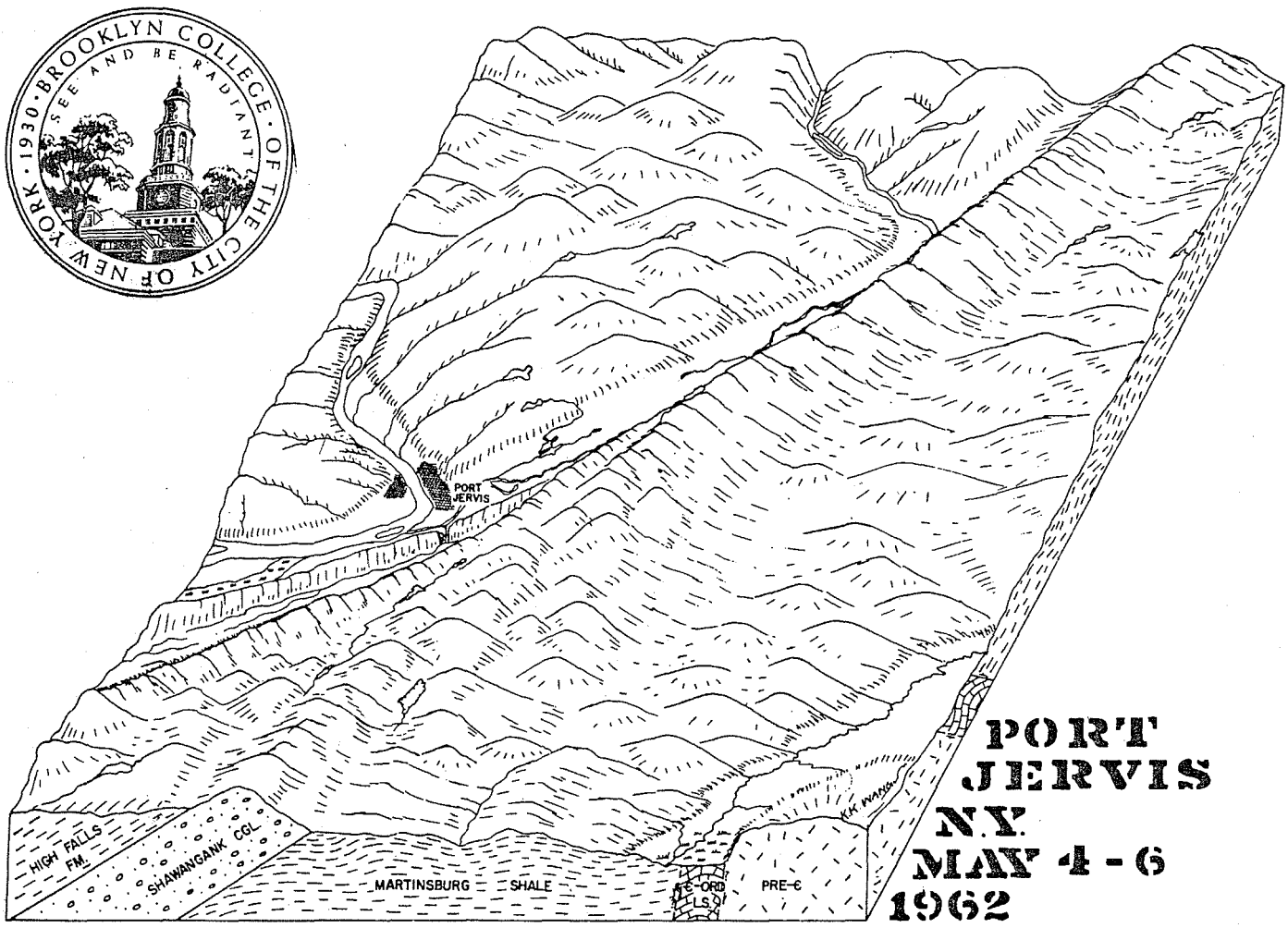
FIELD GUIDE BOOK



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NEW YORK STATE GEOLOGICAL ASSOCIATION 34TH ANNUAL MEETING

GUIDEBOOK TO FIELD TRIPS

NEW YORK STATE GEOLOGICAL ASSOCIATION

34th Annual Meeting

Port Jervis, New York

May 4-6, 1962

Wilbur G. Valentine, Editor

Contributing Authors

Helen Antine-Biren
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Acknowledgements

This meeting of the New York State Geological Association is probably unique in being quite far removed from the host institution, in a region where practically no one from the host institution is currently doing any research. Only Trip E was organized exclusively by a member of the Department of Geology of Brooklyn College, Prof. Helen A. Biren.

I wish to thank especially the authors of the articles comprising this guidebook for the time, energy, and judgment that was required to organize these trips and write the reports. The members of the Geology Department at Brooklyn College who offered to become "experts" on particular trips so that they could be trip leaders also merit special consideration.

This guidebook would not have been possible without the expert and efficient work of Frances Rowley and Ed Pomella, and the cooperation of the Geological Society of Brooklyn College. Kia K. Wang took the responsibility of drafting the cover page and several other illustrations, and was ably assisted by Harold W. Eriksen. John Stewart made valuable suggestions about the presentation and organization of some of the papers. Thanks are due to Arthur Loring, Linda Hamilton, Anna Kurica, Judith Jacobus, Theresa Panetta, and John Carroll for their assistance.

The authors of the several articles assume responsibility for the contents thereof, and the editor assumes responsibility for any deviations from the original manuscript. In some cases, there was insufficient time to check minor editorial changes with the authors.

Wilbur G. Valentine,
Editor

General Information

The material in the guidebook has been arranged in the alphabetic order of the field trips. In each of these sections, the material is paged consecutively A-1, A-2, ---, B-1, B-2, ---, etc. Text references within each unit have been shortened to the page number for brevity. Illustrations are usually placed at the end of the unit, unless they relate to a particular part of the text. Some illustrations have page numbers, others do not.

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THE ONONDAGA LIMESTONE AND THE SCHOHARIE FORMATION IN SOUTHEASTERN NEW YORK

William A. Oliver, Jr.
John H. Johnsen
John B. Southard

TRIP A

Correlation and facies changes in the Schoharie and Onondaga Formations; relationship to the Esopus Formation; relationship of the outlier at Highlands Mills to the main belt along the Catskill Front.

Editor's Note: This trip was organized by John Johnsen in Poughkeepsie, William Oliver in Washington and John Southard in Cambridge. The presentation consists of a paper on the Onondaga in the Front area by William Oliver, a paper by John Johnsen and John Southard as co-authors on the Schoharie in the Front area and the Schoharie and Esopus in the outlier, and combined notes and discussion of the situation at each scheduled stop.

THE ONONDAGA LIMESTONE IN SOUTHEASTERN NEW YORK[1]

by William A. Oliver, Jr.[2]

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[1] Publication authorized by the Director, U. S. Geological Survey

[2] U. S. Geological Survey, Washington, D. C.

Introduction

The Onondaga Limestone in New York is a complex of lithic and faunal facies that has been subdivided into four members of more or less constant age across the state. In central New York, these members are further subdivided into a succession of 12 local faunal zones which persist laterally for several tens of miles. Lateral changes permit the recognition of several facies within each member. One purpose of the present trip is to observe the facies changes along the outcrop belt between Catskill, Kingston, Wawarsing, and Port Jervis, a total distance of about 50 miles. In the following paragraphs, the formation is first discussed in its type area near Syracuse, then in the Helderberg escarpment just north of the trip area, then in the trip area itself, and finally in the vicinity of Stroudsburg, Pennsylvania, just south of the trip area.

The Type Area

In the type area near Syracuse, New York, the Onondaga Limestone has been subdivided into four members (Oliver, 1954). From the bottom these are:

Edgecliff Member: Light-gray, coarse-grained limestone in beds ranging from half a foot to 3 feet in thickness. Light-gray chert is common in the upper part, but in places, especially toward the east, it is found throughout the member. The Edgecliff Member is characterized by solitary rugose and tabulate corals which in places are so abundant as to form coral biostromes. The matrix consists of crinoidal debris; certain large columnals, three-fourths inch in diameter, are characteristic. Brachiopods are found at most exposures but are not common. The member is 8 feet thick at Syracuse and thickens toward the east.

Nedrow Member: Shaly limestone grading upward into more massive fine-grained limestone. The lower part of the member is characterized by an abundance of platyceratid gastropods and two species of solitary coral, but both are less common upward. Brachiopods are very common, but the same species range into the overlying Moorehouse Member. The thickness ranges from 10 to 15 feet.

Moorehouse Member: Medium-gray, fine-grained limestone with black chert throughout but especially abundant in the upper half. A variety of brachiopods, gastropods, small corals, nautiloid cephalopods, and trilobites form the largest and most varied fauna of any of the members. The thickness ranges from 20 to 25 feet.

Seneca Member: A succession of distinctive beds of fine-grained limestone similar to the upper part of the Moorehouse in the lower part, but becoming darker and less cherty upward. The basal unit of the member is the Tioga Bentonite (of Fettre, 1952); successive beds are characterized by the brachiopod Chonetes lineatus and a few additional brachiopod and coral species. This member grades upward into the Union Springs Black Shale (of Cooper, 1930).

The Helderberg Area

Facies changes east and southeast of Syracuse have been described by Oliver (1954, 1956a). Changes in the Helderberg area, just north of the field trip, are summarized in the following paragraphs.

The Edgecliff Member maintains the same lithology and fauna as in the type area, but is represented by a bioherm (reef) facies at many localities from Richfield Springs east to the Helderbergs and south to Coxsackie (Oliver, 1956b). The southeasternmost reef is just 10 miles north of Leeds (stop 2). The normal thickness of the member in this area is 30 feet.

The Nedrow Member passes eastward into a lithology like that of the Edgecliff Member. Although not shaly, the Nedrow is thin bedded in its lower part and is characterized by the same species of platyceratid gastropods and corals as in the type area. Associated with these are a variety of brachiopod and coral species not limited to the member. The thickness in the Helderbergs is the same as in the type area.

The Moorehouse Member thickens to the east and is about 70 feet thick in the Helderbergs where it is divisable into three distinct units: a lower noncherty unit, a middle unit with dark-gray chert, and an upper noncherty unit. All three units are lighter colored and coarser grained than in the type area, but the middle cherty unit is darker and finer than the other two. In the Helderberg area the lower and upper units are lithologically similar to the Edgecliff Member. The typical Moorehouse fauna persists to the east, but a larger variety of Edgecliff-type corals is present.

East of the type area the Seneca Member grades laterally as well as upward into the Union Springs Black Shale of the Marcellus Formation (Oliver, 1956a, p. 1466) and the Onondaga-Marcellus contact is time-transgressive. The Seneca Member is not present east of Cobleskill and the Moorehouse Member grades upward into the black shale in the Helderberg area.

Southeastern New York

(Field Trip Area)

From the Helderbergs, the Onondaga outcrop belt extends south to Catskill and Kingston, then southwest along the Rondout Valley to Wawarsing and Port Jervis. Lithologic and faunal changes are described in detail in connection with the individual stops but are summarized here. Onondaga stratigraphy in this area was described by Oliver (1956a).

Edgecliff Member: At Leeds near Catskill, and at Kingston (stops 2 and 4), the Edgecliff Member is somewhat thicker (36 feet) and much more cherty than in the other area described. Corals are less common but the characteristic large crinoid columnals are present throughout the member. Farther southwest at Wawarsing (stop 5), the Edgecliff is a thinner, darker, and finer-grained limestone with little chert. Fossils include the characteristic crinoid columnals, small corals and scarce brachiopods, bryozoans, etc. At Wawarsing and farther south, the Edgecliff is recognized mainly by its large columnals.

Nedrow Member: The eastern facies of this member as described for the Helderbergs persists as far south as Kingston. At Leeds (stop 2) and Kingston (stop 4) the member is lithologically similar to the Edgecliff. At Leeds some 43 feet of platyceratid-bearing beds are referred to the Nedrow. The thickness at Kingston is unknown, but at Saugerties (midway between Leeds and Kingston) the Nedrow is approximately 34 feet thick. South of Kingston the platyceratids disappear and the member cannot be distinguished from the Moorehouse Member.

Moorehouse Member: No complete section of this member is known in the field trip area. In the Leeds-Kingston area the lithology and subdivisions are as described for the Helderberg area and the member is predominantly a medium-light-gray, medium-coarse-grained limestone. Southwest of Kingston at Wawarsing (stop 5) the lower 50 feet of the member is darker and has a less varied fauna. Exposures in small quarries near Ellenville, just southwest of Wawarsing, indicate that the lighter and coarser limestone persists in the higher part of the member at least that far south. At Port Jervis, only small exposures are known, all lithologically similar to the Wawarsing outcrop. The Moorehouse thickness increases from 70 feet in the Helderbergs to more than 100 feet at Saugerties. The thickness at Port Jervis is estimated at 190 feet.

Seneca Member: The uppermost member of the type Onondaga is replaced in the Helderbergs by the lower part of the Marcellus Shale. No exposures of the uppermost part of the Onondaga are known in the trip area, but it is unlikely that the member reappears in southeastern New York.

Southwest of Port Jervis

Thirty-five miles southwest of Port Jervis, just northeast of Stroudsburg, Pennsylvania, the Buttermilk Falls Limestone of Willard (1939, p. 144) is the approximate equivalent of the Port Jervis Onondaga. The

basal 20 to 30 feet of the Buttermilk Falls contains the characteristic large crinoid columnals of the Edgecliff Member, but it is otherwise similar to the overlying beds.

According to D. C. Alvord of the U. S. Geological Survey, Willard's Buttermilk Falls Limestone includes an upper unit with interbedded shale, approximately 50 feet thick, and a lower, more massive, cherty unit, 150 feet thick (oral communication, 1961). Both units are finer and darker than the Helderberg Onondaga and the lower one is similar in all respects to the Onondaga exposed in the Wawarsing-Port Jervis area.

Between Kingston and Stroudsburg, the typically lighter colored and coarser Onondaga passes into the darker and finer Buttermilk Falls type of lithology. The northeastward extent of the shaly upper unit of the Buttermilk Falls is unknown. However, it may extend into New York, and lack of upper Onondaga outcrops in the Wawarsing-Port Jervis area may indicate that this part of the formation is less resistant to erosion.

Formation Thickness

The eastward thickening of the Onondaga Limestone is indicated by the following approximate figures:

Syracuse	65 to 70 feet thick
Morrisville	90
Cherry Valley	118
Helderberg area	115

South of the Helderbergs in the trip area the formation has a minimum thickness of 165 feet at Saugerties, midway between Leeds and Kingston. At Port Jervis the thickness is probably no more than 200 feet, the known thickness at Stroudsburg, Pennsylvania, 35 miles to the south.

Age of the Onondaga

Oliver (1960) has recently summarized the faunal evidence for a Middle Devonian (Eifelian) age for the Onondaga Limestone. Two coral faunas are recognized in this part of the Devonian in western New York, the lower one being limited to the sub-Edgecliff *Amphicoenia* zone (zone B, 2 feet thick, of Oliver, 1954). In the Helderberg region some elements of this lower coral fauna are found in the typical Schoharie Formation (of Vanuxem, 1840, p. 378). The lower corals themselves are largely endemic and do not bear on the age question. Associated brachiopods are of Early Devonian (Emsian) age, according to A. J. Boucot (oral communication, 1961).

The upper coral fauna is abundantly represented in the Edgecliff Member and in the eastern facies of the Nedrow and Moorehouse Members. These corals indicate a Middle Devonian (Eifelian) age for the Onondaga Limestone in central and eastern New York. Nautiloid cephalopods in the Nedrow and Moorehouse Members and rare goniatites in the Nedrow Member support this age assignment (Flower and House in Oliver, 1960, p. 174).

In the Wawarsing-Port Jervis area corals are not common and the more diagnostic forms do not appear. Correlation is based on tracing the large crinoid columnal beds from the type area and the Helderbergs, south to Port Jervis and Stroudsburg. Such a thin and persistent zone is not likely to vary significantly in age in this short distance. It is concluded that the Onondaga Limestone, in the Wawarsing-Port Jervis area, and the Buttermilk Falls Limestone, in the Stroudsburg area, are of Middle Devonian age.

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THE SCHOHARIE FORMATION IN SOUTHEASTERN NEW YORK

John H. Johnsen [1]
co-authors
John B. Southard [2]

Introduction

This article was prepared from three sources: (1) a paper by Johnsen (1957) which presented a major revision of the Schoharie Formation; (2) an unpublished paper by Southard (1960) dealing in part with rocks of Esopus and Schoharie age in the northern part of a narrow outlier southeast of the main belt of Esopus and Schoharie outcrop; and (3) notes from one summer's field work by Southard in 1961 to work out in more detail the stratigraphy of the Esopus and Schoharie Formations along the main belt of outcrop from Leeds to Port Jervis, New York. Since this article is based on independent work of both writers, neither assumes the status of senior author. The general statement about the Schoharie was written by Johnsen and is based entirely on his work. The description of the Schoharie in the field trip area, exclusive of the outlier, was written by Southard using Johnsen's work as a basis and incorporating his own views (involving a few major changes)[3]. The section on the outlier is entirely Southard's.

The Schoharie Formation Redefined

- A General Statement -

Detailed stratigraphic and petrographic studies permit redefinition of the Schoharie Formation. It is a complex of lithologic facies extending along the Devonian (Onesquethaw) outcrop from Herkimer County, New York, at least to Monroe County, Pennsylvania, a distance of more than 200 miles (Fig. 1). The formation thickens south to Port Jervis, New York, and thins again in New Jersey and Pennsylvania (Fig. 3). The general character of the Schoharie succession is that of a moderately thick transition zone of mixed clastic carbonate rocks lying above the dominantly clastic rocks of the Esopus Formation and below the carbonate rocks of the Onondaga Formation.

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3. These changes concern the recognition of the black bed in the Carlisle Center Member (p. 11), the nature of the contact between the Carlisle Center and Aquetuck Members (p. 13), and the tracing of the Aquetuck Member south from Leeds (p. 13).

Several subdivisions are recognized. The lowest subunit is designated the Carlisle Center Member. It consists primarily of calcareous mudstone and calcareous siltstone and is characterized by a sparse fauna made up of small forms. Taonurus cauda-galli is common in east-central New York (Herkimer to Albany counties), less common in the Mid-Hudson Valley and rare in southeastern New York. A more detailed description of the Carlisle Center follows in the section on the field trip area.

The Carlisle Center Member, for the most part, corresponds to the "Carlisle Center Formation"[4] of Goldring and Flower (1942). These authors applied the name "Carlisle Center Formation" to 20 feet of shale which were formerly included in the upper part of the Esopus Formation and which underlie the "Schoharie Formation" of Vanuxem (1840) in Schoharie and Otsego Counties, New York. They pointed out (op.cit., p. 690) that these beds are present along the belt of outcrop to Port Jervis, New York, where they measure 200 to 225 feet. At Leeds in the Mid-Hudson Valley and at Port Jervis, beds assigned by Goldring and Flower to the "Carlisle Center Formation" are correlated with the Esopus Formation. In these localities, the Carlisle Center Member is higher in the section.

Except in portions of east-central New York, the contact with the Esopus Formation is placed at the bottom of the lowest beds of siltstones or mudstone sufficiently calcareous to effervesce in cold dilute hydrochloric acid. North of Kingston, New York, the base is locally marked by glauconite; south of Kingston, a persistent zone of Leptocoelia acutiplicata aids in defining the base.

The Rickard Hill Member lies above the Carlisle Center Member in east-central New York and corresponds to the "Schoharie Formation" of Vanuxem (1840). It consists principally of sandy limestone and calcareous sandstone containing may brachiopods and conspicuous cephalopods. Some of the rock is argillaceous sandy limestone and calcareous argillaceous sandstone. The member ranges in thickness from a thin film, where it wedges out one mile southwest of East Springfield, New York, to six feet in Schoharie and western Albany Counties. Variations in thickness are not regular but general eastward thickening is apparent. At places glauconite is abundant in the lower part of the member.

The Rickard Hill Member passes laterally into finer calcareous strata in southern Albany County which are readily divisible into two subunits in the Mid_Hudson Valley. The lower subunit, designated the Aquetuck Member, is composed of calcareous siltstone with minor argillaceous limestone and calcareous sandy mudstone. Chert is present within the member in the upper Mid-Hudson Valley, but the chert diminishes rapidly to the south as the subunit becomes vaguely banded and limier. Glauconite is present in association with sand-size grains of detrital quartz in some sections. The member carries meager fauna in all sections.

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4. Originally Sharon Springs Formation, a name subsequently found preoccupied. Winifred Goldring and R. H. Flower, Discussion: Am. Jour. Sci., vol. 242, 1944, p. 340.

The upper subunit, or Saugerties member, is distinguished by conspicuous layers of limestone alternating with layers of calcareous mudstone, calcareous argillaceous sandstone or argillaceous limestone which often contain varying amounts of quartz sand in Albany, Greene and Ulster Counties. Southward pure limestone is absent and the Aquetuck and Saugerties Members gradually become increasingly difficult to separate in the field.

Except for the Richard Hill Member, the Saugerties is the most fossiliferous subdivision of the Schoharie formation. The fauna is not restricted to any one rock type. Brachiopods exceed all other faunal groups in numbers of individuals and species. A few fragmentary orthoceracones and cyrtoceracones, typical of the Rickard Hill Member, are present in highest Saugerties beds in the upper Mid-Hudson Valley, suggesting contemporaniety with the Rickard Hill Member.

In the Port Jervis region, all members of the Schoharie Formation are nearly alike in composition, texture and appearance. At Trilobite Mountain, the Carlisle Center beds are limier upward and, by imperceptible changes, the rock gradually takes on the lithology of the upper members. The selection of the exact position of the boundary between the lower and upper divisions is a matter of opinion.

