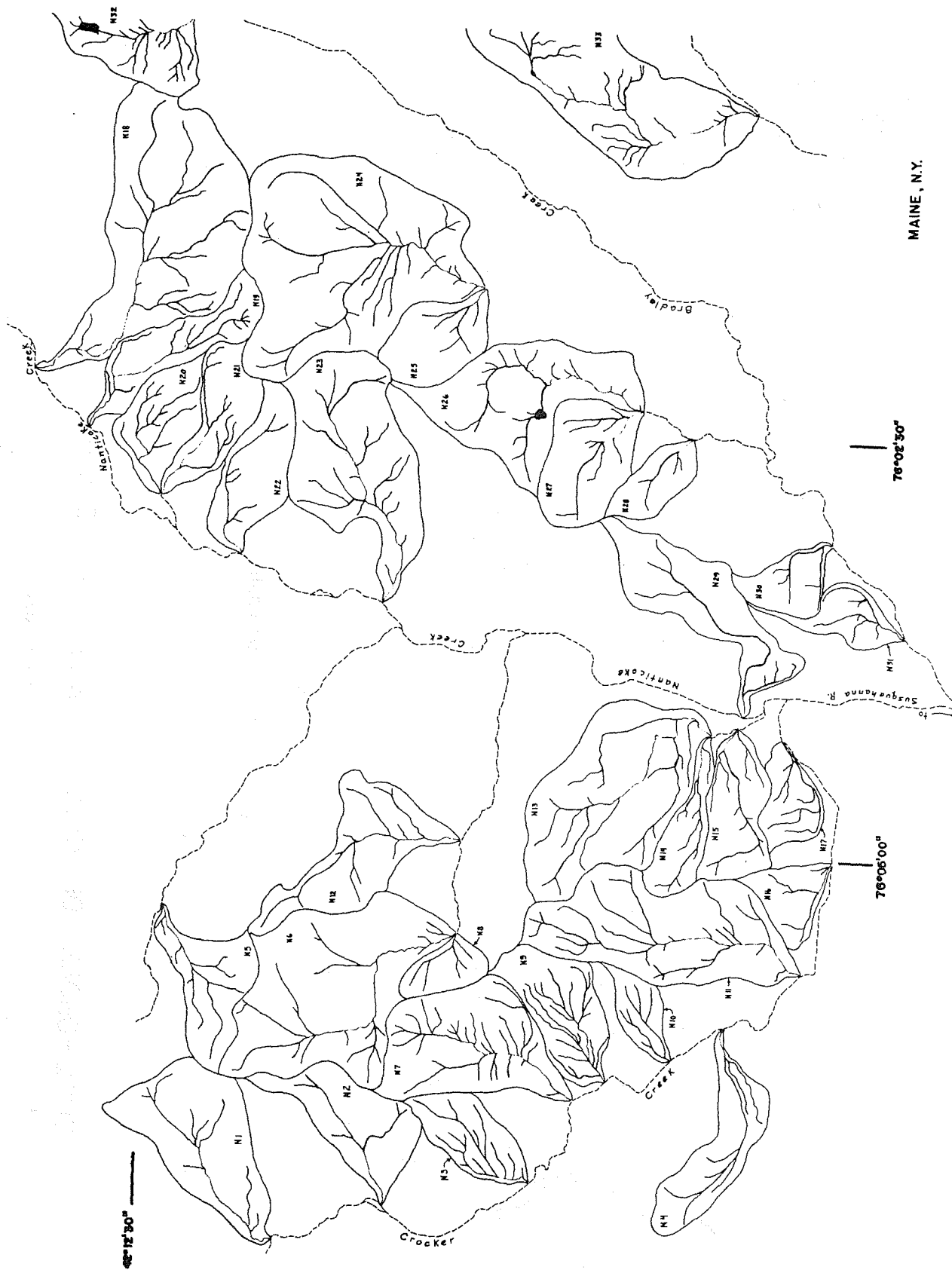
USGS 1:24,000 Quadrangles

SCALE : MILES



