GEOLOGY
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 northeast 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° 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 monoclinal dip is interrupted only by local structural terracing and minor reversals 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 Silurican 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 straitigraphic 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 monoclinal 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 geosycline 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 <u>relic topography</u>, 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 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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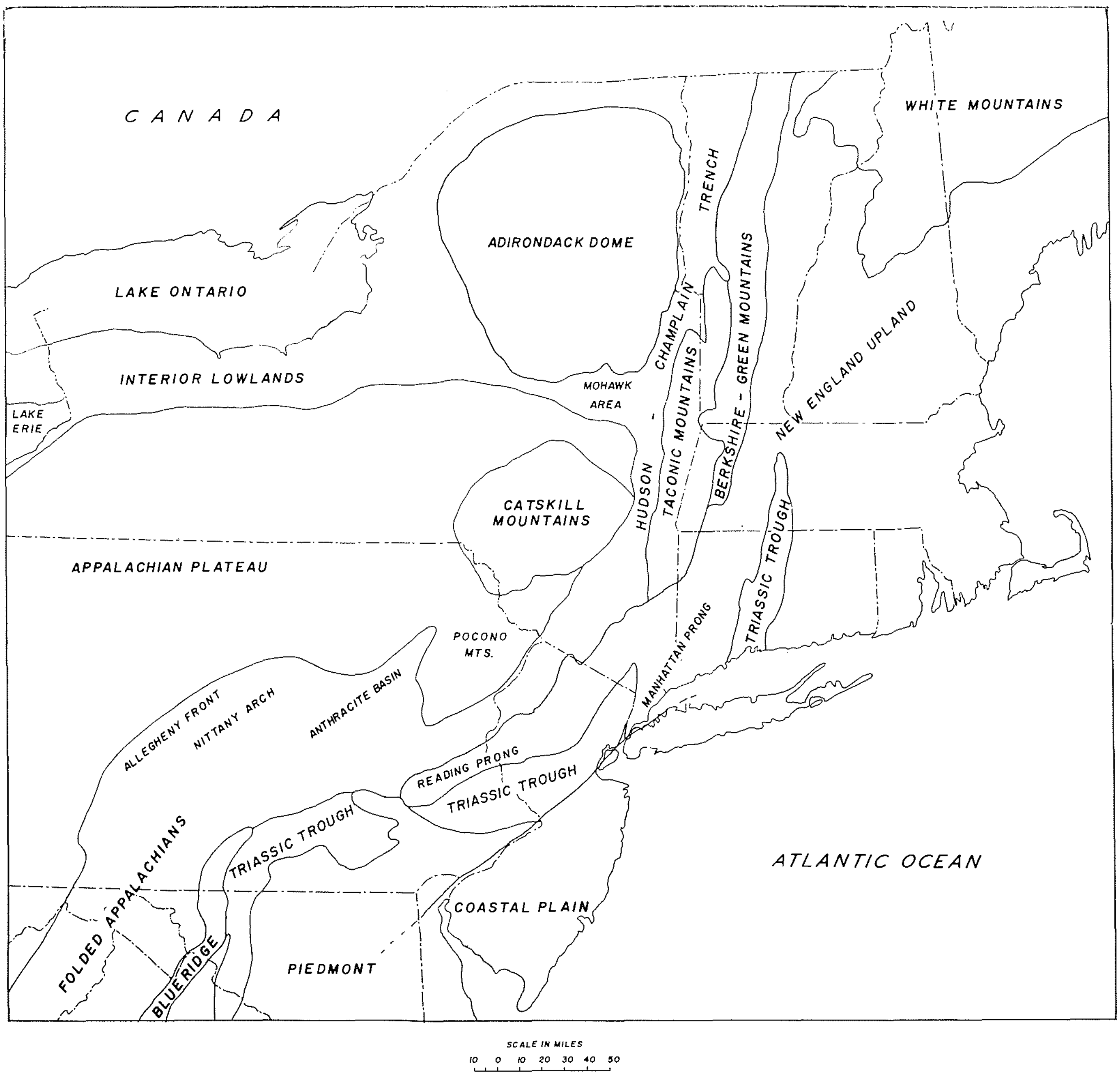

TECTONIC ELEMENTS OF NORTH-EAST UNITED STATES

Figure 1.