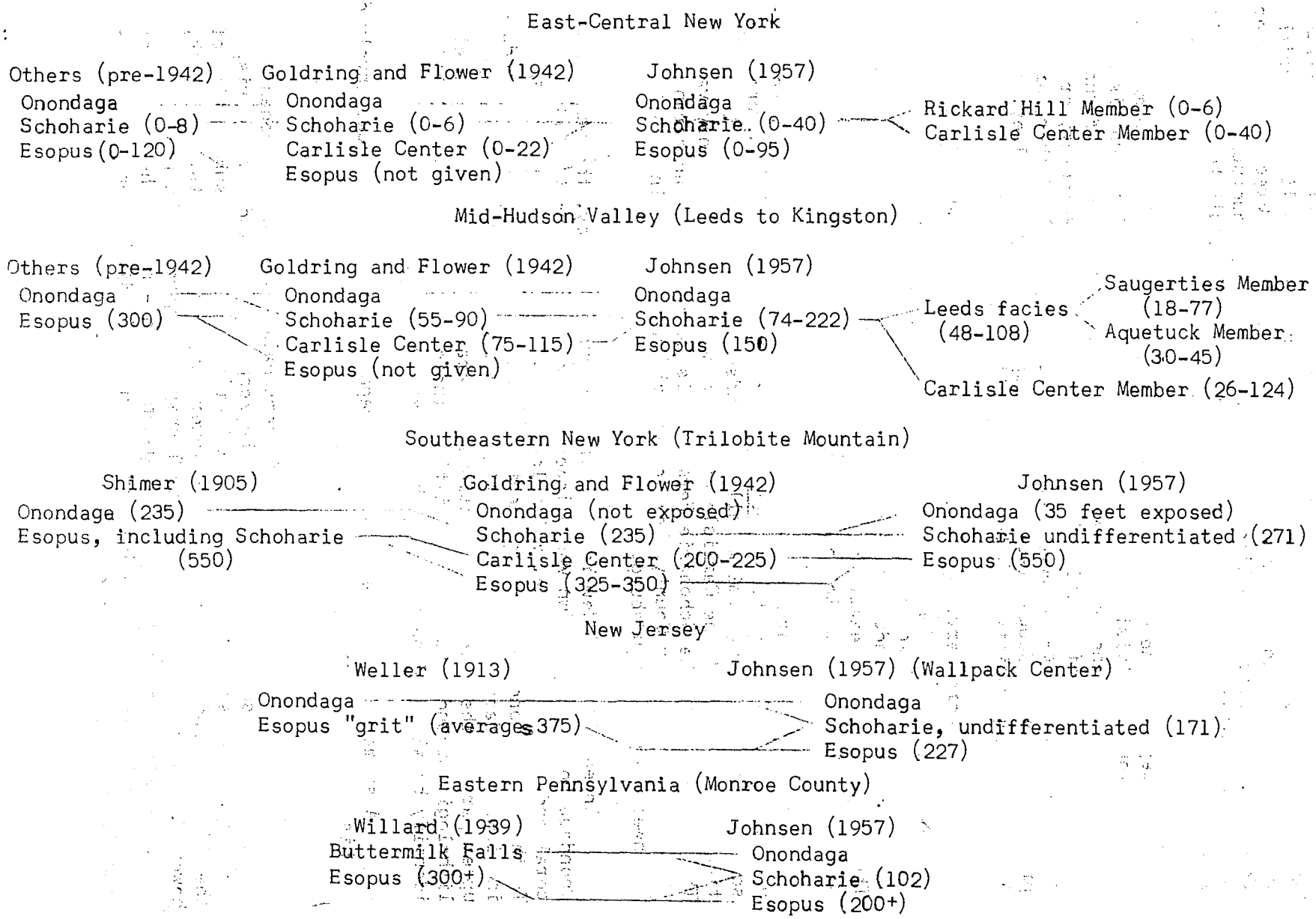
Sections are rare and incomplete in New Jersey and eastern Pennsylvania. Persistance of the Leptocoelia zone to Experiment Mills, one mile south-southwest of Buttermilk Falls (Stroudsburg region) serves to distinguish the base of the Carlisle Center in Monroe County, Pennsylvania. The upper part of the Schoharie Formation is marked by the appearance of quartz sand in Sussex County, New Jersey, which increases in quantity southwestward to Stroudsburg.

In east-central New York and the Mid-Hudson Valley, the Schoharie-Onondaga boundary is drawn where lowest Onondaga limestone is typically a coral and crinoid biostrome, which locally may pass into a bioherm facies. To the south, conditions of sedimentation were more nearly uniform producing lower Onondaga sediments very similar in appearance to those of the upper part of the Schoharie Formation. Separation is difficult on purely lithologic grounds, but characteristic crinoid columnals (Oliver, 1956) identify basal Onondaga to Stroudsburg, Pennsylvania.

A summary of the usage of stratigraphic names for the rocks involved in this study is given in Figure 2.

NOTE: Within the last year, Southard (personal communication) began a restudy of the Esopus-Schoharie rocks between Catskill and Port Jervis, New York. He essentially shares the writer's views on the subdivision of the Schoharie and the placing of the lower and upper contacts. His work, however, has resulted in some internal changes regarding the position of the Schoharie subdivisions in the Kingston region - namely the placing of the Carlisle Center-Aquetuck boundary. Southard's discussion in the section that follows is based on his point of view.

FIGURE 2. THICKNESS OF SCHOHARIE FORMATION (IN FEET) AND USAGE OF STRATIGRAPHIC NAMES



The Schoharie Formation in the Field Trip Area

Carlisle Center Member

The Carlisle Center Member consists of calcareous mudstone with interbedded muddy limestone layers of varying degrees of distinctness. There exists a complete range of beds of rock type intermediate between muddy limestone and slightly calcareous mudstone. The most calcareous beds are thin (4-12 inches), distinct, and widely spaced (2-10 feet). They weather light and are less affected by cleavage than the calcareous mudstone. The less calcareous beds, which comprise most of the member, are thicker and less distinct than the muddy limestone beds. The member shows a gradual increase in lime content upward, so that most of the calcareous beds occur in the upper part; moreover, as the member thickens southward, these highest calcareous beds become more distinct.

The rocks of the member display prominently the results of activity of burrowing organisms. The tubular burrows, 1-5 mm thick, tend to be flattened in the plane of the bedding. They appear both as spots and streaks on weathered surfaces. They show sharp contacts with the surrounding sediment. The organisms have blurred the contacts between layers (such contacts are either abrupt or gradational) by carrying sediment from one layer down into another, resulting in light weathering burrows in dark weathering sediment, or vice versa. Taonurus cauda-galli markings are present in the lowest part of the member as far south as Kingston.

A distinctive two- to three-foot black bed consisting of very hard fine-grained siliceous slightly calcareous rock (not true chert) is present in all sections in the main belt of outcrop from Leeds to Wawarsing, except at Catskill. It is black where fresh and black to reddish purple where weathered. Its extent north of Leeds and south of Wawarsing is uncertain. At Trilobite Mountain (1 mile NE of Tristates, N.Y.) the part of the section in which the bed should occur is not exposed. Its character and great lateral extent suggest that it represents some sort of relatively brief episode of chemical deposition superposed on the normal Carlisle Center deposition.

In all sections from Leeds to Trilobite Mountain the Carlisle Center Member is underlain by the Esopus Formation. The contact is well exposed in most sections from Leeds to Kingston, but at Wawarsing and Trilobite Mountain it is covered. Although the calcareous mudstones of the Schoharie rest with abrupt contact on the non-calcareous mudstones of the Esopus wherever the contact is exposed, there is physical evidence of disconformity only at the railroad cut in Kingston. There the lowest bed of the Carlisle Center truncates the strata of the Esopus at a small angle. This truncation seems to be merely a local feature, however, because where the contact is exposed along the railroad tracks a few hundred yards east of the main section (p. 17) there is no evidence of truncation, the contact having the same character as in sections elsewhere. Glauconite and quartz sand grains are present in the lowest beds of the member wherever the contact can be observed. A break in deposition between the Esopus

and Schoharie is likely, even though a disconformable relationship can be proved in only one locality, because of the abruptness of the upward change from non-calcareous to calcareous strata and the presence of glauconite and quartz grains in the basal beds of the Carlisle Center.

Glauconite grains and quartz sand and fine pebbles also occur in the upper part of the Carlisle Center Member. This is discussed in connection with the lower contact of the Aquetuck Member (see below).

Aquetuck Member

At Leeds the Aquetuck Member consists of interbedded calcareous mudstone and muddy limestone with abundant thin layers of dark-weathering cherty rock not sharply distinct from the calcareous mudstone, and layers of small chert nodules. The muddy limestone layers are similar to those in the upper part of the Carlisle Center Member to the south, as is the nature of the interbedding. To the south (Kingston) the chert nodules disappear and the thin dark-weathering layers in the calcareous mudstone become inconspicuous (but do not disappear). Layers of 3- to 10-inch nodules of light-gray-weathering slightly muddly limestone that show abrupt contacts with the surrounding calcareous mudstone are present instead of continuous layers of muddy limestone. The nodules contain less mud than the limestone beds in the Aquetuck at Leeds or in the underlying Carlisle Center. South of Kingston, exposures of the upper part of the member are poor; the lower part is the same as at Kingston except that the layers of limestone nodules are more widely spaced and the nodules are larger. The member as a whole becomes more calcareous upward, so that in the upper part the calcareous mudstone verges on very muddy limestone. Burrow markings are present throughout the member but are not as conspicuous as in the Carlisle Center.

Although the contact between the Carlisle Center Member and the Aquetuck Member is nowhere sharp, the gradation between them takes place over a progressively greater thickness from Leeds (about 6 inches) to Kingston (4-6 feet). The glauconite and quartz sand in the upper part of the Carlisle Center, occurring as irregular wisps, lenses, and scattered grains, in greatest abundance at the top of the member and decreasing in quantity downward, seem to be closely associated with the change from the Carlisle Center to the Aquetuck. Both their quantity and the proportion of the Carlisle Center in which they occur decrease to the south, along with the increase in thickness of the transition strata between the members. They disappear entirely before reaching the Kingston railroad cut. This evidence suggests, but does not prove, that there was an interval of nondeposition between the members in the north but not in the south. That there was a change in deposition is shown by their differing lithology; that this change was accompanied by (or preceded by) some unusual depositional event is shown by the sand and glauconite. The cause of the increase of sand and glauconite upward to the top of the Carlisle Center and its irregular (non-bedded) distribution is not known; its explanation would help clarify the significance of the contact. South of Kingston the change between the Carlisle Center and the Aquetuck is so gradual that the location of the contact is arbitrary.

Saugerties Member

In the Mid-Hudson Valley the Saugerties Member consists of interbedded medium-gray slightly muddy limestone in even beds 3 to 12 inches thick and medium-gray very calcareous mudstone (or very muddy limestone) in even beds 3 inches to 2 feet thick. The more calcareous beds weather light gray, and the less calcareous beds weather yellowish brown, producing a prominent banding on weathered surfaces. Roughly two-thirds of the member consists of the less calcareous beds, but the proportion of more calcareous beds increases upward. Contacts between the two sorts of bed, although not sharp, are well defined. Burrow markings are present in the less calcareous beds, but they are not conspicuous. At Wawarsing and Trilobite Mountain the member does not show its typical lithology; it is more like the Aquetuck Member. Distinction between the two members there is uncertain.

The contact between the Aquetuck Member and the Saugerties Member is everywhere gradational. In sections around Leeds the gradation takes place over only a foot or two and is accompanied by small quantities of glauconite and quartz grains irregularly distributed throughout the transition beds. The difference in lithology between the two members, together with the relatively rapid gradation between them, makes the contact easy to draw. Between Leeds and Kingston the glauconite and quartz disappears. At Kingston the distinction between the two members (while real) is not as great as to the north. Moreover, the gradation between them is almost imperceptible, so that the contact between them is difficult to place. The contact relations between the Aquetuck and Saugerties are similar to those between the Carlisle Center and Aquetuck in the field trip area, but the evidence suggesting a break in deposition is not as strong.

The contact between the Saugerties Member and the overlying Onondaga limestone is gradational over a thickness of a foot or two everywhere it is exposed from Leeds to Port Jervis. The less calcareous beds in the Saugerties gradually become thinner and less muddy, and disappear upward.

Outlier

About 30 miles southeast of the main Schoharie outcrop belt there is a narrow outlier of Silurian and Devonian rocks extending from Cornwall southward into New Jersey (fig. 1). Rocks of Esopus and Schoharie age are best exposed at Highland Mills, near the northern end.

Boucot (1959) assigned previously unstudied strata everlying the Connelly conglomerate (Oriskany age) and underlying the Kanouse sandstone (pre-Edgecliff Onondaga age) at Highland Mills to the Esopus Formation, and subdivided them into the Highland Mills Member, the middle member, and the Woodbury Creek Member (in ascending order). The Woodbury Creek and Kanouse are described briefly below, and their relation to the Schoharie Formation and Onondaga limestone in the main belt is discussed.

The Woodbury Creek Member consists of indistinctly bedded tan and light gray weathering siltstone which is so deeply weathered that except in the lowest part of the member no fresh surfaces can be found. Strata in the lowest part are slightly finer grained and not as deeply weathered. They are dark gray and slightly calcareous where fresh, and light gray and non-calcareous where weathered. It is suspected (but not known) that the upper part is calcareous where fresh. In an exposure in the northernmost part of the outlier (Cornwall) the entire member is slightly finer grained than at Highland Mills, and the lower calcareous part is thicker. At Highland Mills the member is about 120 feet thick.

Tubular contorted bodies of dark sediment lying in the plane of the bedding and flattened normal to it are a prominent feature of the member, particularly in the lower part. When viewed on surfaces normal to the bedding they appear as strips and lenses. Although they are not so clearly the result of annelid activity as the burrows in the Carlisle Center (p. 11), they seem to be the same sort of feature.

The contact between the Woodbury Creek Member and the underlying middle member is gradational over 2-3 feet. It is marked by an upward change from the abundant Taonurus markings in the middle member to the abundant burrow-like sediment bodies in the Woodbury Creek Member, and an upward change from non-calcareous to calcareous strata.

The Kanouse sandstone consists mostly of indistinctly bedded hard gray medium sandstone composed mostly of quartz; 3- to 12-inch layers of hard gray conglomerate composed of very fine to fine well-rounded quartz pebbles are interbedded with the sandstone in the lower part of the formation. The conglomerate beds have sharp and slightly undulating lower contacts, and they grade upward into sandstone. The Kanouse is less than 5 feet thick at Highland Mills.

The lower contact of the Kanouse is gradational by interbedding. Sandstone beds, showing the same contact relations with the adjacent strata (siltstone) as the conglomerate beds in the Kanouse, appear in the uppermost Woodbury Creek, and upward the grain size of both the coarser beds and the intervening strata increases.

There is an unexposed interval of at least 140 feet between the highest exposed Kanouse and the overlying Cornwall shale (black shale which grades upward into the Bellvale sandstone of Hamilton age).

The unit-by-unit correspondence between the Esopus Formation in the main belt and the strata overlying the Connelly conglomerate and underlying the Woodbury Creek Member in the outlier (a correspondence which exists but is not discussed here) and the similarity of the lower contacts of the Carlisle Center and Woodbury Creek, indicate that the lower part of the Woodbury Creek has the same stratigraphic position as the lower part of the Carlisle Center. This and the lithologic similarity between the lower parts of the two units show that these lower parts are facies equivalents.

Boucot (oral communication, 1961) considers that the Kanouse sandstone and the upper part of the Woodbury Creek Member in the outlier and the sub-Edgecliff strata (zone B of Oliver, 1954) of the Onondaga limestone in western New York are part of the Amphigenia zone. It is not known whether this zone is present in the outcrop belt from Leeds to Port Jervis; if it is, it would comprise the upper part of the Schoharie Formation, as Oliver (this guidebook) considers that the lowest Onondaga in the field trip area is younger than the Amphigenia zone. If there is a hidden break at or near the Schoharie-Onondaga contact, rocks of upper Woodbury Creek and Kanouse age in the main belt might be missing in part or entirely. Apparently quartz silt, sand, and fine gravel were deposited in the outlier region while the main belt region was either receiving predominantly calcareous sediments or was undergoing erosion. The steady upward increase of lime in the Schoharie in the field trip area makes unlikely the possibility that terrigenous sediments similar to the Kanouse were deposited in the main belt region and later eroded. It is not known whether strata similar to the Onondaga overlie the Kanouse in the outlier.

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ROUTE STOPS

Stop #1, Erie Railroad Cuts near Highland Mills

Railroad cuts just north of Pine Hill road, NW ninth of Popolopen Lake 7½' quadrangle, Schunemunk 15' quadrangle.

Although there is a complete section of the Esopus Formation (p. 13) and the Kanouse sandstone exposed on the east side of the New York Thruway one-half mile east of Highland Mills, the stop will be made at the cut on the Erie Railroad a few hundred yards west of the Thruway, because of traffic danger on the Thruway. Here the Highland Mills Member, the middle member, and the lowest 60 feet of the Woodbury Creek Member (p. 14) are exposed. One-half mile north, the upper non-conglomeratic part of the Kanouse sandstone (p. 14) is exposed on a steep slope just east of the railroad.

Stop #2, Leeds Gorge

Gorge of Catskill Creek, just west of Mill Pond in Leeds, SE corner, Leeds 7½' quadrangle, Coxsackie 15' quadrangle.

Onondaga Formation

This is one of the most complete sections of the Onondaga in the trip area. With a steep easterly dip, the lower 115 feet, conformably overlying the Schoharie Formation, are exposed in a fairly short distance in the bed of the creek. Although the formation is well exposed, only a short time will be devoted to the Onondaga at this stop. Facies changes between here and Kingston (stop #4) are minor and the nature of the rocks and the fossils can be observed to better advantage at that place.

The Leeds Gorge section is as follows:

Moorehouse Member (upper part not exposed):

25' + Middle unit; medium-dark-gray, fine-grained limestone with abundant dark-gray chert; corals and bryozoans common, brachiopods and other fossils present.

12' Lower unit; light-medium-gray, medium-grained limestone with no chert; corals common; other fossils present.

Nedrow Member:

4' Light-medium-gray, medium-grained limestone with few chert nodules; platyceratids, corals and brachiopods. This unit is lithologically and faunally transitional to the Moorehouse.

39' Light-medium-gray, medium-coarse and fine-grained limestone with abundant light-medium-gray chert; platyceratids, corals and brachiopods.

Edgecliff Member:

32' Light-medium and light-gray, medium-coarse and coarse limestone with abundant light-medium-gray chert; large crinoid columnals common, corals, and brachiopods.

3' Medium-gray, fine-grained limestone with no chert; fragmental fossils.

Transition to Schoharie Formation:

1½' Alternating limestone and gritty limestone.

Schoharie Formation

The entire Schoharie Formation is excellently exposed at the falls in the gorge of Catskill Creek. The strata are nearly vertical to overturned.

Saugerties Member:

16' Interbedded light-gray weathering limestone and yellowish-brown weathering muddy limestone; proportion of less pure limestone beds decreases upward; purer limestone beds are continuous layers except for a few layers of limestone nodules in lower part; grades up into Onondaga Limestone.

Aquetuck Member:

40' Yellowish-brown weathering dark gray calcareous mudstone, becoming sandy and glauconitic in uppermost 3 feet; interbedded light weathering muddy limestone beds not sharply set off from the mudstone; abundant indistinct layers of dark weathering rock and layers of small chert nodules.

Carlisle Center Member:

13' Yellowish-brown and yellowish-gray weathering dark gray calcareous mudstone with interbedded lighter weathering slightly limier layers; glauconite and quartz sand both in upper part and lower part, but not in middle; "black bed" (p. 11), 3 feet thick, 5 feet from base. Abrupt contact with underlying Esopus Formation.

Stop #3, New York Central Railroad Cut, Kingston

Cut on the N.Y.C. (West Shore) Railroad, just north of West O'Reilly Street, Kingston West 7½' quadrangle, Rosendale 15' quadrangle.

The entire Schoharie Formation is excellently exposed in a small syncline beneath the Edgecliff Member of the Onondaga Limestone.

The section is as follows:

Saugerties Member:

30' Interbedded light-gray weathering limestone and yellowish-brown weathering muddy limestone; prominent banding shown on surfaces of cut; possible to recognize several subunits.

Aquetuck Member:

44' Yellowish-brown and yellowish-gray weathering very calcareous mudstone or very muddy limestone; interbedded layers of light-gray weathering limestone nodules; a few continuous limestone layers; thin inconspicuous dark-weathering layers in the calcareous mudstone.

Carlisle Center Member:

143' Yellowish-brown and yellowish-gray weathering calcareous mudstone; interbedded limier layers, becoming more distinct and more calcareous upward; prominent burrows in upper two-thirds (p.); Taonurus in lower part; "black bed" (p.) 55 feet above base; basal bed of sandy glauconitic calcareous mudstone less cleaved than above, truncates dark gray non-calcareous mudstone of Esopus Formation.

Stop #4, Ulster County Highway Department, Quarry, Kingston

Quarry southwest of Route 209 on west side of Kingston, 0.2 mile WSW of Route 209-28 intersection, Kingston West 7½' quadrangle, Rosendale 15' quadrangle.

This is an excellent exposure of the Nedrow and Moorehouse Members with good (and typical) fossil collecting in both units. The beds are flat lying and fossils are best observed on the extensive flat surfaces in, and at the top of, the quarry.

The section is as follows:

Moorehouse Member (upper part not exposed):

24' Middle unit; lithology as at Leeds; brachiopods, gyroconic cephalopods and small horn corals are common; trilobites and sponges ("Hindia" sp.) are also present.

7' Lower unit; lithology as at Leeds; fossils are common but hard to collect in quarry face.

Nedrow Member (lower part not exposed):

8' Moderately coarse and light-colored limestone with medium-light-gray chert; platyceratid gastropods, brachiopods, bryozoans, corals, "Hindia" sp.

Stop #5, Abandoned Quarry in Wawarsing

Small quarry north of Route 209, 0.5 mile northeast of Vernooy Kill Road, Kerhonkson 7½' quadrangle, Slide Mountain 15' quadrangle.

Between Kingston and Wawarsing the lower part of the Onondaga becomes darker and finer grained. The characteristic Nedrow platyceratids are not present and the member cannot be recognized. The Edgecliff is marked by characteristic large crinoid columnals but is otherwise hard to distinguish from the superjacent Moorehouse Member.

The section is as follows:

Moorehouse Member (upper part not exposed):

29' Medium-dark-gray limestone in beds 2 to 10 inches thick, some shaly beds in upper part; trilobite fragments; 2-inch chert bed at base.

20½' Limestone similar to above; Levenia lenticularis, brachiopod fragments and apparent juveniles are common; trilobite fragments, gyroconic cephalopod, small horn corals.

Edgecliff Member:

13' Medium-gray, medium-fine-grained limestone with scattered chert nodules in the lower-middle part; large crinoid columnals and small horn corals are common; brachiopods and bryozoans are also present.

Transition to Schoharie Formation:

2-3' Brown-weathering silicous limestone forms the lowest beds in the quarry.

Stop #6, Trilobite Mountain

On northwest facing hill between two roads and the Erie R.R. near Port Jervis Golf Club, 1.1 miles northeast of Tristates, Port Jervis South 7½' quadrangle, Port Jervis 15' quadrangle.

Only the lower few feet of the Edgecliff Member are exposed here on the northwest side of the hill, facing the Country Club. The beds are lithologically and faunally similar to the Wawarsing exposures and to the Stroudsburg outcrops farther south. Corals, brachiopods, and the large crinoid columnals are fairly common and make up most of the fauna.

The Schoharie Formation is exposed between the Edgecliff face and the Erie railroad tracks. There are a few large unexposed intervals. Thicknesses, based on dip and slope measurements, are approximate.

8' Unexposed up to the Onondaga Limestone.

Saugerties or Aquetuck Member:

25' Yellowish-gray and yellowish-brown weathering muddy limestone containing vague layers of nodules of purer limestone.

21' Unexposed (concealed by road).

Carlisle Center Member:

12' exposed

25' unexposed

24' exposed

70' unexposed

41' exposed

Olive-gray weathering dark gray calcareous mudstone; interbedded lighter weathering limier layers; a few distinct limestone beds in upper part; traces of burrows (p. 11).

30' Concealed by railroad tracks down to dark gray mudstone of Esopus Formation.

Stop #7, Tristates Point

Delaware River shore near Tristates Point in Laurel Grove Cemetery just west of Tristates, Port Jervis South 7½' quadrangle, Port Jervis 15' quadrangle.

An estimated 25 feet of dark-gray limestone is exposed on the west side of the cemetery. The rock is part of the Moorehouse Member but its exact stratigraphic position is unknown. Corals, small gastropods, and trilobite fragments are fairly common.

ROAD LOG

0.0 Start at Minisink Hotel, Port Jervis. Go north on U.S. Rte. 6 and U.S. Rte 209.

0.1 Turn right, following US 6 and US 209.

0.5 Go straight on US 6 where US 209 goes left.

2.0 Bear left on US 6 at junction with Rte. 23.

16.4 Bear right at fork, off US 6 and onto unmarked short cut.

18.3 Bear right onto old US 6.

18.8 Turn right, back onto US 6 east.

22.1 Onto US 6 and NY 17 east (dual highway).

35.6 Leave dual highway at exit marked "US 6, NY 32" (last exit before Thruway; don't miss it). Turn left (N) at end of ramp, onto US 6 east and NY 32 north.