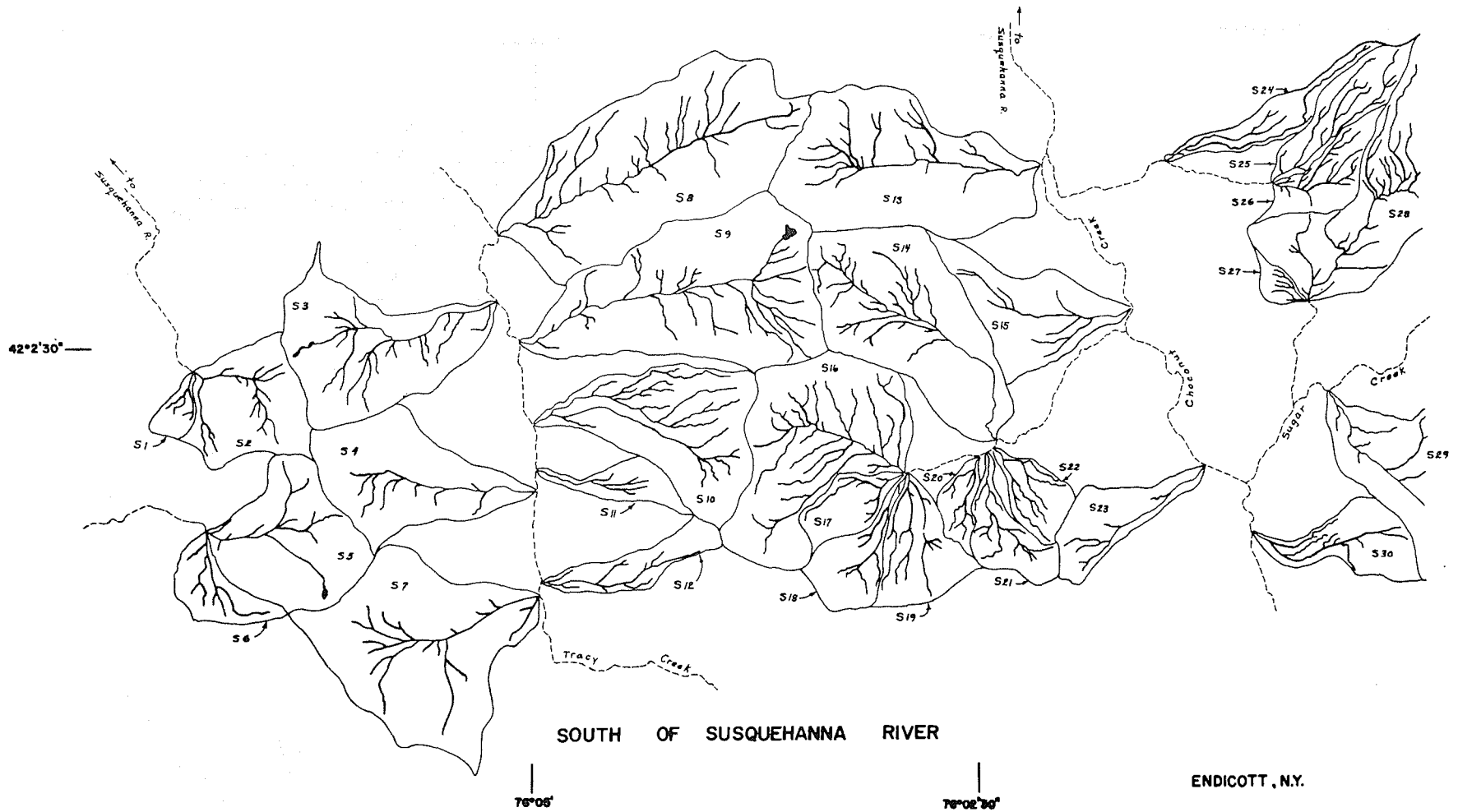
# TOPOGRAPHIC MAP OF BINGHAMTON AREA

Figure 2



MAINE, N.Y.