37.0 Keep straight on NY 32 north (US 6 goes right).

38.2 Turn right onto Park Street, Village of Highland Mills.

38.6 Turn left into parking lot for abandoned Erie RR station.

Stop No. 1 (p. 16): The contacts between the Highland Mills Member, the middle member, and the Woodbury Creek Member are marked with white paint on the railroad cut.
Watch out for trains.

Turn right onto Park Street from RR station parking lot.

39.0 Turn left onto NY 32 south.

41.5 Turn left onto Thruway entrance ramp after crossing bridge over dual highway.

41.7 Thruway toll booth. Take Thruway north "Albany and Buffalo." There will be a short rest stop along the Thruway.

88.9 Leave Thruway at Kingston exit.

89.2 Thruway toll booth.

89.6 Traffic Circle - take Interstate 587 and NY 28 to Kingston.

90.8 Complicated intersection, with traffic lights; take Broadway, roughly straight ahead.

91.5 Turn right on W. O'Reilly Street.

92.0 New York Central RR underpass on W. O'Reilly Street -

Stop No. 3 (p. 17, Stop No. 2, at Leeds, cancelled): cuts on both sides of the track a few hundred feet north along the track. Contacts between members of the Schoharie are marked with white X's on both sides of the track. The top and bottom of the black bed in the Carlisle Center Member are shown by paint marks along the bedding.
LISTEN FOR TRAINS - they come by often.

Continue along W. O'Reilly Street.

92.1 Turn right on Wilbur Avenue (NY 213).

93.0 Straight across at intersection with Greenkill Avenue.

94.5 Turn right on Henry Street (NY 32 and NY 213).

95.0 Turn left (W) onto Broadway.

95.3 Complicated intersection, with traffic lights; follow US 209 south (Albany Avenue).

95.6 Traffic light; bear right on Clinton Avenue (US 209 south).

95.8 Bear left on N. Front Street (US 209 south).

96.1 Turn left onto Washington Avenue (leave US 209).

96.3 Turn right onto Lucas Avenue.

96.5 Turn right into Forsyth Park and Zoo.

Lunch stop. The Ulster County quarry (Stop No. 4) borders Forsyth Park on the north. The Schoharie-Onondaga contact is located along Lucas Ave. near the Park entrance and the outcrops within the Park give a section through the Edgecliff and Nedrow Members.

Leave park, turn left (N) onto Lucas Avenue.

96.7 Turn left onto Washington Avenue.

96.9 Straight through at stop sign (onto US 209 south).

97.0 Turn left on Hurley Avenue (US 209 south).

97.1 Turn left at entrance to Ulster County quarry.

Stop No. 4 (p. 18): The contact between the Nedrow and Moorehouse Members of the Onondaga Limestone is marked with white paint on the quarry wall.

Continue south on US 209.

113 Pass through Village of Accord on US 209.

118 Pass through Village of Kerhonkson on US 209. Main intersection is Times Square, Broadway and 42nd Street.

120.8 Turn right into quarry of Ulster Limestone Corporation (just before reaching Wawarsing on US 209).

Stop No. 5 (p. 19).

Continue south on US 209.

125 Pass through Ellenville on US 209.

151.2 Pass Huguenot Hotel on US 209.

155.2 Enter Port Jervis on US 209.

155.9 Turn left onto US 6 (US 209 goes right).

157.1 Bridge over Neversink River on US 6; turn left onto N. Maple Avenue just past bridge.

157.3 Erie RR underpass.

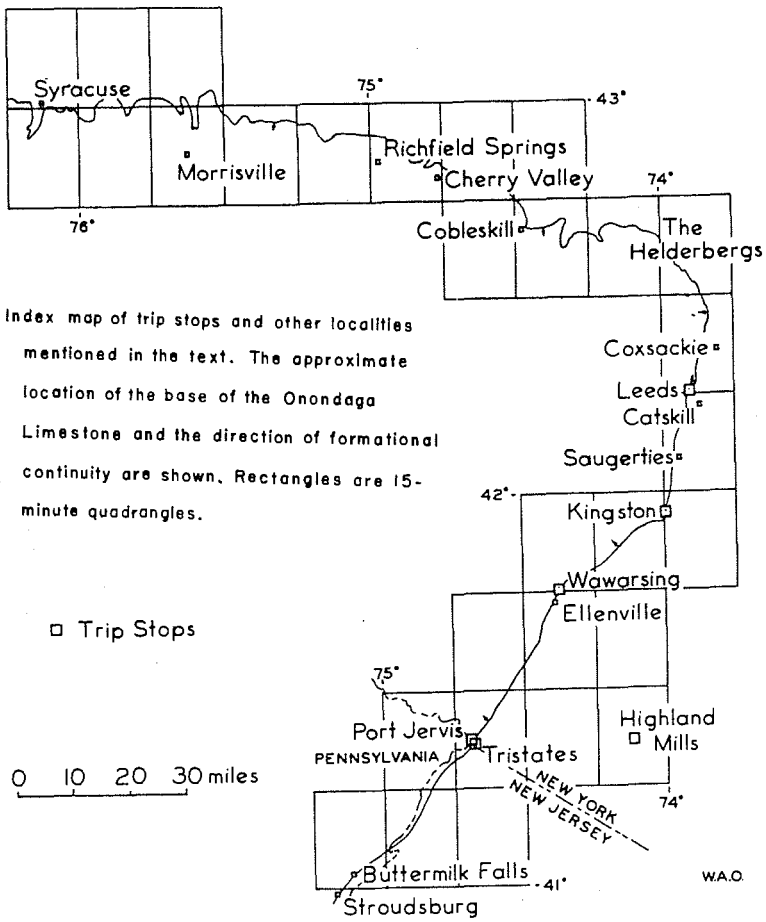
158.3 Stop No. 6 (p. 19): Cuts along both sides of road.

Turn around.

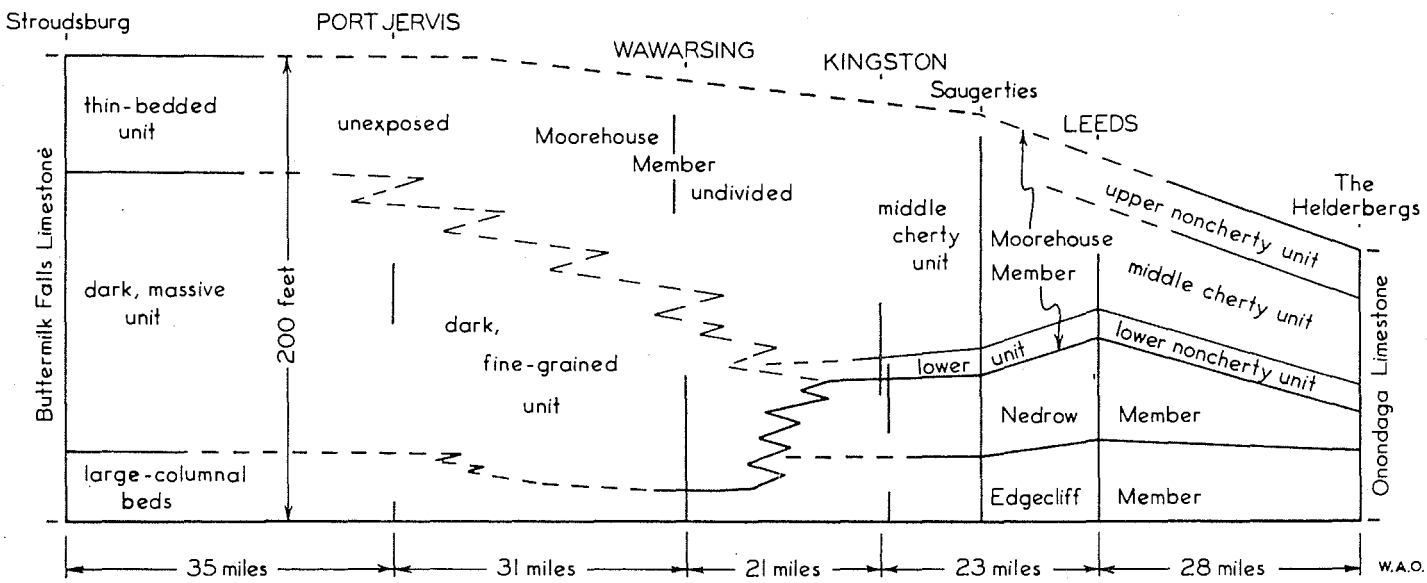
159.5 Turn right onto US 6.

161.1 Turn left, following US 6 and US 209.

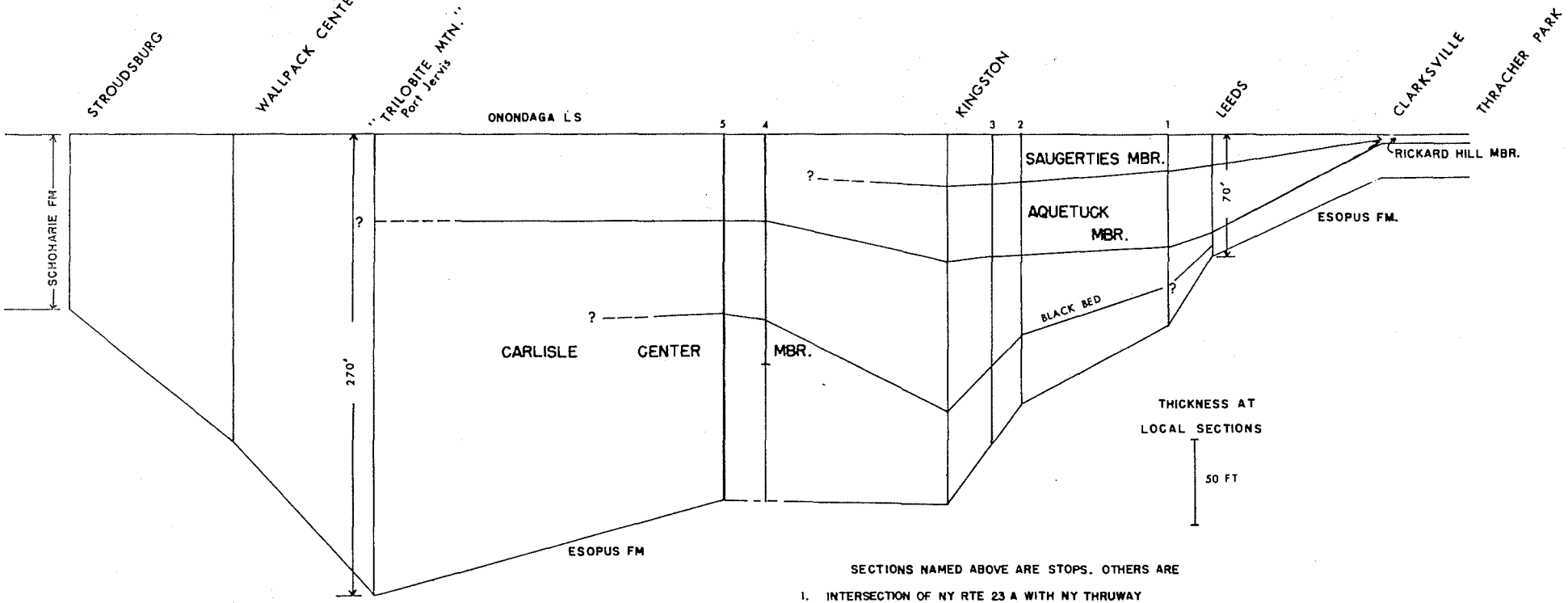
161.2 Minisink Hotel, end of trip.



Index map of trip stops and other localities mentioned in the text. The approximate location of the base of the Onondaga Limestone and the direction of formational continuity are shown. Rectangles are 15-minute quadrangles.



Diagramatic cross section of the Onondaga Limestone between the Helderbergs and Port Jervis, New York. Correlations with the Buttermilk Falls Limestone (Willard, 1939) near Stroudsburg, Pennsylvania are shown.



SECTIONS NAMED ABOVE ARE STOPS. OTHERS ARE

1. INTERSECTION OF NY RTE 23 A WITH NY THRUWAY
2. GLENERIE FALLS ON ESOPUS CREEK, GLENERIE NY
3. APPROACH TO KINGSTON—RHINECLIFF BRIDGE (NY 199), JUST EAST OF US 9W.
4. FALLS OF MILL BROOK, 1 MI. NE OF PATAUKUNK NY
5. WEST OF US RTE 209, 1 MI. NE OF WAWARSING NY

GEOLOGY OF THE PRECAMBRIAN CRYSTALLINE ROCKS, CAMBRO-ORDOVICIAN SEDIMENTS, AND DIKES OF THE SOUTHERN PART OF THE MONROE QUADRANGLE

H. W. Jaffe and E. B. Jaffe

TRIP B

The area covered by this trip lies in the southern part of the Monroe 7 ½' quadrangle, and consists chiefly of Precambrian crystalline rocks of the Hudson Highlands. The crystalline prong is thrust at a high angle to the west over Ordovician and Devonian sediments of the northern extension of the Green Pond syncline. The fault trough is filled with lakes and glacial deposits. To the east, a high-angle fault running roughly parallel to Route 17 and continued through Tuxedo Lake to the south separates the block from the main body of the Ramapo Mountains. A small inlier of Wappinger dolomite, possible downthrown, extends nearly a mile into this fault trough, which also is covered by glacial deposits. The northern end of the block is unconformably overlain by Poughquag quartzite (Lower Cambrian) succeeded by Wappinger dolomite (Cambro-Ordovician), both dipping gently off and roughly parallelling the present outcrop pattern of the crystalline rocks. This may represent original sedimentary onlap with subsequent gentle warping during uplift of the crystalline block. This northern contact of the crystallines, and also some probable fault zones within the crystalline block, are obscured by glacial deposits which form a school of drumlins and drumlinoid hills, trending north to northwest across the regional strike of the crystallines and indicating glacial movement to the southeast. This is further corroborated by the thick glacial deposits on the east side of the northeast-southwest valleys.

Within the crystalline block, strikes and dips of the foliated gneisses indicate a series of folds trending about N 50° E and plunging very gently to the north, with some local warping indicated by south plunges. A generalized cross-section normal to the foliation might show: 1) a steep syncline overturned to the west in the easternmost belt of hornblende granite gneiss; 2) an isoclinally-folded recumbent anticline, possibly thrust to the west, in the belt east of Lake Mombasha; 3) a steep syncline, again overturned to the west, with an axis just west of the west shore of Lake Mombasha; and 4) a steep isoclinal anticline along the last ridge at the west of the block. This generalized picture is very difficult to corroborate in detail because of the complexity of the folding, the large amounts of glacial fill at crucial contacts, and the considerable amounts of faulting.

At least two series of faults may be recognized in addition to the aforementioned border faults to the east and west. The oldest group (not shown on the map), trending roughly N-S at a small angle to the foliation and dipping steeply, can be recognized by the small steep trenches they form, and at times by considerable silicification and skarn formation along their trend. They may have influenced the location of the frequent

small magnetite deposits. This older series is offset by a set of high-angle gravity faults roughly normal to the foliation. Field and petrographic evidence indicates that these may be hinge or pivot faults, with the greatest displacement to the west. Vertical or steeply dipping transverse joints strike northwest, and several of these are filled with melano and leucophyr dikes, which also cut the Poughquag quartzite and Wappinger dolomite. A subordinate set of joints strikes northeast parallel to the gneissic foliation.

A description of the rock types is given in the detailed itinerary which follows. Speaking very broadly, a series of calcareous and siliceous sediments and basic volcanics of the flysch facies were folded in a eugeosyncline and wholly recrystallized with attendant modification by granitic liquids. Were these liquids derived by magmatic fractionation from a basaltic substratum, or by fractional melting of sediments in place, say 10-20 km down? Evidence for temperatures high enough to melt granitic rocks is found throughout the minerals of the crystalline block. For example, microperthites were probably homogeneous at temperatures above 640°C, below which they unmix. Further, the oxygen isotope thermometer gives a temperature range of 320-550°C for staurolite zone minerals and at least a part of this area is in the higher grade sillimanite zone. Almost all of the granitic rocks show concordant relations with the paragneisses. This leaves syntectonic magmatic intrusion or in-place fractional melting as the two most probable means of deriving the granitic rocks and migmatites. In either case, the granitic rocks would have passed through a magmatic stage. The persistence of shredded and partially ingested metasedimentary remnants in most of the granitic-quartz dioritic gneisses of the area would tend to favor an in-place fractional melting hypothesis.

The age of the granitic rocks and associated gneisses is believed to be about 1100 million years, based upon the best evidence from radioactive dating. Pb/U isotope ages on zircon from the Storm King granite are essentially concordant at 1100 M.Y. Discordant Pb/U ages on uraninite and monazite in the Highlands, A/K ages on mica, and Pb/α ages on zircon range from 620-900 M.Y. A recent Pb/α age of 770 M.Y. was obtained on zircon from granite interlayered with amphibolite near the Suffern entrance to the N.Y. Thruway. All of the ages below 1100 M.Y. do not necessarily date a true recrystallization. For example, a metamorphism 300 M.Y. ago might cause 1100 M.Y. old zircon to lose enough of its lead to give an age of about 770 M.Y. The absence of any ages of 200 to 400 M.Y. on minerals from the Highlands, however, indicates that the Precambrian rocks were not completely recrystallized during the Acadian or Appalachian orogenies.

A detailed itinerary of the trip stops follows:

Detailed Itinerary

Starting point:

A. & P. Supermarket parking lot on N.Y. Route 17M. 0.8 miles south on Rt. 17M to the second traffic light; turn right at light on to Stage Road which becomes the Orange Turnpike. At 2.0 miles observe gently dipping Wappinger dolomite outcropping in field on west side of Orange Turnpike, and large drumlin directly ahead to the southeast.

Stop 1:

2.2 miles. Walk 0.16 miles due west over hilltop to edge of cliff formed by 10' section of Poughquag formation (Lower Cambrian). The section consists of alternating 2" to 2' thick beds of ferruginous quartzite, conglomerate, and arkose, striking N 50°W and dipping 8°NE. Return to top of ridge and note 5½' basic dike intrusive into Poughquag quartzite. Continuing east along hilltop note small outcrops of Poughquag quartzite and Wappinger dolomite on each side of concealed contact. Continuing east, stop at 10' thick basic dike on northeast edge of hill. The dike strikes N 18°W and is essentially vertical; it shows flow layering parallel to the strike, and chilled borders. The modal composition of this dike is:

	1	2
albite	23.6%	26.7%
dark red-brown alkalic hornblende	46.5	37.0
augite-pigeonite	6.0	13.1
epidote	7.9	5.2
chlorite	8.4	9.0
apatite	1.8	1.6
opaques	4.9	5.4
biotite	0.2	1.6
garnet	0.2	0.4
prehnite	0.2	---
calcite	0.3	---
	100.0%	100.0%

(calculated SiO_2 content: 44-46%)

The texture is seriate-porphyritic with hornblende and augite forming the phenocrysts, which lie in a groundmass of albite laths.

This rock is a melanophyr, here defined as a dark, dense, fine-grained, porphyritic dike in which only the mafic minerals form phenocrysts. The abundance of the alkali-rich red-brown hornblende and the low calculated silica content indicate that this dike is compositionally related to the undersaturated alkalic rocks (camptonite lamprophyre of Johanssen). It is not a diabase or a "basaltic dike" but a true alkalic rock. This dike and two others in the area intrude the Wappinger dolomite and are here considered to be of post-Ordovician age. Similar dikes are found in the

Adirondacks in close association with true diabases and in the Champlain Valley without the accompanying diabases. The Champlain Valley dikes are clearly post-Ordovician with the upper age-limit unknown. The melanophyr dikes in the southern and central part of the Monroe quadrangle are numerous; they intrude the crystalline rocks and Cambro-Ordovician Poughquag-Wappinger series; but none have yet been found cutting the immediately adjoining thick section of Devonian sediments in the same small quadrangle. This would suggest that the dikes are older than the Triassic diabase sequence. Further evidence suggesting a pre-Triassic age is the presence of garnet and abundant epidote presumably formed during a pre-Triassic orogeny. Inasmuch as albite should not be expected in a rock containing 75% of mafic minerals, the epidote may be assumed to have unmixed from an originally more calcic plagioclase during a regional metamorphism. In thin-section most of the epidote is included in the albite laths.

Return east to the road and observe outcrop of blue-gray Poughquag arkose or feldspathic quartzite. This rock consists of 1-3 mm subrounded strained detrital quartz, microcline-microperthite, and minor oligoclase in a finer-grained quartzo-feldspathic-clay-sericite-"limonite" matrix. The principal cement is authigenic quartz overgrown in optical continuity on detrital quartz. The absence of rock fragments and the low interstitial paste content indicates that the rock is not a graywacke. Minor amounts of zircon, sphene, brown tourmaline, anatase, and opaques are present. The abundance of microcline microperthite and quartz suggests that the rock was derived from the adjoining Precambrian granitic gneisses.

Stop 2:

2.6 miles. Leaving Stop 1, the Orange Turnpike turns southwest and crosses the concealed unconformable Cambrian-Precambrian contact. Beyond the Lipalian interval, the first Precambrian rock encountered is a fine-grained pink alaskite with no more than 1% of dark minerals. It is composed mainly of 1-3 mm microcline microperthite, microcline, and quartz, with much less sericitized albite-oligoclase and an occasional flake of biotite or chlorite. Within 100' to the south, the pink alaskite grades through a narrow zone of coarse biotite microperthite oligoclase granite and granodiorite into a medium-grained, gray, essentially massive quartz diorite gneiss which forms the bulk of the southern outcrop at this stop. The quartz diorite gneiss (quartz oligoclase gneiss of other workers) consists of oligoclase antiperthite about 70%, quartz about 25% and hypersthene, biotite, magnetite, chlorite about 5%. In thin-section, quartz is not uniformly distributed and forms long tongues which embay adjoining oligoclase grains. Oligoclase is well-twinned and antiperthitic. On top of the outcrop, observe several tongues of biotite hornblende hypersthene labradorite (An_{55}) pyribolite infolded in the quartz diorite gneiss. Foliation measured on the pyribolite is N 35°-50°E, dip is essentially vertical. Slickensided joint faces strike N 24°W and N 65°W.

About 0.3 miles south (not a scheduled stop) the quartz diorite gneiss darkens in color, the quartz content drops and the rock grades to an augite diorite gneiss with abundant interlayered hornblende hypersthene

oligoclase-andesine pyribolite. Where quartz becomes locally abundant, it embays and replaces both plagioclase and the ferromagnesian minerals.

The quartz diorite gneiss is thus formed from the reconstitution of pyribolite accompanied by the introduction of silica and small amounts of potash. These constituents could logically be derived from granitic liquids formed from the fractional melting of sediments.

Stop 3:

3.6 miles. Turn east on Harriman Heights Road. A fresh road-cut exposes a dark gray and pink banded migmatite. The gray rock is a calcarious siliceous paragneiss composed of quartz, microcline, bytownite (An_{80}, n_α 1.575), augite, epidote, dark brown sphene, zircon, apatite, and magnetite. The pink bands consist mainly of quartz and microcline or microcline microperthite. Other samples of this migmatite carry anorthite with An_{95} ($n_\alpha = 1.574$, $n_\beta = 1.581$, n_γ 1.585, $2V \sim 75^\circ$, opt. -). This migmatite carries abundant epidote produced by a retrograde metamorphic alteration of anorthite and augite.

Stop 4:

5.1 miles. Return west to Orange Turnpike and turn south, parking at Monroe Town Line sign. The prominent road-cut on the east side of the road is gray and pink banded biotite migmatite. The dark gray rock is a siliceous, calcareous paragneiss composed of quartz, labradorite (An_{50}), biotite, microcline, hornblende, epidote, apatite, zircon, augite, and ilmenite. The pink bands consist wholly of quartz and microcline, the latter occasionally microperthitic. These kalialaskite bands are believed to be formed from low-temperature metasomatic introduction of quartz and microcline. In-place melting would require an appreciable amount of albite, which is not present. As the microcline is only occasionally microperthitic, it is doubtful that it could hold much soda in solid solution. The foliation strikes N 24°E and dips 45°SE; fold axes plunge gently NE.

The outcrop on the west side of the road, just south of the Town Line, is the same rock. Here the foliation strikes N 22 E, dips only 12°SE and fold axes plunge 5°NE. The gentle dip is due to isoclinal folding overturned to the west.

Stop 5:

5.5 miles. Continue south on Orange Turnpike to top of hill with prominent overhanging cliff to the east side of the road. The cliff is made up of a silicified epidotized migmatite with some coarse recrystallized hornblendes in the granitic component. The outcrop is strongly warped, part of it showing recumbent isoclinal folding overturned west, part of it showing fairly steep dips east. The undersides of overhanging bedding planes are commonly slickensided and silicified. Both this outcrop and the one immediately preceding it suggest an old period of thrusting to the west.

Stop 6:

6.9 miles. Continue south to the junction with the second of two roads entering from the west. Outcrop on the west side of the road shows a 20-25' hornblende albite melanophyr (spessartite) dike which strikes N 38°W, dips 86°NE, and cuts across the foliation of the granite gneiss which strikes N 55-75°E and dips 80°SE. The dike shows normal green hornblende phenocrysts up to $\frac{1}{4}$" lying in a matrix of albite laths, 0.2 x 0.4 mm. The modal composition of the dike is:

albite	53.3%
hornblende	21.5
epidote	12.6
chlorite	7.3
apatite	0.1
opaque	3.2
quartz	1.2
calcite	0.4
K-spar	0.4
	100.0%

(calculated SiO_2 content = 53.5%)

The granite gneiss contains occasional schlieren of biotite-rich gneiss.

Lunch:

Proceed south $\frac{1}{2}$ mile to N.Y. 17, turn right, and continue another $\frac{1}{2}$ mile south on 17 to Red Apple Rest on east side of road. Lunch and return by the same route to stop 6. At 8.7 miles, note swamp in major cross-fault.

Stop 7:

8.7 miles (lunch mileage not included). Turn west at second road beyond stop 6 (Bramertown Road - note sign to Lake Mombasha Farms), and turn right on first dirt road (East Mombasha Road) heading north. The road parallels the contact of granite gneiss (east) and pyribolite (west). At 8.4 miles the road crosses this contact. Stop 7 shows a 16' thick granodiorite leucophyr dike which strikes N 48°W, cross-cutting the foliation of the surrounding amphibolite which strikes N 57°E and dips 20°SE. Note large wedge of amphibolite in center of dike and occasional pink potash-feldspar-quartz bands in the amphibolite. This dike is unique in this quadrangle and perhaps in the Highlands. It is composed of sparse phenocrysts of oligoclase, quartz, less microcline, and rare biotite, lying in a matrix which is again porphyritic on a microscopic scale. The second generation of micro-phenocrysts is made up of square to rhombic zoned potash feldspar and laths of albite-oligoclase. These lie in a very fine granophyric groundmass made up of feldspar, quartz, mica, chlorite, and "limonite." The "limonite" forms megascopic crenulated black streaks which give the dike a flow layering in places. A mode was not obtained

because of the fine-grained nature of the groundmass. X-ray data on a powdered sample indicate that oligoclase > quartz > microcline, hence the dike is of granodioritic composition. East of the road the dike is not found, and may be cut off by a north-south fault; if this is so the dike is very old. An outcrop of the same type of rock was found 0.25 miles to the west cutting migmatite: this may be an extension of the same dike.

Stop 8:

9.3 miles. Continue north on East Mombasha Road stopping at steep cliff on east side of road. This is a fine-banded dark gray and pink biotite migmatitic paragneiss, the fine-bedded analogue of stop 4. The dark gneiss bands here are more altered and are marked by the appearance of muscovite and epidote replacing biotite and plagioclase. A small amount of rutile is formed from the titahium present in biotite. Occasional large pods of pink alaskite are concordantly interleaved in the migmatite. The foliation strikes N 37°E and dips 20°SE.

Stop 8A:

9.7 miles. Continue north on East Mombasha Road stopping at the sillimanite-bearing outcrop just north of number 8A on the map. This is a tightly folded, crenulated biotitic paragneiss in the sillimanite zone of metamorphism. It is composed of thin bands of a gray biotite microcline labradorite quartz paragneiss interlayered with orthoclase cryptoperthite (anorthoclase) quartz bands. Abundant garnet (almandite-pyrope), dark blue-green tourmaline, and minor prismatic sillimanite are developed at the interfaces of the biotitic and alaskitic layers. The biotite is pleochroic from "paprika-red" to almost colorless and is an iron-rich variety. Sillimanite and tourmaline lie in the foliation planes with their long axes parallel to the fold axes. The fine paragneiss bands have an average grain size of 0.3 mm; the coarse alaskitic bands, up to 10 mm.

Stop 9:

10.2 miles. Continue north on East Mombasha Road to sharp bend north after short jog east. Outcrop on east side of road contains abundant garnet in biotite migmatitic paragneiss. Outcrop to the west in an open field, near swamp, shows a biotite migmatitic paragneiss and pyribolite intimately folded in medium to coarse massive alaskite. The alaskite forms the core of a fold plunging north and the outcrop may be a small anticline overturned to the west. Here chloritized amphibolite pods are completely enclosed in alaskite. A thin section of the dark gneissic rock showed completely fresh hypersthene: (normally an unstable mineral) and biotite associated with completely scapolitized plagioclase, and quartz. Garnet occurs sparingly. To the west the rocks grade rapidly to almost pure alaskite. This is the northernmost outcrop of garnet migmatite.

Stop 10:

10.9 miles. Continue northeast on East Mombasha Road to bottom of hill at rough track to the west. On the east side of the road is an out-

crop of coarse, gneissic, partly recrystallized amphibolite. It contains plagioclase ranging from andesine to bytownite with abundant hypersthene, brown and green hornblende, and less biotite, the composition varying with layering. To the east in the woods (not visited) the plagioclase is all scapolitized, the hypersthene serpentinized, and a pale blue-green hastingsite or edenite amphibole is developed near the contact with the alaskite of stop 2. On the west side of the road, about 60' in the woods, a thin layer of foliated green hypersthene quartz oligoclase gneiss (quartz diorite gneiss) is in sharp contact with fine-grained pink alaskite. This may be a fault contact. Boulders of Poughquag conglomerate, and a melanophyr dike (camptonite), parallel the contact zone.

Stop 11:

13.7 miles. Continue NE to Orange Turnpike, then NW past stop 1 to Rye Hill Road. Turn sharply SW, noting NW-trending drumlins to the west. Stop 11 is the first outcrop beyond the glacial fill on the east side of the road, which now is called Berry Road. The outcrop contains abundant layers and schlieren of biotite two-feldspar quartz paragneiss in coarse pink granodiorite and granite with abundant antiperthite, microperthite, and oligoclase. A swarm of eight or ten small melanophyr (camptonite) dikes, up to 2' thick, fill a tension fracture pattern striking N 8 W to N 48°W. The foliation of the host granitic rock strikes N 52°E, and dips 50-60°SE. To the west, in the woods, the biotitic paragneiss is resorbed by massive biotite granite-granodiorite. Occasional samples are of quartz syenite composition.

It is worth noting here that melting of biotite would yield an additional large amount of potash feldspar and magnetite:

$$KFe_3AlSi_3O_{10}(OH)_2 \longrightarrow KAlSi_3O_8 + Fe_3O_4$$

biotite ⟶ K-feldspar + magnetite

This would sweeten the granitic liquid and perhaps explain the frequent occurrence of potash-feldspar pegmatites in association with the many small magnetite deposits of the area. It should further be noted that many of the alaskites in the quadrangle contain magnetite as the only accessory mineral of consequence.

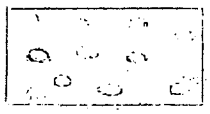
Stop 12:

15.9 miles. Continue SW on Berry Road, noting alternation of folded dark gneiss and pink granite-granodiorite; turn NW on West Mombasha Road, then NE on Cedar Cliff Road to stop 12, about 200' beyond farmhouse. Outcrop on east side of road shows fine-grained narrow bands of folded pyribolite (here amphibolite) overturned slightly to the west and being replaced by coarse massive buff-gray granodiorite. The granodiorite cuts across the folded amphibolite and contains schlieren of the latter which retain their original attitude in the folds. The infolded amphibolite contains brown hornblende, albite-oligoclase, microperthite (introduced),

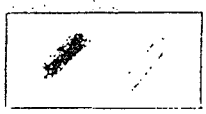
biotite, magnetite, and apatite. The granodiorite is composed of albite-oligoclase, quartz, less microcline microperthite, biotite, hornblende, zircon, and some fragments of altered hornblende, plagioclase, and calcite.

Pyribolite layers are very abundant in this zone but are not continuous, the widest observed being 80' thick near the old magnetite mine on Mine Road. Westward the rocks grade to contaminated gneisses and then alaskite, which forms the western edge of the crystalline block.

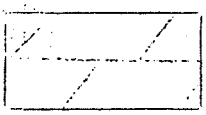
Continue north along Cedar Cliff Road to Lakes Road. Turn right, and follow Lakes Road to traffic light at Route 17M. Final mileage 18.1.



Quaternary alluvium and glacial deposits



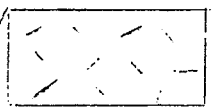
Melanophyr and leucophyr dikes: Post-Ordovician



Wappinger dolomite: Cambro-Ordovician

Poughquag quartzite, arkose, and conglomerate:
Lower Cambrian

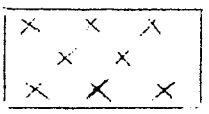
PRECAMBRIAN



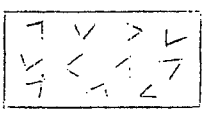
Alaskite (Magnetite biotite albite-oligoclase microperthite quartz)

Andesine alaskitic gneiss
(Garnet magnetite oligoclase-andesine microperthite quartz gneiss)

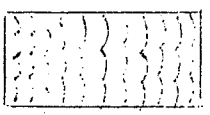
Hornblende granite gneiss
(Biotite hornblende albite-oligoclase microcline microperthite quartz gneiss)



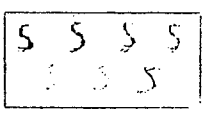
Biotite granite-granodiorite-quartz syenite with abundant schlieren of biotite two feldspar quartz paragneiss.



Quartz diorite gneiss
(Biotite hypersthene quartz oligoclase-antiperthite gneiss with paragneiss and pyribolite schlieren and inclusions)



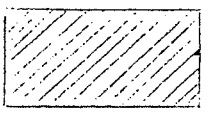
Garnet migmatite
(Granite interleaved with crenulated biotite paragneiss)



Biotite migmatite
(Epidote hornblende biotite andesine-labradorite quartz paragneiss/microcline quartz

Pyroxene migmatite
(Epidote sphene pyroxene bytownite-anorthite quartz paragneiss/microcline-quartz)

Granite and granodiorite gneiss with abundant schlieren and inclusions of pyribolite



Pyribolite (metavolcanic or paragneiss)

SOUTH PART OF GEOLOGIC MAP OF AND CRYSTALLINE ROCKS IN SEDIMENTS QUAD. MONROE 7½' QUAD.

H.W. & E.B. JAFFE
MAY, 1962

Quadrangle Location
N.Y.

SCALE
1 mile

True North
Magnetic N.
12°

74°-10'
74°-12'-30"
41°-15'
74°-15'

UNMAPPED CRYSTALLINES
BOUNDARY OF
N.Y. 17
N.Y. 17M
Harriman
Harriman Hts. Rd.
Orange Tpk.
Lake
East Mombasha Rd.
Mombasha L.
Rye Hill Rd.
N.Y. 208
Monroe
Lakes Rd.
Cedar Cliff Rd.
Round L.
West Mombasha Rd.
Walton L.
School Rd.
Greenwood Lake Rd.
Quad.
Warwick Quad.
Monroe
Sloatsburg
Quad.
Quaternary
Sloatsburg fault

Garnet isograd
Intermediate
Sillimanite
Trip stop

THE STRUCTURE AND STRATIGRAPHY OF

THE PORT JERVIS SOUTH-OTISVILLE QUADRANGLES

co-authors

Sidney Fink, Dept. of Geology, Brooklyn College
C. J. Schuberth, The American Museum of Natural History

TRIP C

INTRODUCTION

The area of this field trip, Port Jervis South-Otisville Quadrangles, (Fig. 1) includes parts of the Folded Appalachian Mountain, Great Valley and the Appalachian Plateau geomorphic provinces. The Paleozoic formations, deposited originally as horizontal sediments in an extensive geosyncline, have in this area an aggregate thickness in excess of 5,000' and consist of the following units, in ascending order: Martinsburg Graywacke Shale and Sandstone (Middle (?) and Upper Ordovician), Shawangunk Conglomerate (Lower to Middle Silurian), High Falls Red Beds (Middle to Upper Silurian), Poxono Island Shale, Bossardville Limestone and Keyser Group (Upper Silurian), Helderberg and Oriskany Groups, Esopus Shale and Ondondaga Limestone (Lower Devonian), and the Hamilton Group (Middle Devonian). Quaternary glacial drift and till occurs throughout the area (Pl. 1).

There is evidence for at least three periods of tectonic activity. The Late Ordovician Taconic Orogeny affected the Martinsburg Shales and Sandstones and older sediments prior to the deposition of the basal Silurian conglomerate. At the close of the Early Devonian Epoch, a second orogenic movement culminated in the Acadian Mountains. The final period of tectonic activity, terminating the Paleozoic Geosyncline formed the Appalachian Mountains during the Permian, with Kittatiny (Shawangunk) Mountain the easternmost ridge of this extensive range. Thrust faults, cross faults and tight folds (gentler towards the northwest) attest to the severity of this last orogenic movement. Folded synclinal structures, thrust towards the northwest, ruptured along cross faults. The oversteepened and overturned western limb of an anticline demonstrates the severity of the dragging along the eastward dipping major thrust fault plane.

The complicated folded and faulted structures found in the Port Jervis Quadrangle die out as they are traced northeast towards Otisville. In this area a monoclinal structure characterizes the northeast continuation of Kittatiny Mountain. The regional strike is N30-35°E with dips of 40°NW decreasing as the beds are traced westward. The western limit of Appalachian folding is marked by a steep east facing escarpment, The Alleghany Front. The Alleghany Front separates the Ridge and Valley province from the Appalachian Plateau province.

Sculpture of the area into its present topography is the result of post-Paleozoic erosion. The area was glaciated during the Pleistocene. The affects of glaciation are seen in the till covered valleys and the disturbed drainage pattern in the area. Glacial movement was toward the west and southwest.

Although the site of several lead-zinc mining ventures in the 1880's and 1890's, present day activity is limited to sand and gravel quarries in the Neversink Valley.

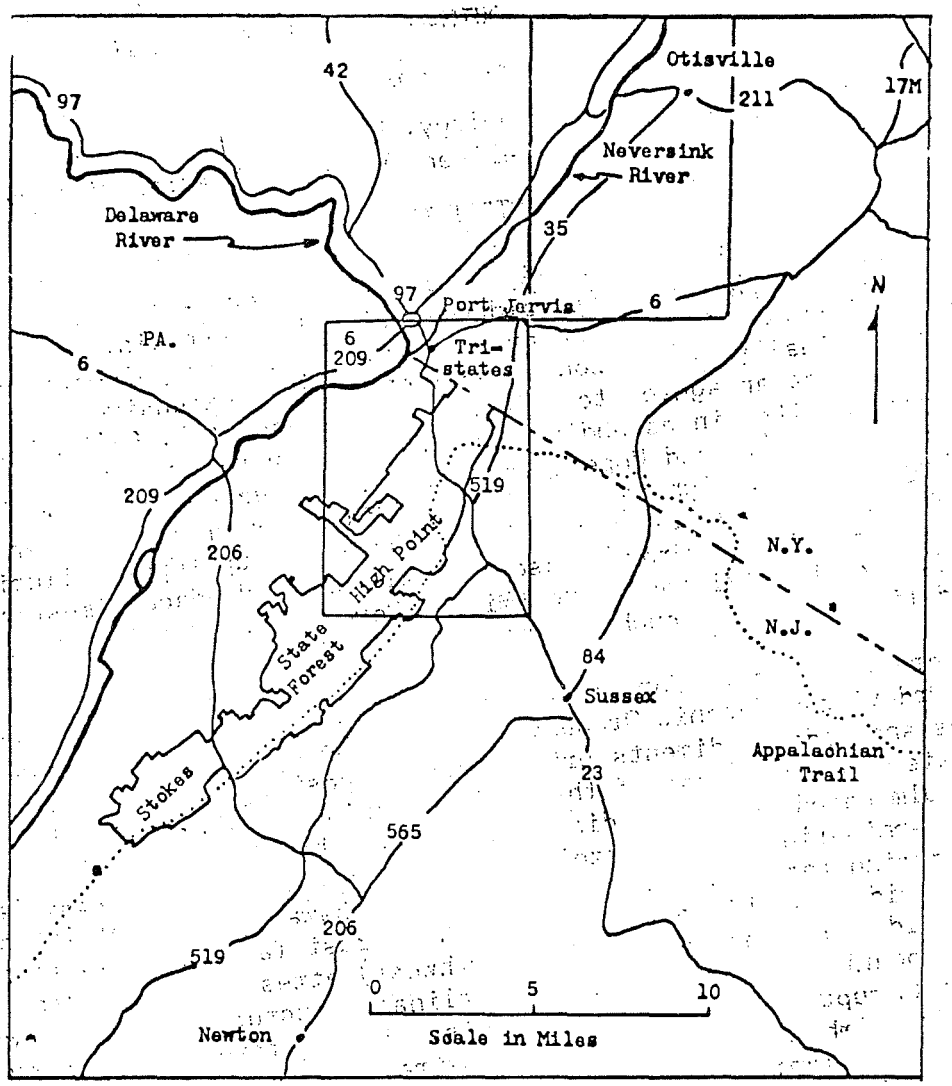


FIG. 1 INDEX MAP SHOWING THE LOCATION OF THE PORT JERVIS SOUTH AND OTISVILLE 7 1/2' QUADRANGLES

Structure of Kittatinny Mountain

Kittatinny (Shawangunk) Mountain, occupying the greatest portion of this area, is one of the major ridges of the Folded Appalachian Mountain chain. This ridge, supported by the extremely resistant basal Silurian conglomerate and quartz sandstone, is frequently illustrated in cross section as a monocline, dipping approximately 30° to the northwest (Fink, 1959, M.S. thesis, New York University, page 27). Younger belts of weaker and more resistant rocks form valleys and topographically lower ridges than Kittatinny Mountain to the northwest. Its monoclinal nature is nicely expressed at the northeastern limit and the southwestern limit of the Port Jervis quadrangle. Between these two limits, the structure of Kittatinny Mountain becomes noticeably complex.

Lake Rutherford lies in a syncline (called the Lake Rutherford syncline for simplicity) formed in the Shawangunk Conglomerate. The western limb of this syncline forms a formidable ridge of considerable topographic height. This ridge may also be considered the eastern limb of the anticline, whose western limb forms a second pronounced ridge slightly to the west (Pl. 2). This western limb of the anticline marks the upper portion of the lithologically fairly uniform Shawangunk Conglomerate. High Falls outcrops are encountered several hundred feet down-dip (west) of this ridge. The anticline is partially breached and extending parallel the length of its valley, is a thrust fault dipping steeply eastward. Surface indications of this major fault are scarce. Aerial photographs do not show conclusively a fault parallel to the axial plane of this partially breach anticline. However, the western limb of the anticline is considerably oversteepened, with dips ranging from vertical to 75° NW to 75° SE (overturned) along the strike. A 500 foot water well drilled by the American Telephone and Telegraph Company about 530' S 20°W of BM 1513 encountered a considerable fault zone within the Martinsburg Shale at a depth of 412 feet. At the same locality, the face of a steep outcrop of the Shawangunk Conglomerate had been extensively slickensided with the western limb having moved down with respect to the eastern limb of this partially breached anticline. A second well drilled to a total depth of 500 feet approximately fifty feet east of the first well location, did not encounter this fault zone. Apparently, the fault plane is steep, having a dip of approximately 80° to the east.

The Lake Rutherford syncline plunges to the southwest, with the nose of the structure about 1 mile north of Lake Rutherford. High Falls Sandstone is nestled in the trough of this structure as far south as the vicinity of the east-west road (southern portion of quadrangle), for only northwesterly dipping outcrops of conglomerate occur south of that area. On this basis, it is assumed that the Lake Rutherford syncline is actually doubly plunging.

Immediately north of the synclinal nose a spur of the Martinsburg Shale extends as an outcrop belt northwestward as far as the oversteepened western limb of the anticline. (This limb continues northeastward where it dips become gentler, averaging 20-30° northwest.) These shales then trend north as far as Lake Marcia and outcrop as a considerably thinner belt. Where meagre outcrops of shale occur in this belt, no bedding planes

are evident; the shales being highly cleaved. The fine, chip-like fragments, a type of mylonite within this zone, indicates that possibly the thrust fault passes through this area. With the thrust fault plane passing near the crest of this anticline and the concentration of tension joints due to the stretching of the conglomerate near the crest of this structure, weathering and erosion succeeded in partially breaching this anticline and exposing the older Martinsburg Shale as this north trending spur (Pl. 3).

A tightly folded, doubly plunging syncline rises as a high ridge east of Lake Marcia. The highest topographic elevations in the State of New Jersey occur along the steeply eastward dipping west limb of this syncline. The southwestern nose extends to the northwest trending belt of Martinsburg Shale, where it terminates with a precipitous drop of 100 feet or more, the base of the cliff supported by Martinsburg Shale.

Both synclinal structures, having an undulatory axis, are thus doubly plunging. The northeastern, tightly folded syncline, must have once been continuous with the Lake Rutherford syncline. Apparently, movement along a cross-fault permitted the northeastern syncline to be thrust as a complete unit (nose and all) farther towards the northwest, with the differential movement resulting in the much tighter folding. Considerable erosion along the cross-fault exposed subsequently the older northwest trending belt of Martinsburg Shale.

The northeastern nose ($\frac{1}{2}$ mile northeast of Cedar Swamp) of this tightly folded structure shows evidence of additional cross-faulting. The deformation was of such a nature that the northwest-southeast strike of the gently southwest dipping beds of the nose butt up directly against the southeast dipping beds of conglomerate from the western limb of the syncline. Apparently, this second cross-fault did not allow the comparatively incompetent conglomerate to adjust completely to the distorting forces, and the nose of this structure ruptured horizontally along this northwest-southeast trending fault. A portion of the nose then was thrust against the eastern limb of the anticline, with the remaining portion apparently faulted out altogether along the major thrust. These cross-faults do not extend any considerable distance to the northwest or southeast. Even though they are comparatively local in extent they contribute materially to the over-all deformation picture of this area. The gap between Trilobite and Wallpack Ridge may be the result of a third cross-fault in this area.