NORTH OF SUSQUEHANNA RIVER



THIRD-ORDER DRAINAGE PATTERNS OF BINGHAMTON AREA



Figure 3

EXPLANATION

- STREAMS
- == ABANDONED CHANNELS
- ⊗ QUARRY
- × BORROW PIT
- ▲ BED ROCK HILLS
- A.....B FIGURE 5 SECTIONS

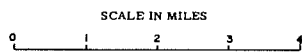
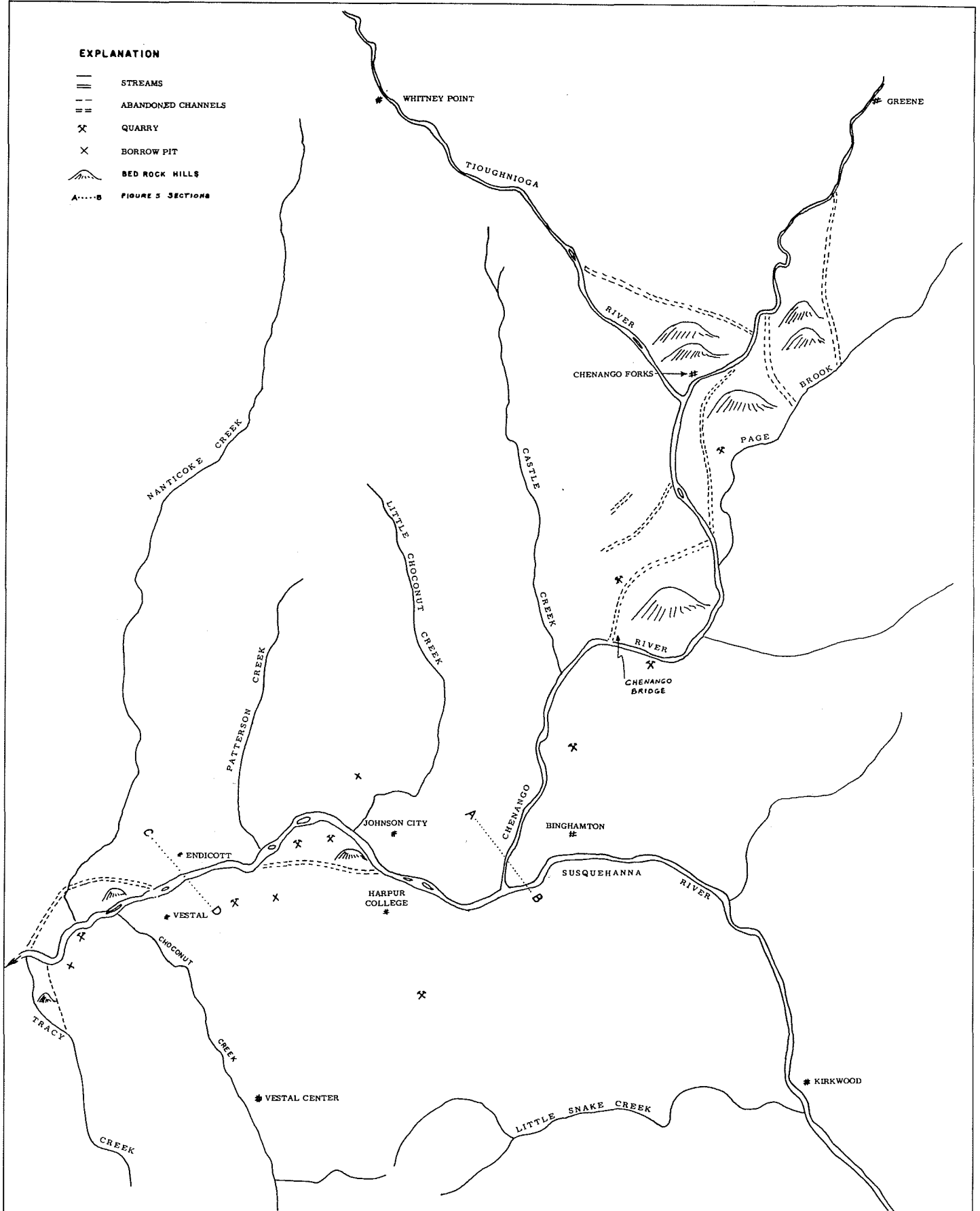
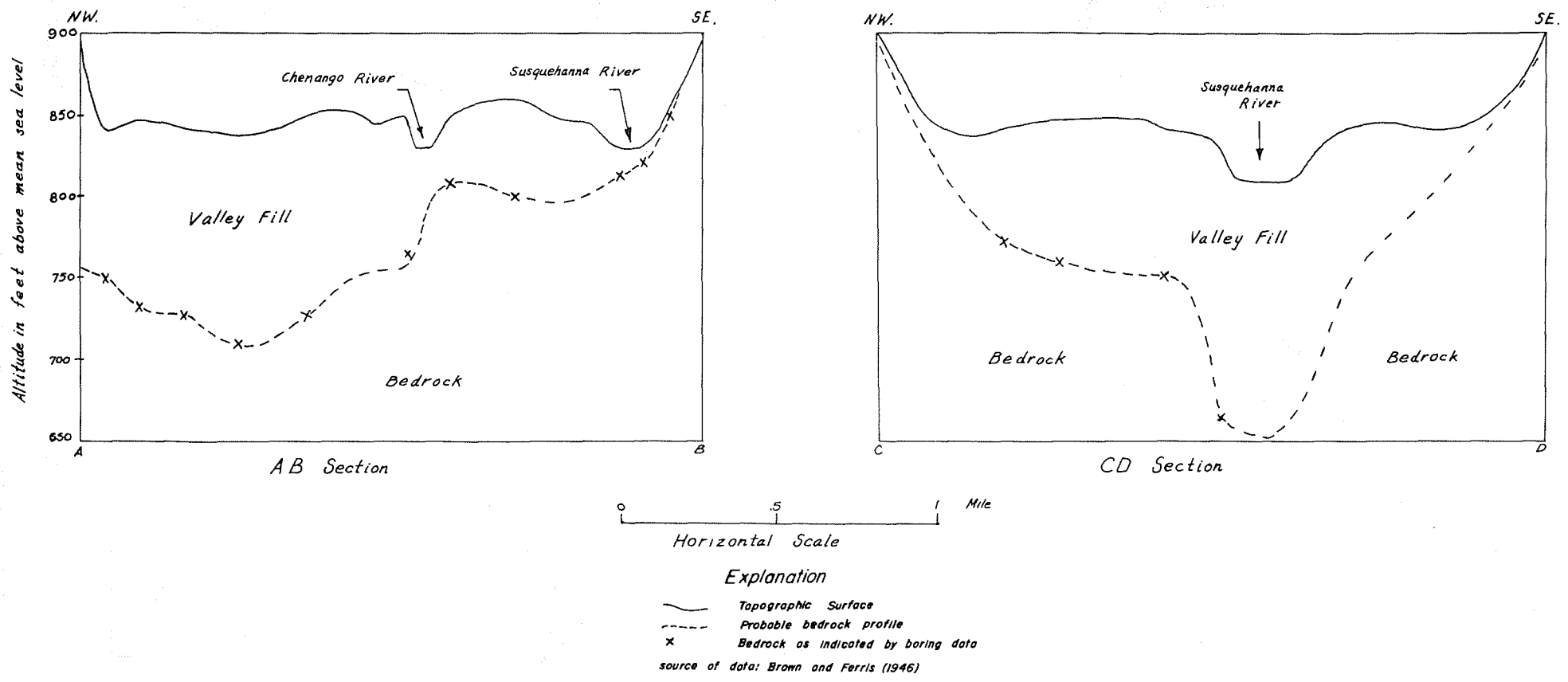