From the Camp Minisink Lakes (immediately northeast of Cedar Swamp) northeastward, the conglomerate dips consistently with angles up to 30° towards the northwest.

The entire down dip slope of Kittatinny Mountain is covered with glacial drift. Outcrops are scarce and consist almost entirely of High Falls. This formation flairs out considerably to the southwest, thinning toward the northeast. The thinner outcrop belt may be the result of steeper dips due to greater compressional forces in the northeast. The wider outcrop belt of High Falls to the southwest might be the result of shallower dips; the compressional forces being of lower magnitude.

Wallpack and Trilobite Ridges

Along the northwestern foothills of Kittatinny Mountain, the writer undertook geologic field work on a reconnaissance basis. Trilobite Mountain (northeast of Tristates) is underlain by the same Lower Devonian formations as is Wallpack Ridge to the southwest. The formations, however, at Trilobite Mountain are thinner in outcrop; the result of steeper dips due to differentially greater compressional forces in this sector of the quadrangle. A thrust fault has faulted out the Lower Devonian limestones to a great extent, leaving the Esopus Shale and some Oriskany Limestones as the only formations at Tristates, New York. The same situation exists at Duttonville, New Jersey, where the northeastern limit of Wallpack Ridge consists of Esopus Shale, the other Lower Devonian formations having been faulted along the thrust fault.

Pocono Plateau

During the brief time spent in this geomorphic province, the writer established gentle westerly dips (10-15°) for the Middle Devonian sandstones and shales. The area is essentially a gently westerly dipping plateau that is in the mature stage in the cycle of erosion.

CONCLUSION

At Port Jervis, New York, the diverse lithologies and structures attent to the pronounced changes the tectonic framework of sedimentation underwent during the Paleozoic Era. The coarser clastics (Shawangunk Conglomerate and Hamilton Group) deposited in the extensive geosyncline, were derived from rapidly rising source areas during the close of the Late Ordovician and Early Devonian Periods. Folded and faulted structures along Kittatinny Mountain are reflections of the Late Paleozoic orogenic movements that elevated the thick accumulation of sedimentary rocks in the geosyncline to form ultimately the Folded Appalachian Mountains.

Doubly plunging anticlinal and synclinal structures of the conglomerate are ruptured along cross-faults and thrust faults. The northern portion of a once continuous syncline was thrust several hundred feet more towards the northwest than its southern counterpart, with dragging along the thrust fault plane resulting in oversteepened dips along the western limb. Today, the highest elevation in New Jersey has been established along this limb. A second thrust fault in the Lower Devonian rocks along the eastern foothills of Wallpack - Trilobite Mountain thrust out several of the limestone formations.

The topographic expressions as seen today are the result of epeirogenic movements since Cretaceous time. Differential erosion along the belts of weaker and stronger rock has developed the present ridge and valley topography while continental glaciation, spreading a veneer of ground morainal deposits over this entire region during Pleistocene time, developed the gently rolling landscape seen in the Great Valley today.

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ROUTE STOPS

Mileage	
0.0	Hotel Minisink in Port Jervis - straight (NE) on Pike St.
0.1	Right (SE) on E. Main St. at traffic light.
0.4	Left (NE) on U.S. 209 at traffic light.
1.1	Roadcut through kame (at sharp turn).
2.0	Outcrop of Esopus Formation (along right side of road); well-developed southeast slaty cleavage.
2.3	Travelling along base of Appalachian Front on left (NW). The lowland is underlain by the Onondaga Limestone, which is hidden by a cover of till.
3.5	Helderberg Ridge (lower Devonian) on right (SE); dip-slope of Kittatinny (Shawangunk) Mountain farther east.
6.0	Marcellus Shale dipping gently NW (into Appalachian Front) at left (NW). Overlying these black fossiliferous shales are the olive-gray graywacke shales and sandstones of the Hamilton group. These represent the sediments derived from source areas to the east at the onset of the Acadian Orogeny.

Mileage

7.6-8.2 Unsorted and unstratified glacial till.

8.5 Cross over Neversink River

9.2 Right (E) on U.S. 211.

9.2-9.7 Crossing (E) Neversink Valley covered with glacial till

9.8 Entering Helderberg Ridge.

10.1-10.3 STOP 1: Esopus Formation.

The rocks exposed along the road are the black shales of the Esopus Formation. This formation is characterized by its well-developed southeast dipping slaty cleavage. The normal northwest dip of these lower Devonian beds is obscured due to the cleavage. The Esopus is the most important formation in the ridge west of Shawangunk Mountain (Pl. 5, Fig. 1). At the crest of this ridge is the Glenerie Cherty Limestone. The Glenerie is a limestone facie of the Oriskany Sandstone. In the valley between this ridge and Shawangunk Mountain to the east is found the limestones of the Helderberg Group (Pl. 5, Fig. 2).

11.4 Cross over Erie Railroad tracks via bridge.

12.2 STOP 2: Unconformable contact between Martinsburg Shale and Shawangunk Conglomerate (walk approx. 300 feet east along railroad tracks).

In this railroad cut is exposed an angular unconformity between the Martinsburg and Shawangunk Formations. The Martinsburg dips 37°NW and the overlying Shawangunk dips 28°NW. The Martinsburg is made of interbedded graywacke shales and sandstones. The Shawangunk is a massive quartz sandstone with a 40-50 foot basal quartz conglomerate. The high percentage of quartz, the well-rounded grains, the high index of sorting, and the great thickness, all characterize a beach deposit developed over a long period of time. In an old quarry above the road, Schuchert (1916) found Eurypterids in the shale beds found within the Shawangunk. In places the Shawangunk is cut by quartz-filled veins that are mineralized with pyrite, chalcopyrite, galena and sphalerite. These veins near Guymard (3.5 miles southwest of this locality) were the site of a small lead-zinc industry approximately 75 years ago.

12.2 Intersection with Orange County road 61.

12.2 Left (NW) on Orange County road 61.

Mileage

13.4 STOP 3: Small quarry in New Scotland Formation.

The beds exposed in this cut are those of the Lower Devonian New Scotland Formation. Most of the formation consists of dark blue-black shaly limestones. Toward the base of the formation abundant chert is found. The chert layers represent the Kalkberg Member of the New Scotland. The non-cherty beds are characterized by the following fauna:

Spirifer maclopleura
Leptaena rhomboidalis

13.4 Return to U.S. 211 via Orange County road 61.

14.6 Left on U.S. 211.

15.8 Right at T-intersection with Sanatorium Ave. (Kelley Hill).

16.2 STOP 4: Recumbent fold in Martinsburg (east side of Erie Railroad tunnel) - walk approx. 500 feet along railroad track.

On the north side of the track, the Martinsburg has been folded into a recumbent fold. In the same locality other signs of deformation are seen, (1) overturned beds, (2) small scale fault east of the recumbent fold. Although folding and faulting are seen in the area, metamorphism of the shales is not evident. It is interesting to note that the Shawangunk-Martinsburg contact is found near the crest of Shawangunk Mountain and not near the base. This is due to the predominance of sandstone beds that are quite massive in the upper part of the Martinsburg. The valley east of Shawangunk Mountain is part of the Great Valley and is underlain in this area by the Martinsburg Formation.

16.2 Return to U.S. 211.

16.6 Left at intersection with U.S. 211.

16.6 Left over bridge.

16.6 Right at end of bridge.

17.1 Fork in road; left (SW) onto Field Road.

18.2 Martinsburg on right (W).

19.0 Exposure of Martinsburg on right (W).

21.1 Intersection with Orange County road 24 and 35; continue southwest on Orange County road 35 (Finchville).

Mileage

26.2 Intersection with U.S. 6; cross-over U.S. 6 and continue southwest on Orange County road 55.

28.5 Intersection with road leading right (NW) to Camp Minisink; continue on Orange County road 55 (southwest).

29.6 New York-New Jersey border; continue southwest on Susse County road 519.

29.9 STOP 5: Martinsburg Formation.

Cyclic repetition of graywacke sandstone (with some layers becoming quite heavily bedded) and black, fissile shale characterizes the lithology of the upper portion of the Martinsburg, the oldest formation in this area (Upper Ordovician). Massive graywacke, several feet in thickness, quite prevalent near the top of the Martinsburg section (striking northeast and dipping on the average of 30 northwest), partially supports Kittatinny Mountain. The contact between this formation and the overlying Shawangunk Conglomerate, nowhere exposed in this area, lies just below the topographic crest of this ridge. Irregularities in sedimentation (seen readily in other exposures along the strike) are represented by irregularly-shaped fragments of shale within the massive graywacke layers. These isolated pieces are lenticular and the subjacent beds show no gaps into which they might fit. Other fragments are concave and sharply angular at their ends and appear torn from their position by slight tectonic movements. Undoubtedly, irregularities in primary sedimentation or slumping or other settling movements, incidental to primary deposition but taking place after sufficient hardening of the deformed layers, permitted them to act as competent units. Van Houten (1954) proposed that Martinsburg mud accumulated slowly in a marine environment. Sand, periodically stirred up in the shallow sea was carried to deeper water environments by spasmodic turbidity currents, and as the velocity decreased, the unsorted sediments settled in graded beds (not a prominent feature in the sandstone because no great range in grain size is involved in vertical sorting). These deposits may represent a "poured in" type of sediment, derived from the rapid erosion of tectonic source areas.

32.5 Intersection U.S. 23; right (W) onto U.S. 23.

33.0 Boundary of High Point State Park.

33.6 Entrance to High Point State Park.

33.7 Boulder of Shawangunk Conglomerate in center of road.

33.8 Right (E) on "Monument via Scenic Drive" road.

Mileage

34.0 STOP 6: Exposure of Shawangunk Conglomerate.

This is near the nose of a doubly plunging syncline of this formation. (See Pl. 6 and accompanying discussion.)

34.5 to 35.0 Lake Marcia on left (W) underlain by strongly sheared Martinsburg Shale. The "scenic drive" parallels the strike of the western limb of the syncline; dips range from 30° to 70° southeast.

35.0 Intersection with Monument Drive; right (NE).

35.4 Base of monument; park buses; walk to monument.

35.4 STOP 7: Highest elevation in New Jersey. 1,803 feet a.s.l.

This is the highest point in New Jersey. We are still on the western limb of the plunging syncline. Note the steep southeast dips (60°SE). Lake Marcia is located in the Martinsburg Shale as a result of breaching of the anticline immediately to the west and erosion along a thrust fault. The anticlinal, unbreached structure continues southwest (southwest of the A. T. & T. tower) until it ultimately dies out (in the southwestern portion of the Port Jervis South Quadrangle). All structures are doubly plunging. Toward the west lies the Pocono Plateau and along the east, the Great Valley underlain by the Martinsburg Formation.

37.2 Intersection with U.S. 23; right (W).

42.1 Intersection with U.S. 6 at traffic light; left into Port Jervis.

43.7 Intersection with U.S. 209 at traffic light; continue to second traffic light.

44.0 Intersection with Pike St.; left at traffic light.

44.1 Hotel Minisink.

GENERALIZED COLUMNAR SECTION
PORT JERVIS, N.Y.- N.J.- PA.

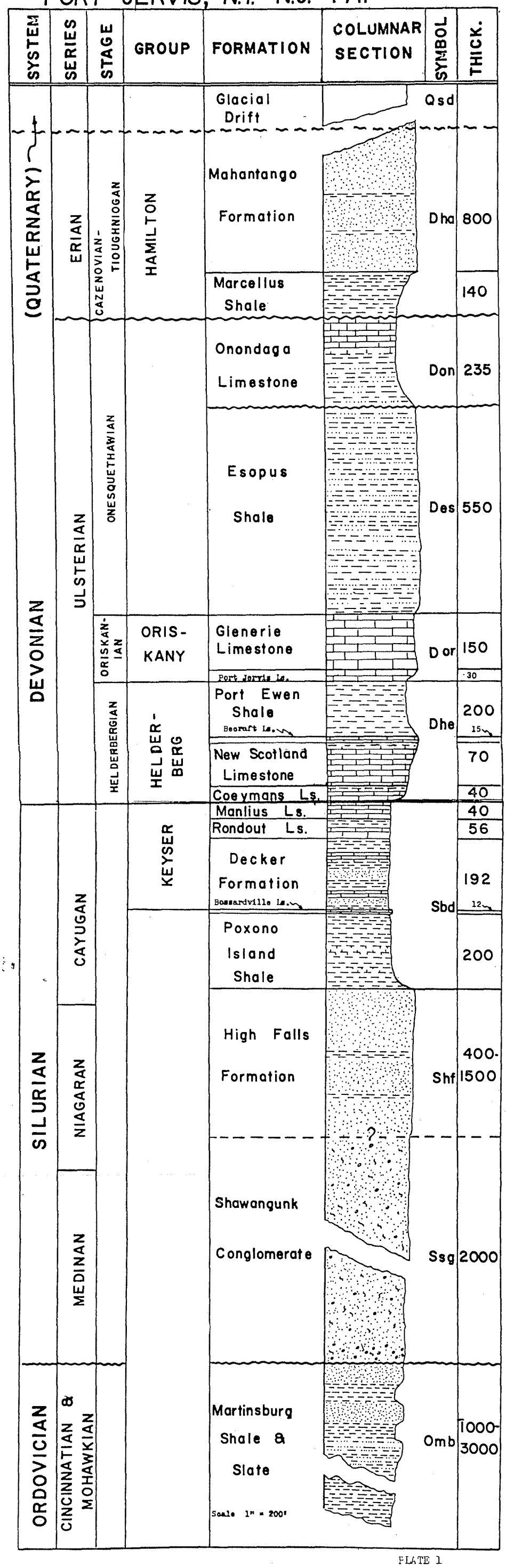
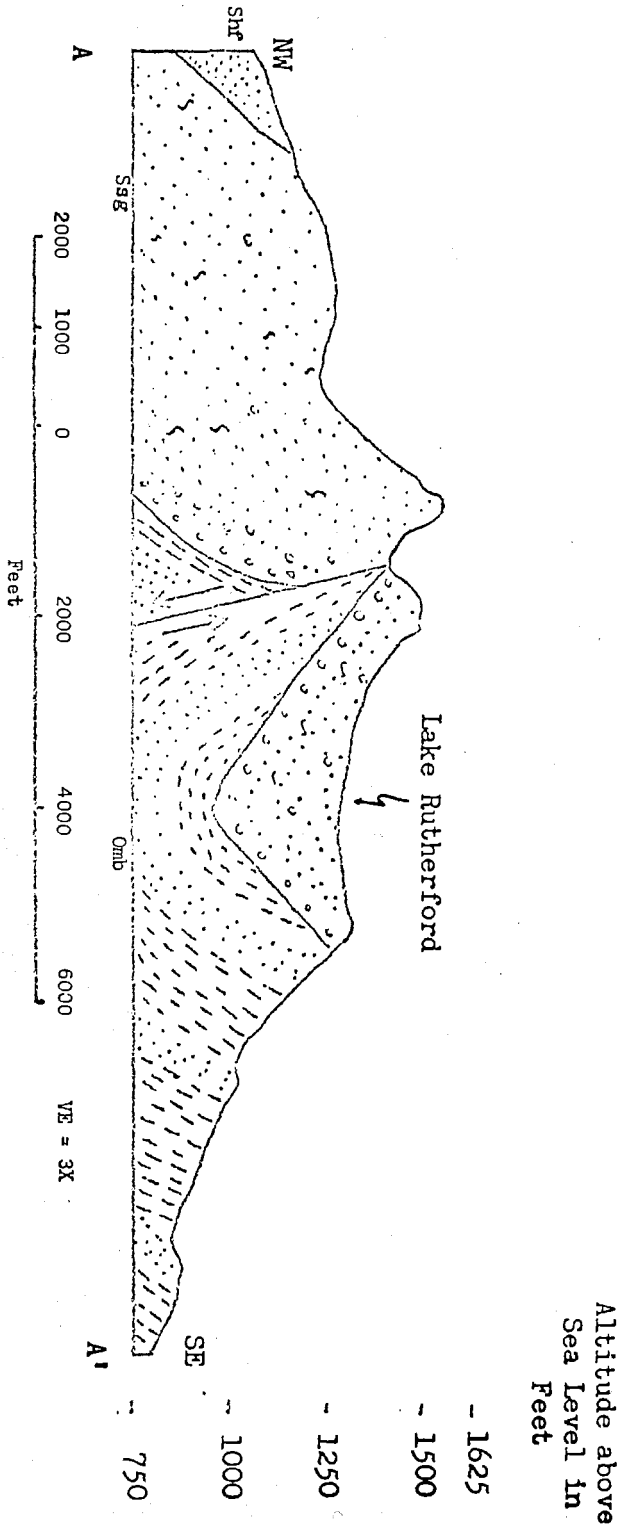
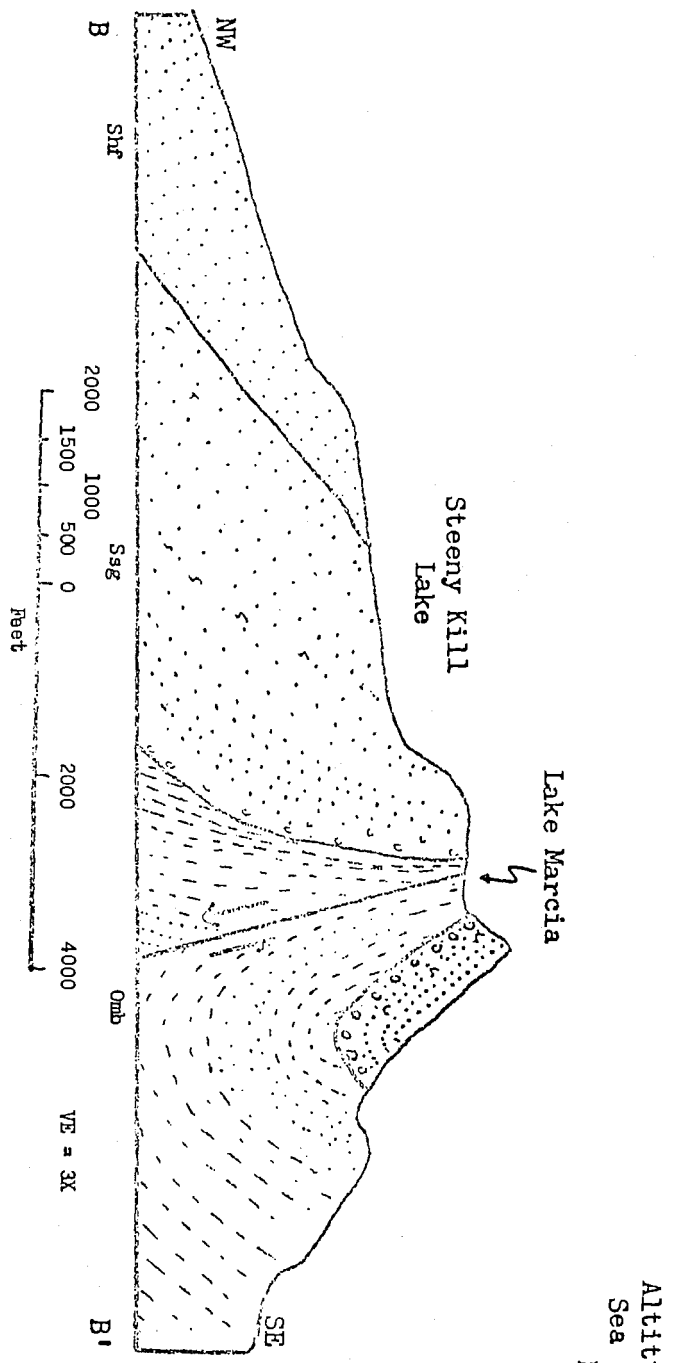


PLATE 1

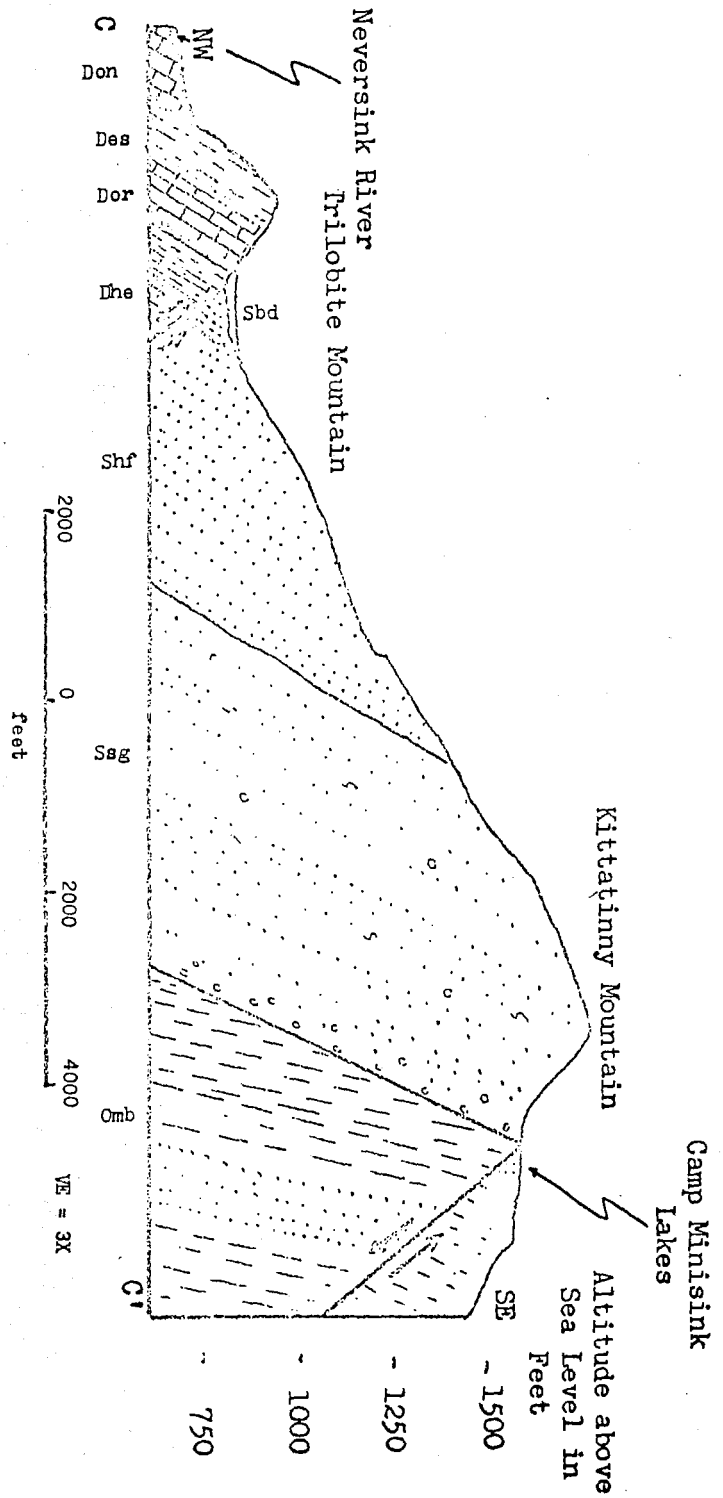
Section Through Lake Rutherford, New Jersey

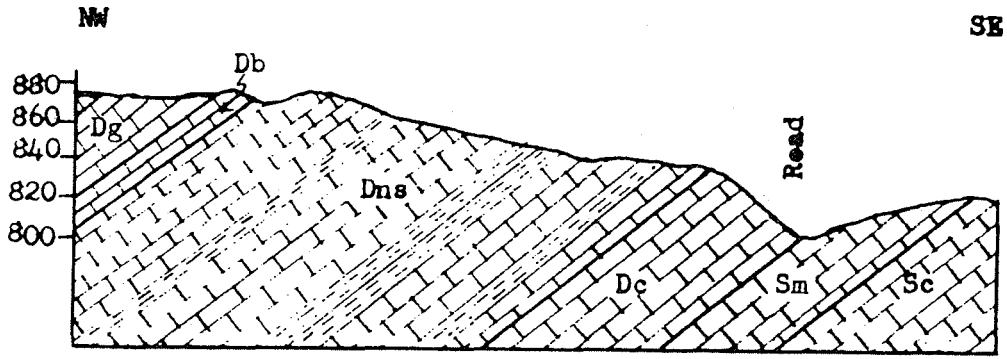


Section Through Lake Marcia, New Jersey



Section Through Kittatinny and Trilobite Mountains
New York





LEGEND

Dg Glenerie ls
Db Becraft ls
Dns New Scotland beds
Dc Coeymans ls
Sm Manlius ls
Sc Cayugan group

Fig. 1 Cross section of Helderberg Mt. south end of Guymard Lake
Scale 1"=100'

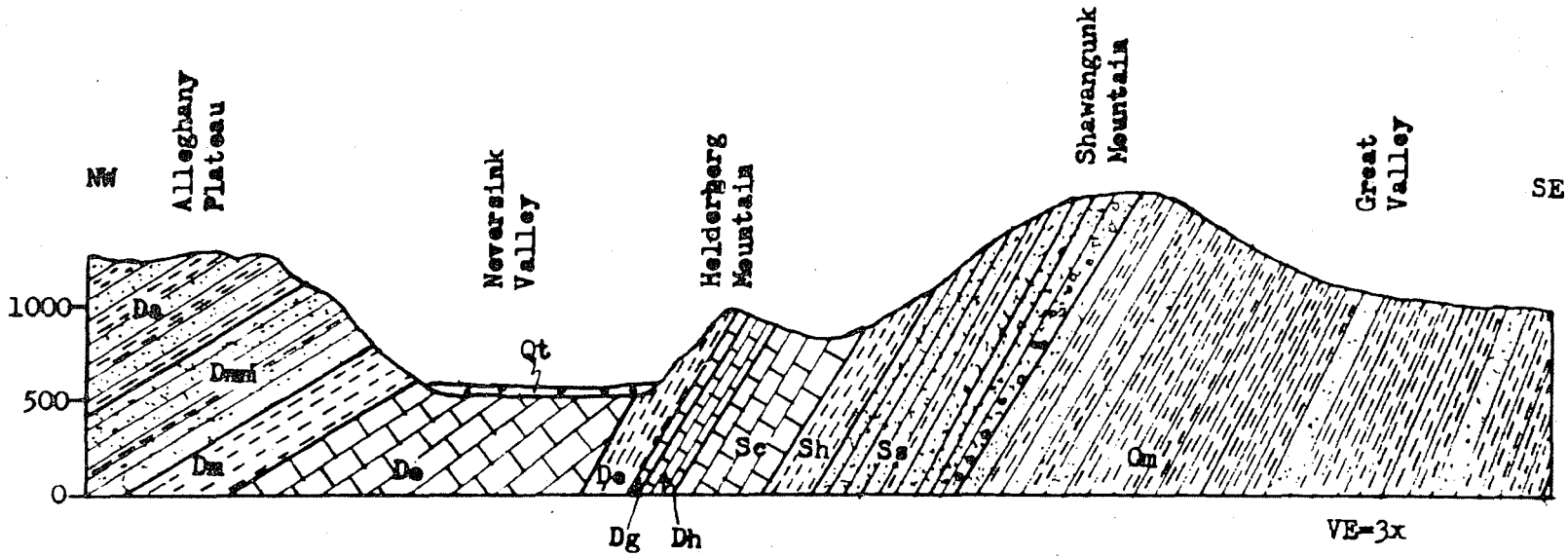
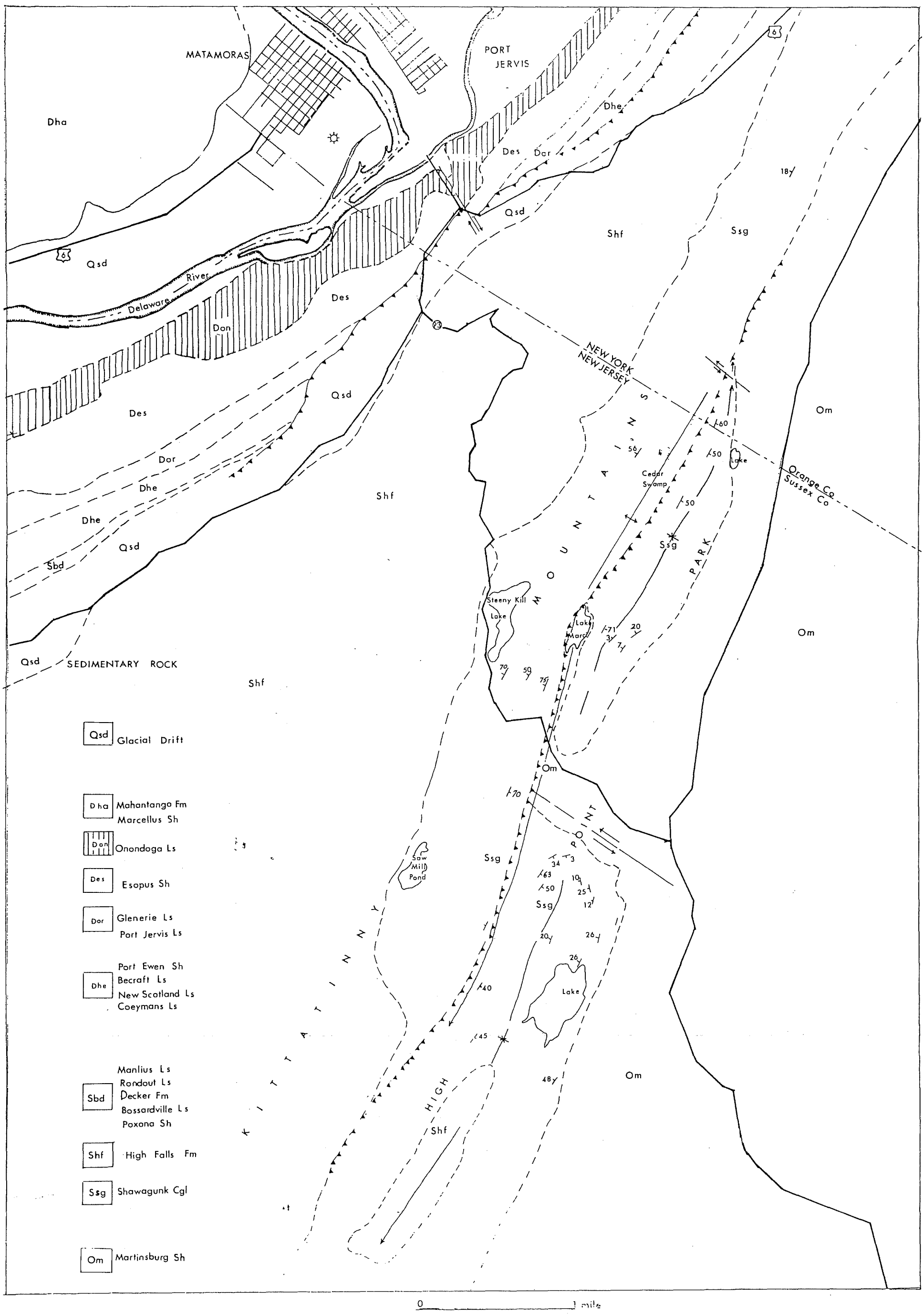
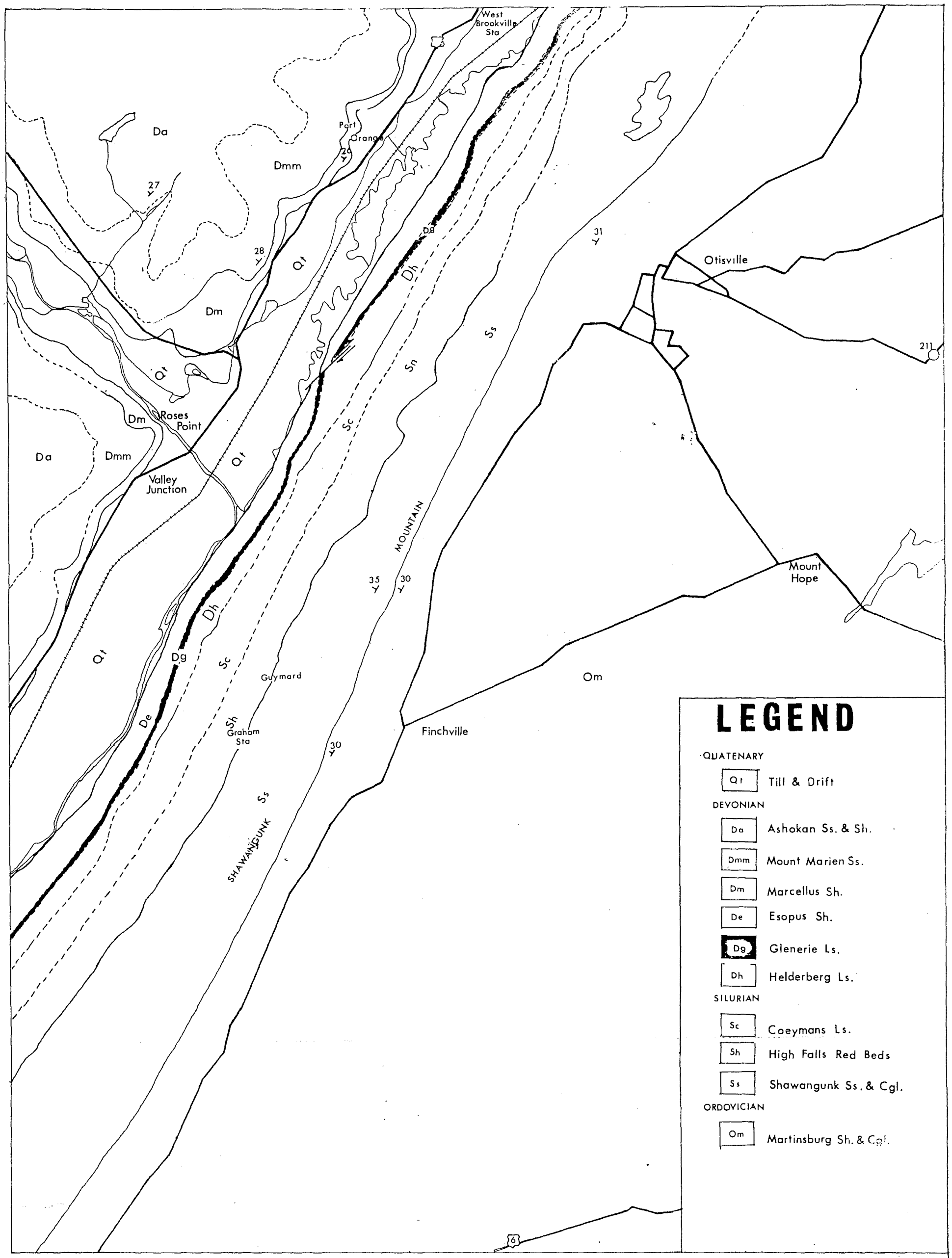


Fig. 2 Generalized cross section of the Otisville quadrangle
Scale 1"=0.5mi.

Port Jervis


MATAMORAS
PORT JERVIS
Dha
Dhe
Des
Dor
Qsd
Shf
Ssg
18y
Delaware River
Don
NEW YORK
NEW JERSEY
Om
Cedar Swamp
Lake
Orange Co
Sussex Co
MOUNTAIN PARK
Steeny Kill Lake
Lake Marcia
Saw Mill Pond
POINT
KITTATINNY
HIGH
Sbd
SEDIMENTARY ROCK
Qsd Glacial Drift
Dha Mahantango Fm
Marcellus Sh
Don Onondoga Ls
Des Esopus Sh
Dor Glenerie Ls
Port Jervis Ls
Dhe Port Ewen Sh
Becraft Ls
New Scotland Ls
Coeymans Ls
Sbd Manlius Ls
Rondout Ls
Decker Fm
Bossardville Ls
Poxona Sh
Shf High Falls Fm
Ssg Shawagunk Cgl
Om Martinsburg Sh
0
1 mile

OTISVILLE



LEGEND

QUATENARY

- Qt — Till & Drift

DEVONIAN

- Da — Ashokan Ss. & Sh.
- Dmm — Mount Marien Ss.
- Dm — Marcellus Sh.
- De — Esopus Sh.
- Dg — Glenerie Ls.
- Dh — Helderberg Ls.

SILURIAN

- Sc — Coeymans Ls.
- Sh — High Falls Red Beds
- Ss — Shawangunk Ss. & Cgl.

ORDOVICIAN

- Om — Martinsburg Sh. & Cgl.

STRATIGRAPHY AND STRUCTURE OF THE "CATSKILL GROUP" IN SOUTHEASTERN NEW YORK

Frank W. Fletcher

The University of Rochester

TRIP D

> "A blackboard drawing or a textbook illustration of a sedimentary facies has quite a different appearance from a sedimentary facies when one encounters it in the field. In the field, facies changes seem baffling and bewildering, especially in an area of new and unknown stratigraphy. It is as if stratigraphy, hitherto subject to natural laws and capable of rational analysis, had suddenly gone lawless and planless."
>
> P. B. King

THE CATSKILL PROBLEM

Introductory Statement

Within the Devonian rocks of southeastern New York there are approximately 5000 feet of interbedded red and gray sandstones, shales and conglomerates known collectively as "Catskill." After more than a century of investigation, virtually the only conclusions agreed upon by the various workers in the area are that the facies changes are complex, the location of formation boundaries is difficult, few fossils are present, correlation is uncertain, and the sedimentary environment is either subaerial or subaqueous.

The complex intertonguing and intergrading of strata of the Catskill delta offers excellent opportunity for the study of sedimentary facies. The rocks which comprise the "Catskill group" exhibit exceptional intricacy because of three major variations: lateral and vertical intergradation of lithologies, lateral intertonguing of lithologies, and changes in color. The first facies variation is represented by changes in grain size in the sandstones and conglomerates. Grain size increases vertically in the stratigraphic section and decreases laterally from east to west. Intertonguing of lithologies is expressed by the relationship between the red siltstone and the shale beds and the green- and blue-gray sandstones. The red beds thin or "pinch out" toward the western portion of the Catskill delta. Whereas the previous two facies changes are gradual, color changes often occur within a few feet. The red color is caused by the presence of finely divided hematite; the blue- and green-gray colors by chlorite, magnetite and other dark minerals.

Conditions of Deposition

The two views of the environment of deposition of the sediments are well expressed by J. J. Stevenson (1891) and Joseph Barrell (1913). Barrell, whose interpretation has been the generally (if not dogmatically) accepted one, believed the sediments represent subaerial deltaic deposits derived from a high, nearby source. He pictured the paleogeography as a low alluvial plain shading off through fringing lagoons into a shallow mud-bottomed sea. Stevenson, on the other hand, concluded that the strata were laid down in a shallow basin undergoing differential subsidence in which the basin was connected with the open sea. To him, the lack of animal life was not, as Barrell believed, caused by the fact that marine life cannot exist in a subaerial deltaic environment. Stevenson claimed that the environment was unfavorable because of the influx of large quantities of river silt into the basin.

A number of criteria have been given in support of the theory of subaerial deposition. The two most quoted are the large amounts of red sediments and the lack of marine fauna. Red color in sediments has always signified an oxidizing environment. The lack of marine fossils, although negative evidence, points to a nonmarine origin. Other, and perhaps less conclusive, criteria are alleged raindrop prints, rootlet markings and mudcracks. Conglomerates, cut-and-fill structures, cross-stratification, plant fragments and the presence of the large pelecypod Amnigenia catskillensis, believed to be a fresh water clam, have also been put forth by various investigators as evidence for continental sedimentation of the "Catskill" rocks. A proponent of the subaqueous theory of deposition must either disprove the presence of the features which have been accepted as conclusive proof of subaerial environment or give reason for their presence. The field trip has been designed so that most of the features may be observed and their validity evaluated.

Source Area

The direction of lateral grain size diminution, currect direction criteria, i.e. cross-bedding, primary current lineation and oriented plant fragments, and "lensing-out" of the red beds seem to indicate a source area to the east of the present outcrops. In 1914, Barrell stated that the sediment was brought in along the whole front of the geosyncline by more than one river. He did not draw an analogy with the present day Mississippi River delta, but instead, pictured a series of deltas in which there were several centers of growth. Preliminary study of directional properties indicates two major directions of sediment transport. The two directions, N 20° W and N 90° W, alternate several times vertically in the stratigraphic section. Mencher (1939) believed in a fairly close source of sediment derivation. He thought it inconceivable that material in which the grains are extremely angular could have been transported from more than 75 miles from the present eastern limit of the outcrop. Thus far, no one has been able to propose a source area which adequately explains the presence of the conglomerates in western New York as well as those in the region of the Catskill front.

STRATIGRAPHY

What is Catskill?

The first appearance of the name Catskill as a geologic unit is found in the Fourth Annual Report of the First Geological District by W. W. Mather (1840). Mather defined the Catskill Mountain Group as consisting of white, gray and red conglomerates with gray, red, olive and black grits, slates and shale. He chose the Catskill front in the vicinity of Kaaterskill Clove as the type section and included in the group all of the strata from the Onondaga Limestone to the Pottsville Conglomerate. The latter Mather thought capped the Catskill Mountains.

The term "Catskill group," as used here, has no formal stratigraphic connotation, but is employed in an informal sense to designate the massive wedge of interbedded, Devonian red and gray strata which crop out in southeastern New York. Therefore, the name denotes geographic as well as stratigraphic location. This course is taken only because the name appears to be irretrievably entrenched in geologic literature and to discard it entirely (perhaps the best course of action) would only serve to complicate an already confused situation (see Chadwick, 1936).

Hawks Nest Formation

The name "Delaware River Flags" was first applied by I. C. White in 1882 to the rocks which overlie the marine Hamilton (?) beds just north of Port Jervis, New York. He reported a thickness of approximately 1400 feet. Willard (1936) redefined the formation as 1500 feet of greenish flags without red beds. He states that the formation is correlative with the Onteora Formation of the Catskill front. However, he fails to give an adequate reason for the disappearance of almost 3000 feet of red strata (the combined thickness of the Onteora and pre-Onteora red beds) which is necessary to support such a correlation. Examination of rock samples from exploratory oil and gas wells in the area has shown that a thick sequence of red strata occurs in the upper 700 feet of Willard's Delaware River Flags. This sequence of red beds can be traced, in a series of wells, north along the Delaware River and into the region of Oneonta, New York, where it is called the Oneonta Formation. This has prompted Fletcher to discard the name Delaware River Flags. The section of gray sandstones and shales which, in southeastern New York, lie beneath the Oneonta Formation, are defined as the Hawks Nest Formation after the excellent exposures on the high cliffs at Hawks Nest, N. Y. This 800 foot sequence of strata is probably correlative with the Unadilla Sandstone of the Oneonta region.

The dominant lithology is a fine- to medium-grained, light to medium bluish gray subgraywacke. The fine-grained sandstones are finely laminated and flow rolls are common. The medium-grained sandstones exhibit low angle cross-bedding. A limonite stain is present on the weathered rock surface. Interbedded with the sandstones are medium dark gray to grayish blue siltstones which are brownish gray on weathered surface and lack fissility. The formation is generally unfossiliferous.

Oneonta Formation

In the same report in which Mather defined the Catskill Mountain Group, L. Vanuxem (1840) proposed the name "Montrose sandstone or sandstone of Oneonta" for the red and gray rocks found in Otega, Broome and Chenango counties, New York. The Geologic Map of New York shows these 700 feet of strata correlated with the Onteora Formation. Fletcher, however, has suggested an alternative correlation (see Plate IV). Stratigraphic columns constructed from samples from gas wells located in the northeastern Catskill Mountains show that only the lower 800 feet of Chadwick's Kiskatom red beds "drop out" before they reach the type section of the Oneonta Formation. Beneath the Twilight Park Conglomerate is a 900-foot zone of predominantly red strata, 250 feet of dark gray shale and sandstone with two thin beds of coarse-grained, white quartzose sandstone, and about 800 feet of intercalated red and dark bluish gray sandstone and shale. The 250 feet of rock containing the two thin white sandstone beds forms a distinctive and persistent marker horizon in subsurface samples. This zone has been traced to the Durham quadrangle where it was called by G. A. Cooper (1934) the eastern equivalent of the Portland Point Member of the Moscow Formation. In the Durham quadrangle the zone is underlain by 350 feet of red beds. In the Margaretville quadrangle, west of the Catskill front, only 100 feet of red beds underlie the white sandstone units. At the type locality of the Oneonta Formation this zone is located approximately 900 feet beneath the lowest red bed. As a result of these findings the strata Chadwick called Kiskatom have been divided into three units. The lower red zone, which loses its red beds rapidly to the west and south, is designated the Plattekill Formation and its type section is taken as Plattekill Clove. The middle zone is called the Potter Hollow Formation after Potter Hollow, Greene County, New York. The upper red zone is the Oneonta Formation.

The Oneonta contains micaceous, pale red purple and grayish purple siltstones and mudstones. The red mudstones exhibit slickensides formed by slumping of unconsolidated mud before induration. The sandstones are medium grained, red purple and light gray to greenish gray subgraywackes. They weather light greenish gray. The flaggy sandstones have primary current lineations on bedding surfaces and, with the exception of one type of freshwater (?) pelecypod and plant fragments, are unfossiliferous.

Kattel Formation

The name Kattel was first used by Chadwick (1932) for the marine shale previously designated as lower Enfield. The lithology is similar to the Chemung facies and consists of fossiliferous gray and dark gray shale interbedded with thin gray and brownish gray siltstones. Although it is easily recognizable in subsurface samples because of its stratigraphic position between the red Oneonta and Onteora Formations, the fossiliferous portion does not extend to the southeast past Hancock, New York. Therefore, separation of it from similar units in the underlying and overlying formations around Barryville, where the Kattel should crop out, has not be accomplished. If Fletcher's tracing of the Oneonta Formation to the Catskill front is correct, then the Kattel Formation is correlative with the Twilight Park Conglomerate and, perhaps, with the Kaaterskill Sandstone.

Onteora Formation

The Onteora Formation was defined by Chadwick (1933) as the 1150 feet of red and gray beds which lie between the Twilight Park Conglomerate and the Stony Clove Sandstone in the vicinity of High Peak and Round Top Mountains, Greene County, New York. The name is derived from the Indian name for the Catskill Mountains which means "hills of the sky." The lithology differs very little from the underlying red and gray strata. Subtle increase in grain size in the sandstones occurs, but is almost imperceptible to cursory examination.