Figure 4



### CROSS SECTIONS TRANSVERSE TO VALLEY AXES

Figure 5

## TRIP B ROAD LOG AND ROUTE DESCRIPTION

## GEOMORPHOLOGY OF THE BINGHAMTON AREA

Donald R. Coates

Total miles	Miles	ROUTE DESCRIPTION
0.0	0.0	Harpur College entrance. East on Rt. 17 to east Binghamton and Rt. 7 (4.2 mi.). Susquehanna River is 830' and greatest hill elevation 4 mi. south is 1877'. Till in road south of river, outwash occurs north of river.
4.2	4.2	Court St. red light and Rt. 7 north to Rt. 369 (4.6 mi.). This is Chenango River valley, 840'.
5.7	1.5	Binghamton Brick Company. See report for Trip A.
6.6	.9	Phelps Creek and south side of Hillcrest. Cemented gravels attest to high lime content of sediments. This kame terrace with 900' level extends along east side of road 1.5 mi.
9.8	3.2	<u>STOP 1.</u> Valley train outwash plastered on bedrock of shale and siltstone to height of 140'. Strata are in contact between Upper Sonyea Group at the base and Lower West Falls Group (Rhinestreet Formation) on top.
10.3	.5	Turn left (north) on Rt. 369 and continue 4.0 mi.
11.6	1.3	Bedrock is Upper Sonyea Group. This marks site of the post-glacial Chenango River channel that was incised owing to ice and sediment blockage in old channel to the west. Northward the valley contains a wide range of outwash deposits, terrace and plain levels, and alluvial fans. The original outwash plain slopes north from 880' to more than 1,000' at Chenango Forks and has been trenched by the Chenango River and Page Brook tributaries.
14.3	2.7	Turn left (west) into Park area. Pass over Page Brook.
14.9	.6	Chenango Valley State Park entrance. Continue straight and make counter-clockwise circuit of Park.
15.6	.7	<u>STOP 2.</u> Park in parking area near pavilion. Elevation of sharp ridge is 950' which is 60' above Lily Lake on the north and Chenango Lake on the south, both are kettle hole lakes. The ridge is composed of unconsolidated materials and is probably the finest example of a crevasse filling in this part of the State. The Park contains numerous kettles and plains; however, this is not kame and kettle topography. Instead the stratified materials are largely horizontally bedded (Stop 3) indicating transport from the north that engulfed stagnant ice blocks.
17.3	1.7	Out of the Park and turn left (north) on blacktop .1 mi.
17.4	.1	<u>STOP 3.</u> Sand and gravel quarries in horizontally-bedded glacio-fluviatile materials. A characteristic of quarries in the Binghamton area is coarse material on top with finer material at the bottom which are commonly sands showing cross bedding and deltaic bedding. Continue north and notice many excellent kettles along route, some more than 60' deep.