By considering the Kiskatom Formation as belonging to the Hamilton Group, it becomes necessary to correlate the Onteora red beds (which then must be Upper Devonian in age) with the Upper Devonian red beds to the west - the Oneonta. If, however, the Oneonta Formation actually lies beneath the Twilight Park Conglomerate as Fletcher proposes, the Onteora is equivalent to the sequence of strata called the West Danby Shale and Sandstone (upper Enfield) and, farther to the west, the Cashaqua Shale.

Stony Clove Formation

Chadwick (1944) described the Stony Clove Formation as "gray sandstones coarsely flaggy and without a noticeable trace of red color through a thickness of eight or nine hundred feet." The formation's type locality is the "deep and constricted pass of Stony Clove," Greene County, N. Y. This formation has a marked physiographic effect on the Catskill front. It forms a distinct escarpment which can be traced topographically along the front. Along the Delaware River the Stony Clove forms high cliffs in contrast to the lower topography caused by the less resistant red musstones and shales of the surrounding Onteora and Damascus Formations. Chadwick's correlation of the Stony Clove with the Kattel Formation was based on "... color, lithology, proper expected thickness and general position ..." The same criteria could be invoked to support correlation with the lower part of the Rhinestreet Shale.

Damascus Formation

Above the Stony Clove Formation in the Delaware River region are about 400 feet of strata composed almost entirely of red sandstone, siltstone, mudstone and shale. Willard (1936) gave the name Damascus Formation to these rocks after Damascus, Pennsylvania where this sequence is well exposed. These strata were originally named "Montrose" by White (1882) who believed they were the same red beds which crop out around Montrose, Pennsylvania. Fletcher has correlated the Damascus with the basal portion of the Katsberg Formation, called Lower Katsberg on the Geologic Map of New York State. At the type locality the formation lies in the center of a large syncline (see section on structure), so that along the Delaware River older beds occur both to the south and north of the outcrop of the Damascus Formation.

The sandstones are fine- to medium-grained and are grayish red purple. The few interstratified greenish gray sandstones range from

medium- to coarse-grained. Both red and gray sandstones exhibit cross-stratification. The red mudstones and siltstones strongly resemble the same in the two previously described red formations; however, more of the fissile red shale is found in the Damascus Formation.

Post-Damascus Formations

The strata above the Damascus Formation in Pennsylvania have been divided into the Honesdale, Cherry Ridge, Elk Mountain and Mount Pleasant Formations. These units have not been recognized in New York. Along the Catskill front Chadwick (1933) proposed the name Katsberg (the old Dutch name for the Catskill Mountains) for the almost 1500 feet of rocks between the Stony Clove Sandstone and the Slide Mountain Conglomerate. The lower part of the Katsberg Formation, mainly red sandstones and shales, is correlated with the Damascus. The upper portion, as yet not adequately differentiated, consists of coarse-grained greenish-gray and red sandstones and white quartz pebble conglomerates with red and green sand matrix. Chadwick (1936) believed that "it is embarrassing to have any formation name lap across a subperiod line, such as that between the Middle and Upper Devonian." His stratigraphic interpretations are founded on this thought. The result (see Plate II and figure 1) is that he applied different names to rock zones which are stratigraphically continuous because they transgressed time boundaries. To strata which are actually stratigraphically equivalent to the Katsberg Formation, he gave the names Catawissa and Montrose.

Capping the highest peak in the Catskills, Slide Mountain, is a very distinctive quartz pebble conglomerate which bears the name of that peak. The formation is 400 feet thick and was named by Chadwick in 1933. The conglomerate, which contains white quartz pebbles commonly greater than 70 mm. diameter, is cross-bedded and weathers whitish or greenish yellow. Besides the quartz pebbles, a few green siltstone pebbles may also be found. The lithology is strikingly similar to the conglomeratic portions of the Pocono Sandstone. If the two are correlative, Slide Mountain may be an outlier of the more westerly plateau area of Pennsylvania.

STRUCTURE

General Statement

The dominant structural feature of the region is a synclinorium in which the axis plunges southwest and passes through Hunter, New York and Damascus, Pennsylvania. The strata of the southeastern flank strike about N 30° E and dip to the northwest at angles which vary from 40° at Ellenville, N.Y. to less than 1° in the vicinity of Liberty, N.Y. The strata of the western flank strike N 85° E and dip toward the south at angles of 2° just north of the Gilboa Reservoir to less than 1° along the Pepacton Reservoir. Many small local flexures are superimposed on the regional structure. Combined with the facies changes and lack of marker beds, these subtle changes in dip angles and directions make stratigraphic interpretation difficult.

Fractures and Fracture Systems

Two major joint sets are present. The first set strikes almost due north and is generally vertical. The joint face is smooth and its trace is straight. Plumose markings are common and, along the Delaware River outcrops at least, mineralization has occurred along the joint planes. The second set strikes N 85° E and is also vertical. However, the joint faces are rough and their traces are wavy. Plumose markings are also present on the joint planes of this set, but no mineralization has taken place. Both sets of joints are well expressed in the sandstones, but do not occur with any regularity in the shales and siltstones. In these finer grained rocks there is small scale "crinkling" caused by minute slippage along microjoints which parallel the east-west joint set.

In the sandstones, parting of the strata also occurs along the bedding planes between the topset beds and between the foreset beds. This parting, caused by the parallel alignment of small plates of muscovite along the stratification planes, makes possible the flagstone industry of the Catskill Mountains. The presence of slickensides along a few of the bedding planes of the sandstones indicates that some movement has taken place. The slickensiding is probably the result of gentle flexure folding.

Some faults with small displacements have been noted. One good example may be seen along the southern shore of the Pepacton Reservoir just east of Downsville, N. Y.

THE PROBLEM AGAIN

The Pocono-Catskill Contact

Two alternatives have been suggested for the contact between the "Catskill group" and the Pocono Formation (see Plate VI). In eastern Pennsylvania the lower boundary of the Mississippian Period has been placed at the base of the Pocono Sandstone. However, the confusion in identification between the Pocono and the Honesdale-type sandstone and conglomerate by early workers in Pennsylvania is well known. Willard (1936) concludes that the contact between the Mount Pleasant Red Shale (the highest formation of the "Catskill group" in eastern Pennsylvania) and the Pocono Formation is unconformable. He states, "The writer has long entertained the feeling that this lithologic change in passing from the Devonian to the Mississippian continental formations is the direct expression of a marked orogenic movement...." This conclusion is based on the fact that the Mount Pleasant Formation thins rapidly to the west and the nature of the contact, which is locally irregular. He says that the thinning is due to subaerial beveling, even though "...nowhere has an angular discordance of dips been seen." Thus, Willard says that the Pocono was subsequently deposited upon this erosion surface. A very different picture can be constructed if the "thinning" of the Mount Pleasant Red Shale is caused by facies change. Also, irregular contacts between sandstone and shale units are the rule and not the exception in the "Catskill group." If, as suggested earlier, the Pocono and Slide Mountain Formations are equivalent, where, then, should the Devonian-Mississippian contact be located?

Concluding Remarks

The interpretation of stratigraphic relationships in the Catskill delta presented here differs from those commonly accepted only with respect to the magnitude of the facies changes. The fact that red beds were being deposited in the eastern part of New York State at the same time black shales were being laid down in the western portion has been well documented. Plate VII shows the three types of facies changes mentioned previously. At any particular stratigraphic level grain size decreases from east to west. This is true because each level transects the more landward portion of the sedimentary basin in the east and passes to deeper water environmental conditions toward the west. If carried far enough the sequence at a particular level from east to west is: red shale, sandstone and conglomerate - gray fossiliferous shale and sandstone - black shale and limestone.

The vertical grain size increase is the result of the gradual regression of the sea from the eastern part of the basin. The diagram also shows that the marine units attain their greatest thickness in the west; while the red beds are thickest in the east. This results in intertonguing of the two lithologies. All units do not thicken toward the east at a constant rate as once thought.

The location of time boundaries in the eastern portion of the Catskill delta can be perilous, indeed. However, it appears that the Twilight Park does not mark the base of the Upper Devonian. Actually, Upper Devonian sedimentation began somewhere in the lower portion of the Oneonta red beds. The imaginary line denoting the base of the Upper Devonian crosses the facies from the red beds through the Unadilla-type rocks and into the black shales of the Geneseo Formation. Only at local outcrops can one say that a particular unit lies at the top of the Middle Devonian or at the base of the Upper Devonian.

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ROAD LOG

Mileage	Description
0.0	Junction of Rtes. 209 and 6. Proceed north to Rte. 97.
0.8	Point Peter, Port Jervis, N. Y. Outcrop of dark gray shales and sandstones called Portage by Willard (1936) and marine Devonian beds on the Geologic Map of Pennsylvania. These rocks contain many of the same fauna as the Mount Marion Formation along the Catskill Front.
3.2	Junction of Rtes. 97 and 42. Continue straight ahead (north) on Rte. 97.
3.9	Beginning of outcrop which shows the type section of the Hawks Nest Formation.
5.1	STOP #1. Type section of Hawks Nest Formation.
5.6	Cross the Mongaup River.
8.1	Outcrop at left along the river. A clear expression of the regional dip, cross-bedding, and joint pattern.

10.2 Large quarry at the right.

11.2 Bridge at Pond Eddy, N. Y.

12.0 Sandstone outcrop on Pa. side of the river.

13.3 Outcrop at right.

13.9 STOP #2. Outcrop of the Oneonta Formation.

14.9 Sandstone outcrop along railroad on Pa. side of river.

16.1 Sandstone outcrop on right side of highway. Notice well-expressed joint sets. Red siltstone at top of hill.

17.1 Outcrop along railroad on Pa. side.

18.2 Outcrop of sandstone on right side of highway. Cross-stratification is absent. Red siltstone near bottom of hill.

18.8 Junction of Rte. 55 and 97. Continue straight ahead (north) on Rte. 97 through Barryville, N. Y.

20.2 Outcrop on right. Watch for appearance of red mudstone which indicates the regional dip.

23.0 Minisink Ford. Continue on Rte. 97. Lackawaxen River enters the Delaware River at this point.

23.3 Large outcrop of the sandstone on the right.

26.6 Outcrop showing well-developed cross-stratification.

28.2 Outcrop on both sides of the highway. Red siltstone and a dark gray shale are exposed.

28.5 Outcrop of the Barryville member of the Shohola Formation (see Willard, 1936). Notice the distinctive weathering "holes."

30.0 Cross the Ten Mile River.

30.5 Sandstone outcrop at left showing well-developed cross-stratification.

32.9 Junction of Rtes. 52 and 97. Continue north on Rte. 97.

33.7 Rte. 52 leaves Rte. 97. Bear right and continue on Rte. 97.

34.7 Outcrop near the top of the sandstone on the right side of the highway.

39.9 Outcrop at right. Notice the abundance of red soil.

40.2 Red siltstone exposure at right.

41.2 Red siltstone exposure at right.

41.4 Outcrop of red siltstone and mudstone on right side of highway. Notice anticlinal structure.

42.0 STOP #3. Type locality of the Damascus Formation.

42.5 Red shale and mudstone exposed on both sides of highway.

42.7 Leave Rte. 97 and bear to the right (east).

47.6 Fosterdale, N. Y. Junction of Rtes. 52 and 17B. Turn left (north) on Rtes. 52 and 17B.

48.1 Leave Rte. 17B. Bear right on Rte. 52.

49.1 Outcrop of gray sandstone in Damascus Formation at right.

50.3 Continue on Rte. 52 through Kenoza Lake, N. Y.

51.4 Junction of Rtes. 52 and 52A. Turn right (east) and continue on Rte. 52.

53.9 Continue on Rte. 52 through Jeffersonville, N. Y.

64.6 Red sandstone exposure at right.

66.3 Liberty, N.Y. Junction of Rtes. 52 and old Rte. 17. Turn right (south) and continue on Rte. 52.

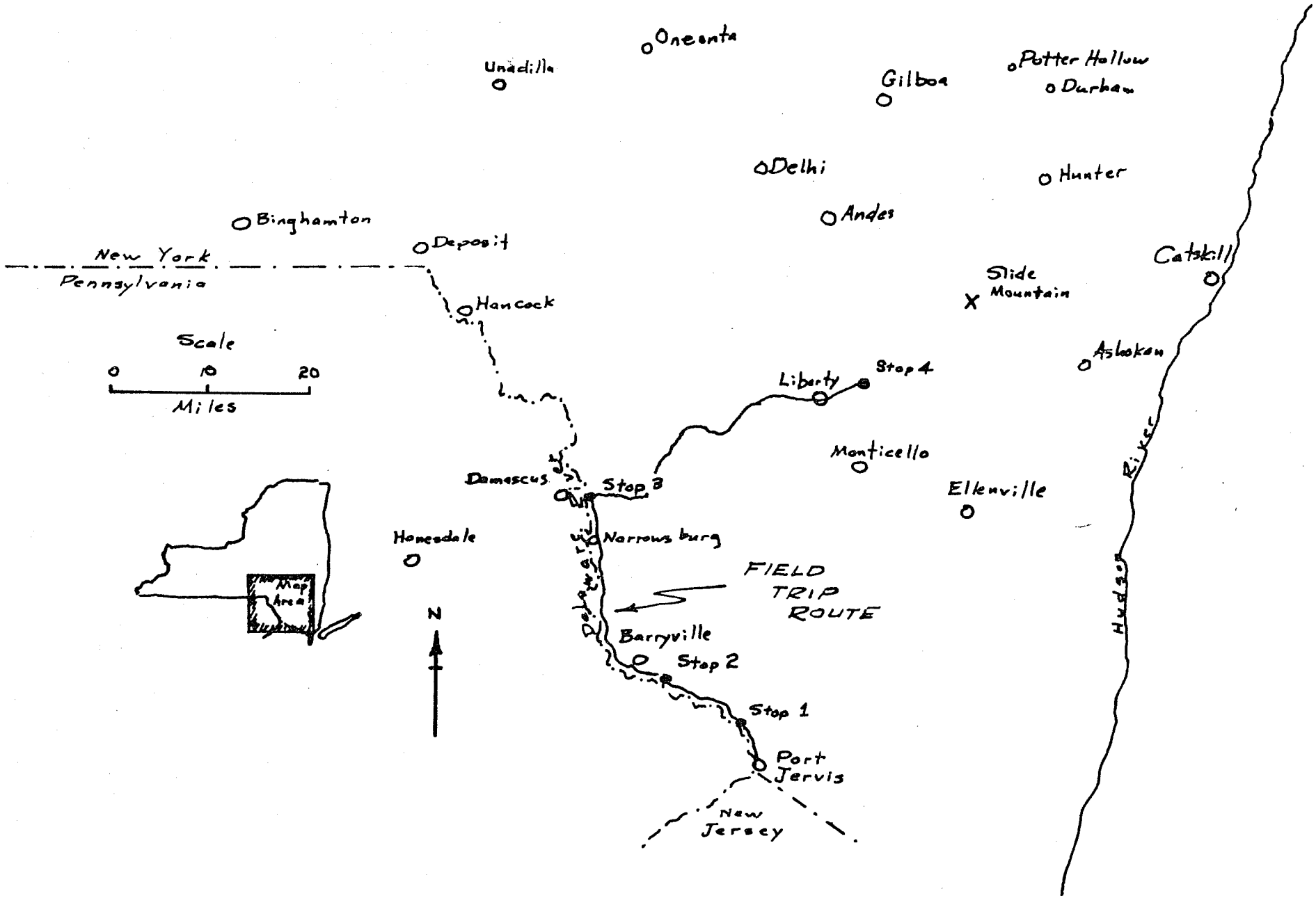
66.7 Junction of Rtes. 52 and 55. Turn left (east) and proceed on Rte. 55.

72.0 STOP #4. Outcrop of the Lower Katsberg Formation.

END OF ROAD LOG

Return to Port Jervis via Rtes. 55, 17 and 209.

SKETCH MAP OF SOUTHEASTERN NEW YORK



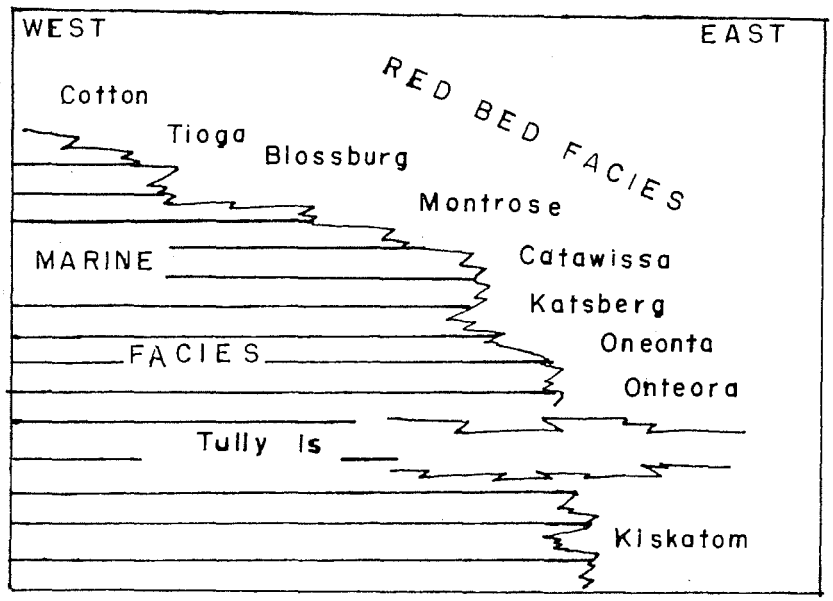
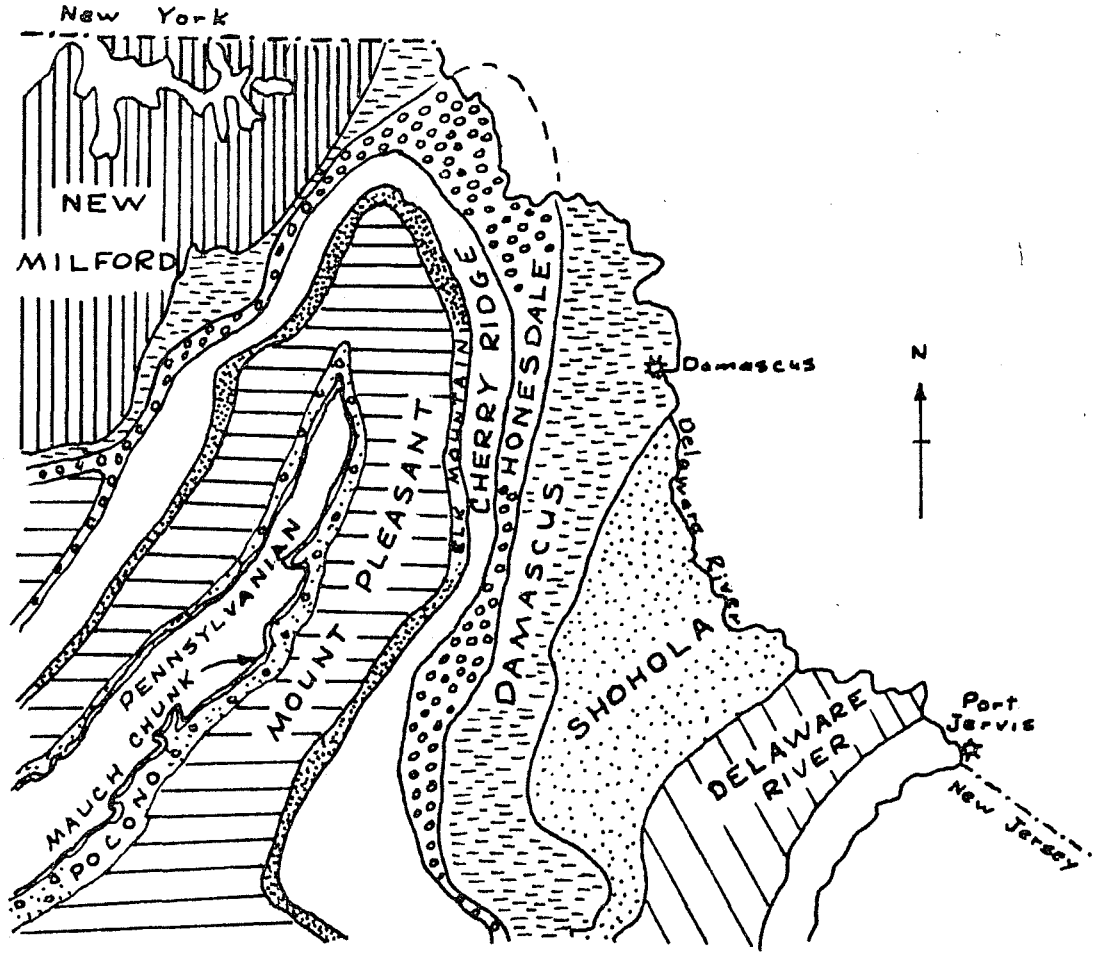


Figure 1. (Suggested by Fisher, 1956, Jour. Geology, v. 64, p. 621, fig. 2.)