## TRIP B

- 19.7 2.3 Keep left, pass over Chenango River bridge to Chenango Forks and intersection with Rt. 12. This area is junction with Tioughnioga River. Excellent exposures of bedrock, till, and lacustrine beds occur 1.2-1.7 mi. upstream in Tioughnioga River. Here it is flowing in post-glacial gorge with bedrock walls. The pre-glacial channel is 2 mi. northeast and parallel to same direction and part of the old stream bed is occupied by Ockerman Brook. (Fig.4)
- 20.0 .3 Turn left (south) on Rt. 12 to Kattelville, 3.0 mi. Along this part of route the Chenango River flows in post-glacial channel, the older channel was east and is now filled. Stratified outwash occurs along west side of route and at high levels above the valley walls are several small 'through-valleys'. These saddles and cols are a type of wind-gap created by high-level meltwater streams when the valley was ice filled and the uplands had become ice-free.
- 22.0 2.0 Ascending a high-level saddle, 1070', one of the overflow passes.
- 23.0 1.0 Turn left at Kattelville off of Rt. 12 and continue south.
- 23.8 .8 STOP 4. The railroad marks the axis of the pre-glacial Chenango River channel. This area contains many quarries in outwash sand and gravel. A recently drilled well, April 1, 1963, produced 120 gpm from sand and gravel 98' below ground surface.
- 25.6 1.8 Chenango Bridge red light. Turn right and continue west to red light and intersection with Rt. 12, then turn left and continue on Rt. 12 to Prospect Street. Good exposures of outwash and terrace levels in main part of valley floor. On the valley walls are exposures of Binghamton till at Rappaport's and Grand Union.
- 30.3 4.7 Prospect Street. Turn right (west).
- 31.6 1.3 STOP 5. Old borrow pit on right side of road is in Olean till. Elevation 940'. See text for characteristics of valley fill across the Chenango and Susquehanna valleys. S 30°W is well field for ANSCO. Yield of wells range from 150- 1,800 gpm. ANSCO has a recharge program in which water is recycled back into the aquifers.  
Continue west to the next stop by taking Prospect Street, Harry L. Drive, and just west of Calvary Cemetery.
- 34.3 2.7 STOP 6. Borrow pit on right side of road in Olean till. Used as fill in flood wall construction.  
Return to Rt. 17 on south side of Susquehanna River through Oakdale, Rt. 17H and Riverside Drive, and across Johnson City-Vestal Bridge.
- 37.7 3.4 Intersection Rt. 17 and Bunn Hill Road, continue west on Rt. 17.
- 38.1 .4 Star-Victory marketing area is located in kettle hole. This is one feature in a morainic complex that extends 0.8 mi. west and was the former site of Susquehanna River prior to blockage.
- 39.0 .9 Good view of 860' level terrace, one part of a vast outwash plain that continues west past Tracy Creek.

- 39.2 .2 Binghamton-lithology till in borrow pit on left side of road (Stop 9).
- 39.4 .2 Deltaic outwash on south in area of Federal Electronics.
- 39.9 .5 Bedrock, claystone and shale. Lower West Falls Group (Rhinstreet Formation). Used for bricks and fill.
- 41.5 1.6 Chocomut Creek. Flood walls built by Army Corps of Engineers as part of flood-control project in the Triple Cities area. This area is site of Town of Vestal well field. Wells did not encounter bedrock at 170' and yield 70,000 gallons per day per foot of drawdown. West of this area at Castle Gardens are large quarries in sand and gravel outwash.
- 42.5 1.0 Unconsolidated glacial materials on left side of road (Stop 8).
- 43.5 1.0 Turn left to Ross Corners and Tracy Creek Road. Stop sign .1 mi on Owego Road, but continue straight (south) on Tracy Creek Road.
- 44.4 .9 STOP 7. Bedrock walls of Tracy Creek. (Rhinstreet Formation) This is post-glacial gorge and typical of the many drainage diversions in the Binghamton area. It is common for these derangements to occur near the junction with major streams. This is similar to the Tioughnioga junction diversion. The pre-glacial Tracy Creek channel is east and became choked with morainic debris. The stream, unable to locate its clogged former channel with disappearance of the ice, incised a new channel as a superimposed stream, even though in bedrock.
- 44.9 .5 Bus stop only to show the west side of Tracy Creek. Olean till occurs in stream cut but varve clays are at the top of the sequence. This exposure completes the history of this local area for the morainic dam impounded waters flowing north and formed a lake, the outlet of which overflowed and started incisement of the bedrock gorge. The lake may have been in existence more than 200 years. Olean-Binghamton transitional facies also occurs.
- 45.0 .1 Turn sharp left on Ross Hill Road. Outcrops of Olean till occur on the right side of road. This area is site of pre-glacial Tracy Creek.
- 46.1 1.1 Owego Road and turn right (east).
- 46.5 .4 Rt. 17 turn right (east).
- 46.8 .3 STOP 8. Triple Cities Construction Co. equipment area and borrow pit. The glacial deposits are lacustrine sands, silts, and clays at 840' with Binghamton till on top. The till has the appearance of being in part ice-rafted.  
Continue east on Rt. 17.
- 50.3 3.5 STOP 9. Large borrow pit near African Road. This material was used in construction of flood walls for the containment of the Susquehanna River. This is typical Binghamton till. The oxidized and leached upper 12' are characteristically brown and below is gray unleached till with high limestone content. The pebbles have bi-modal roundness parameters indicating a dual source, one of local derivation, and the other of longer transport that initially were river-worn. The small butte-like remnant is composed of glacial-lacustrine beds at 850'. Recent excavation (April 6, 1963) reveal the locality from African Road to Federal Electronics to be a complexly developed till-lacustrine-deltaic-ice contact area capped by alluvial fan materials.

## TRIP B

- 50.5 .2 Turn left at African Road and in .2 mi. turn right on Vestal Road. This is outwash terrace with quarries occurring .6 mi. on left side of Vestal Road.
- 51.6 1.1 Turn left at Y in road into Barney Dickenson Company quarry area. STOP 9. The materials originated as valley train outwash in the Susquehanna valley glacial sluiceway. The coarse materials are horizontally-bedded and underlain by sands that are commonly cross-bedded. Cemented conglomerates in the southeast part of the quarry show the results of the high limestone content in the lithology. In materials larger than gravel size the limestone is more than 25% and the igneous-metamorphic crystallines are more than 15%. Heavy mineral composition of the sands show more than 40% magnetite, 18% garnet, 10% ilmenite, and also containing kyanite, zircon, tourmaline, hematite, rutile, and hornblende. A mastadon tusk was found in the higher outwash gravels immediately south of the washing-sieving equipment in 1953. It is reported that the skull, jawbone, and teeth of a "horse-like animal" were found in 1956 in the same horizon 700 feet east of the mastadon location. These materials presently reside at Yale University, waiting for final identification.

1962 Annual Report of Barney & Dickenson, Inc.  
(sent to U. S. Dept. of Interior, Bureau of Mines)

<u>Type of Material</u>	<u>Quantity (Tons)</u>	<u>Value</u>
1. Sand	54,222	\$86,756.64
2. Gravel		
a. Building	63,477	95,215.50
b. Paving	75,405	143,269.50
c. Fill	24,267	19,413.60
Total	217,371	\$344,655.24

Sharp left on Vestal Road to Bunn Hill Road, and return to Harpur College. Along the road is morainic area but large hill on the left, Roundtop, is bedrock.

- 54.6 3.0 Harpur College entrance.