WILLARD'S INTERPRETATION OF CATSKILL STRATIGRAPHY



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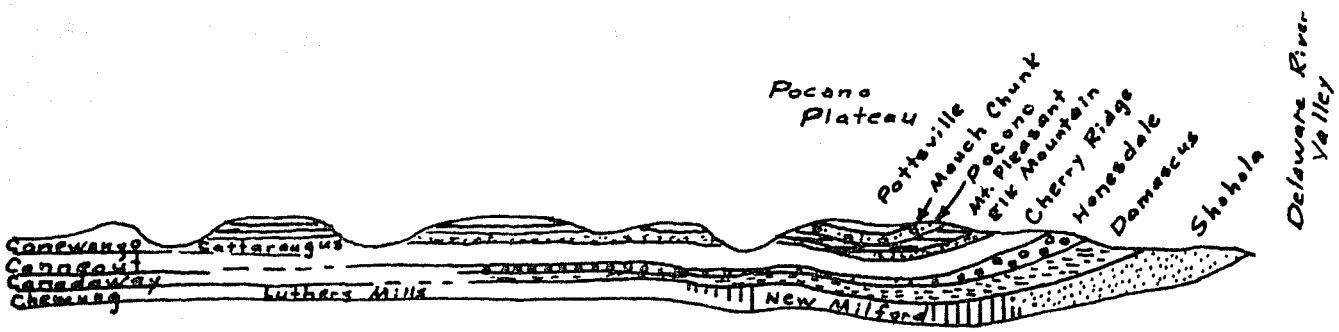
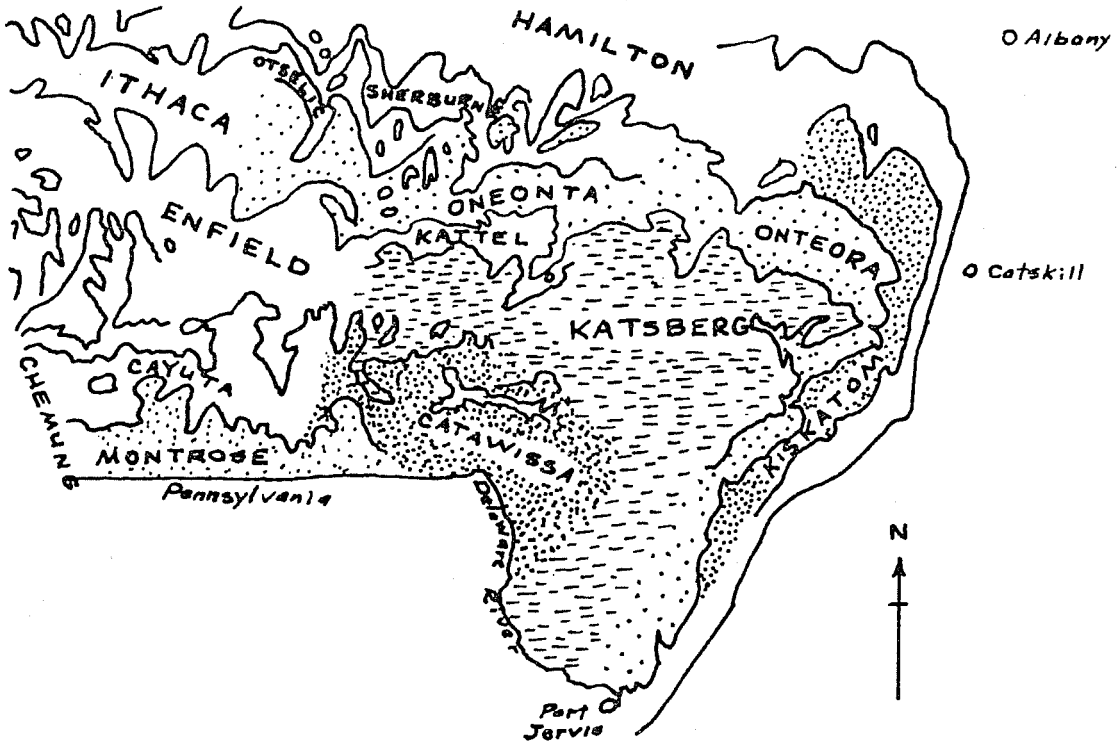


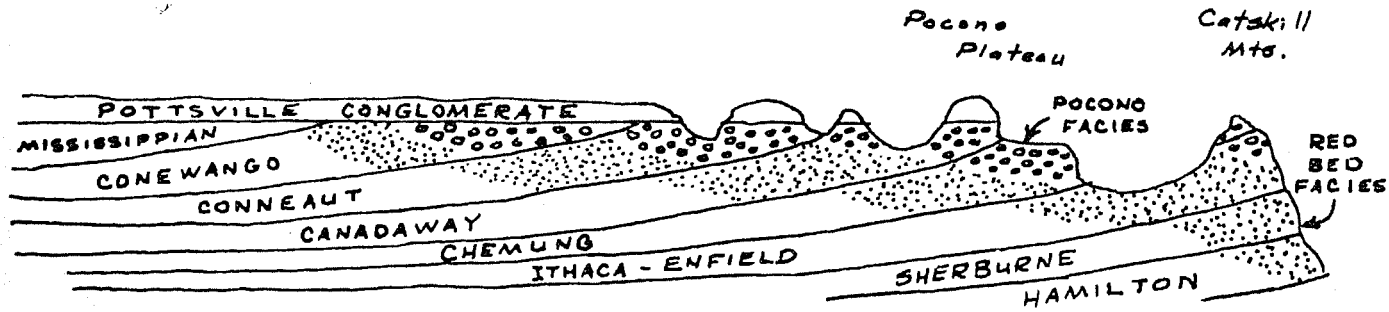
(After Willard, 1936, Geol. Soc. America Bull., v. 47, p. 602, fig. 3-B.)

PLATE I

CHADWICK'S INTERPRETATION OF CATSKILL STRATIGRAPHY



(After Chadwick, 1944, N. Y. State Mus. Bull. 307, p. 9, fig. 3.)

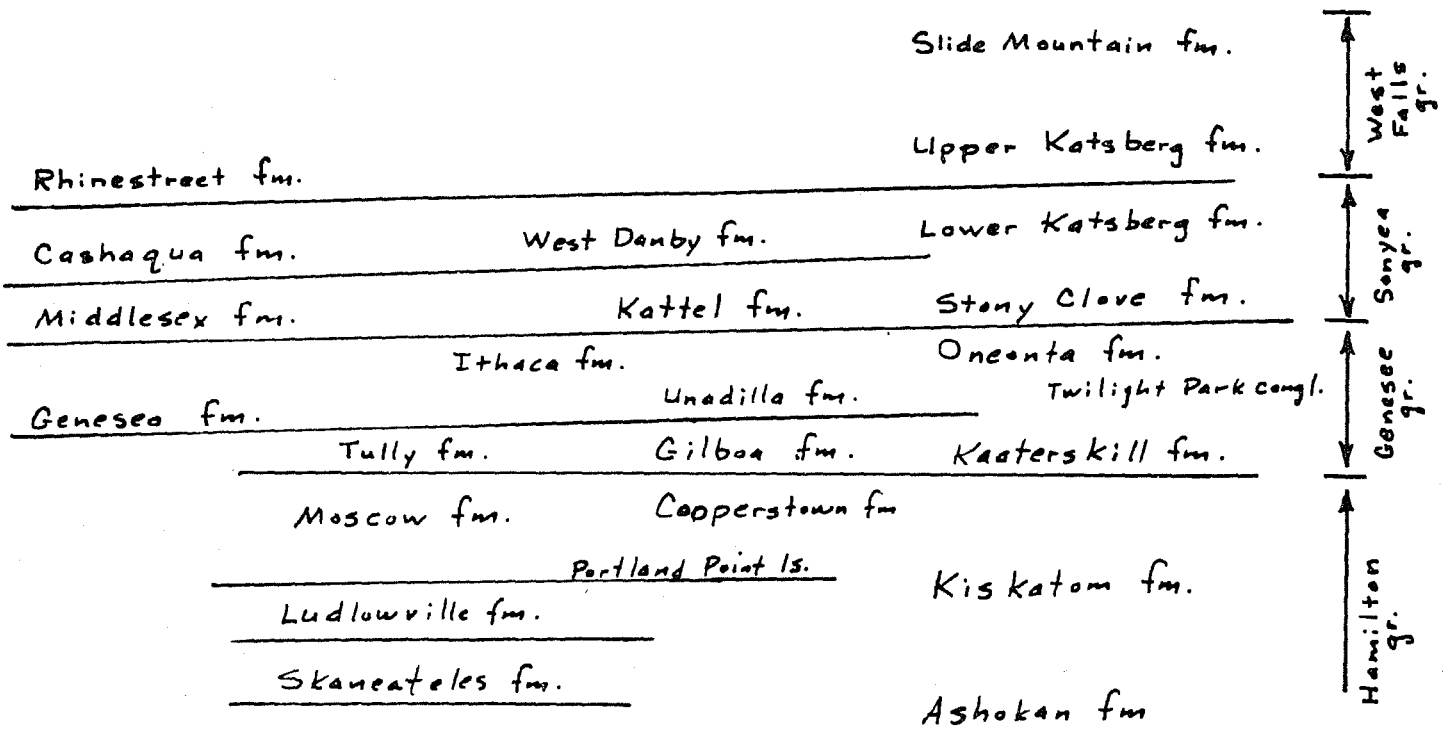


(After Chadwick, 1935, Am. Jour. Sci., 5th ser., v. 29, p. 134, fig. 1.)

PLATE II

CORRELATION CHART

Suggested by the Geologic Map of New York State - 1962 Edition



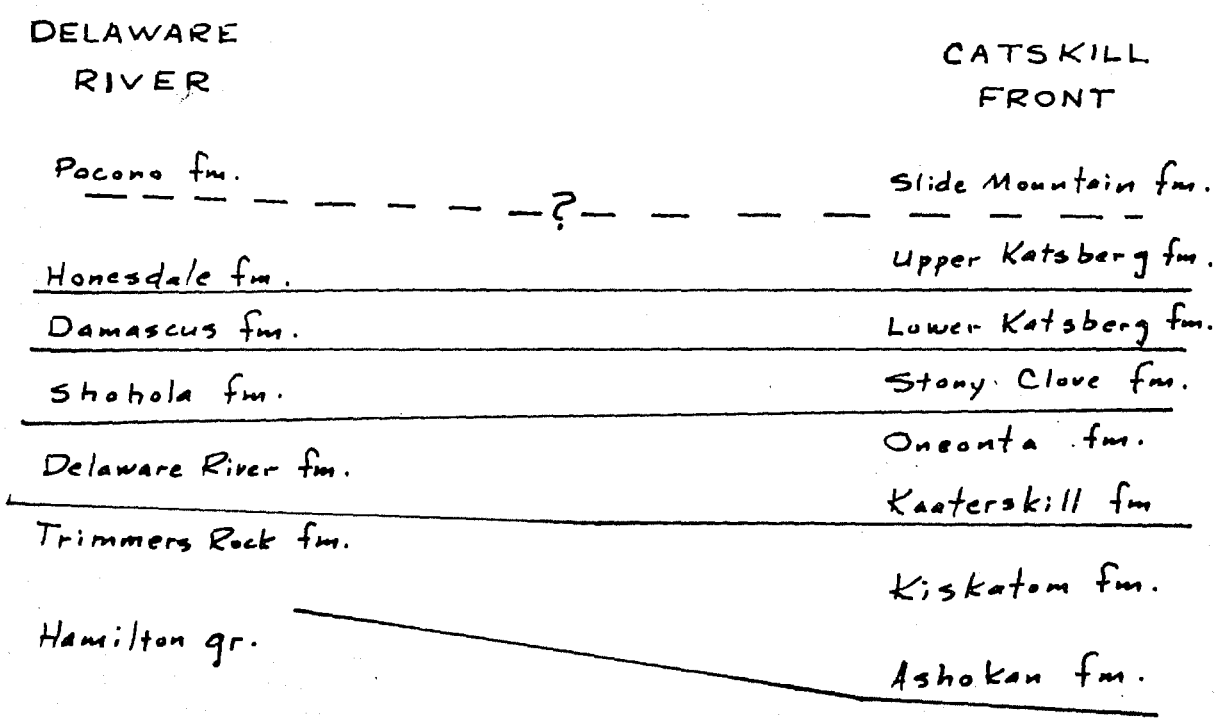
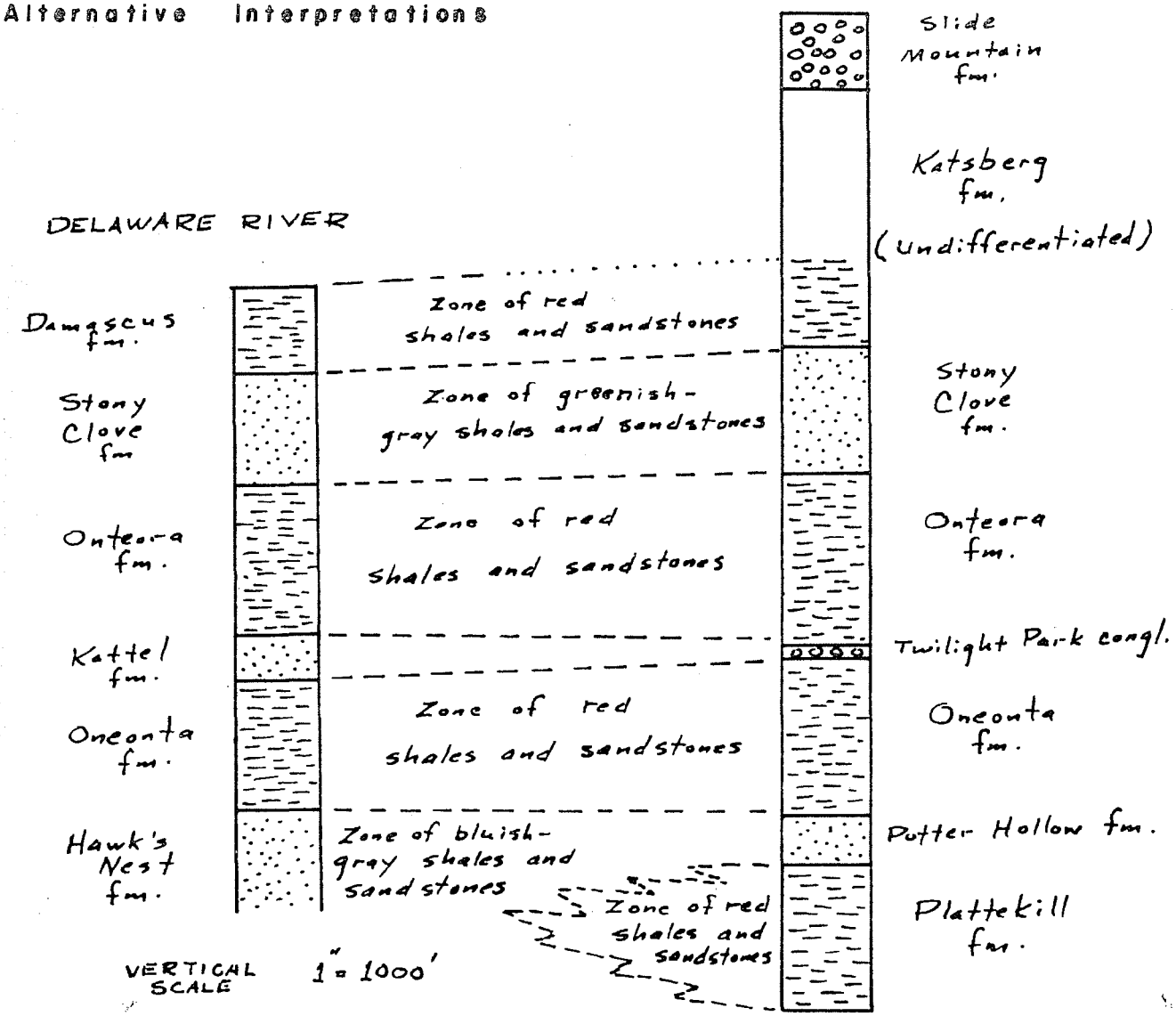


PLATE III

CORRELATION CHART

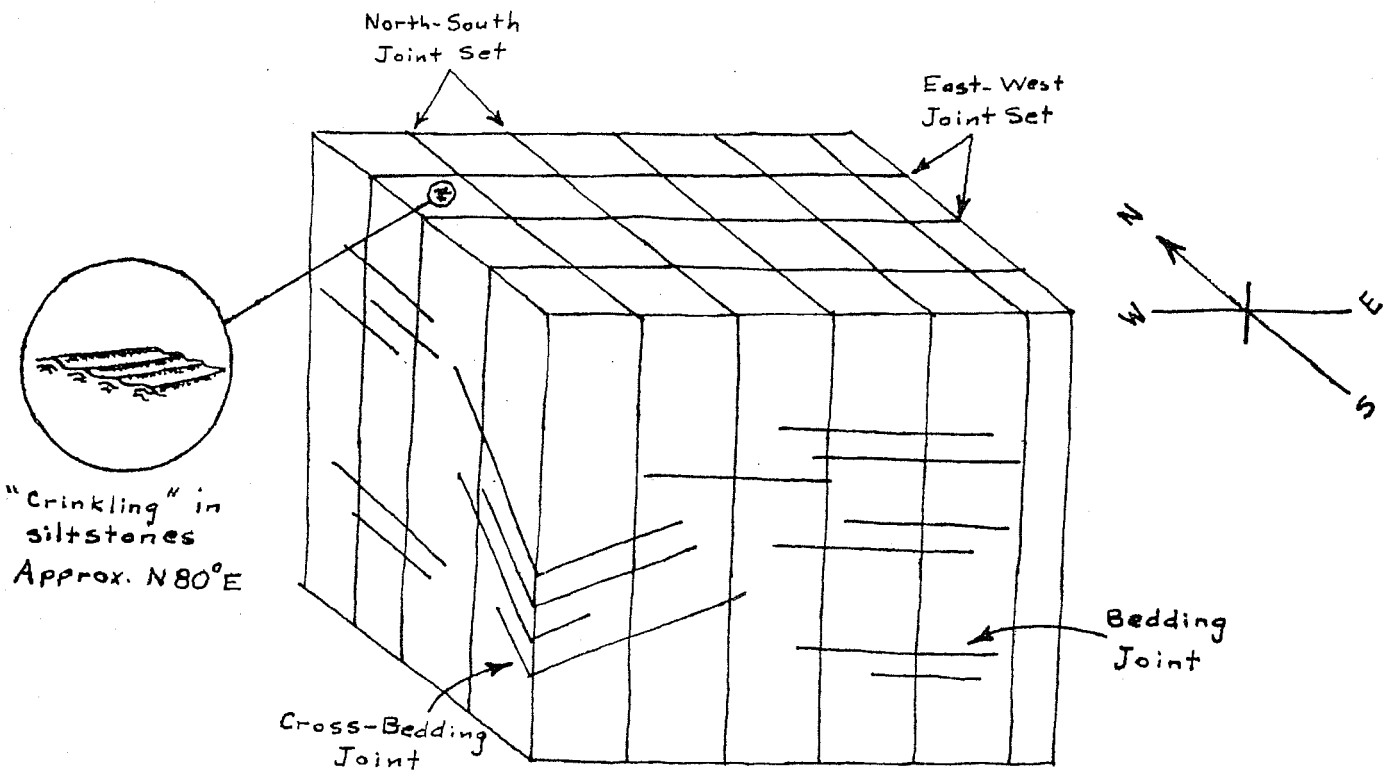
Alternative Interpretations



Delaware River		Catskill Front		western & Central New York	
Willard 1936	Fletcher	Chadwick 1944	Fletcher		
Honesdale		Slide Mountain	Slide Mountain		West Falls group
		Katsberg	Katsberg		
Damascus	Damascus				
	Stony Clove	Stony Clove	Stony Clove	Rhinestreet	
Shohola	Onteora	Onteora	Onteora	Cashaqua	Sonyea group
	Kattel	Twilight Park	Twilight Park	Middlesex	
Delaware River	Oneonta	Kaaterskill	Oneonta	Ithaca	Genesee gr.
	Hawk's Nest	Kiskatom	Potter Hollow	Moscow	Hamilton gr.
——	"Hamilton"		Plattekill	Ludlowville	

PLATE IV

TECTONIC STRUCTURES



SEDIMENTARY STRUCTURES

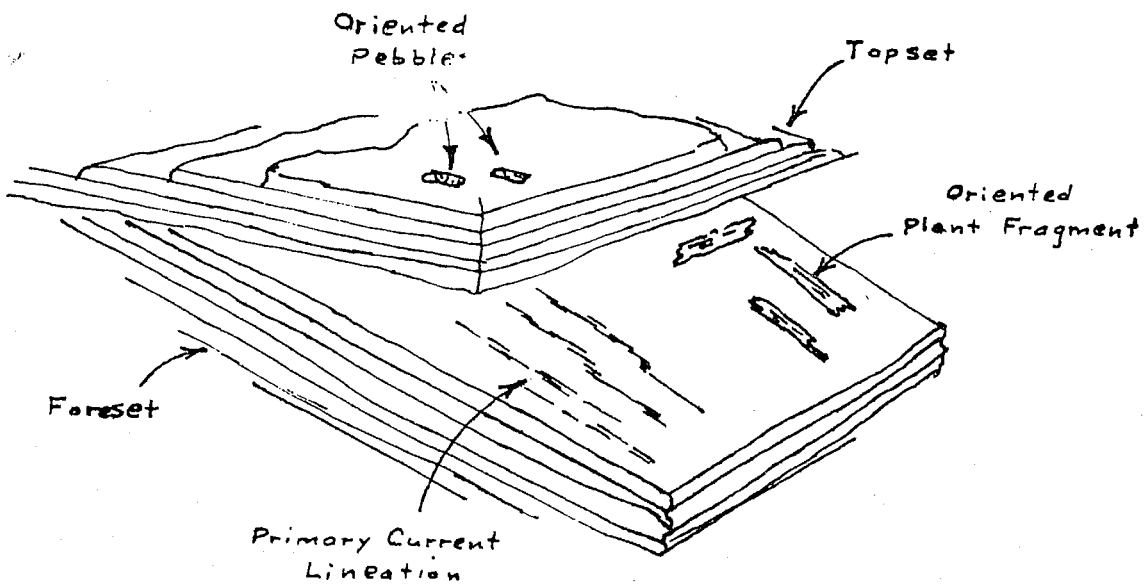
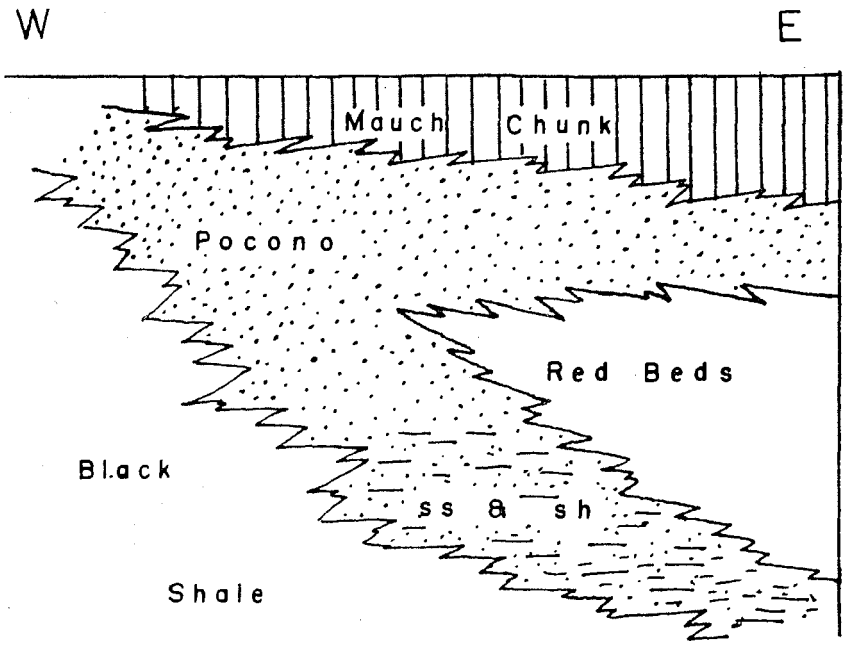


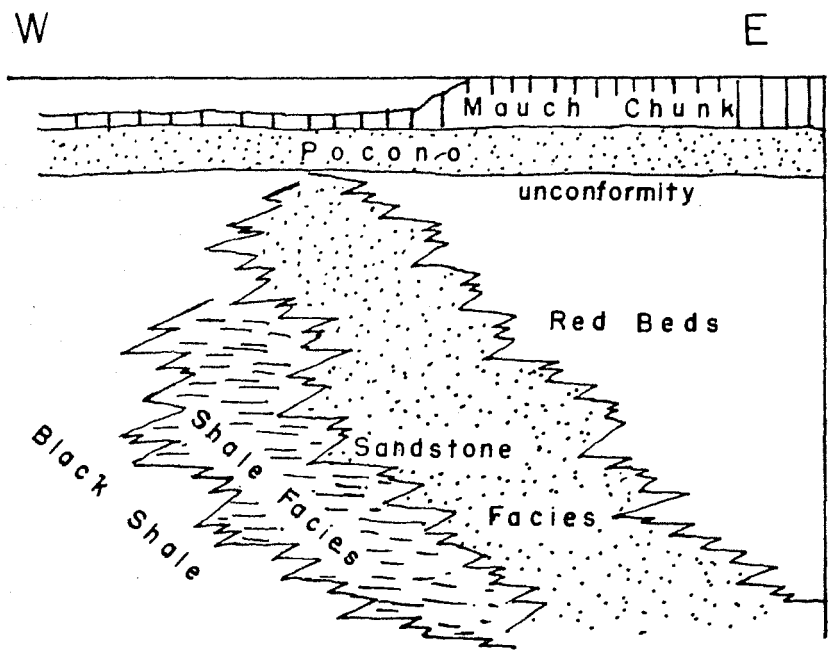
PLATE V

PLATE VI

ALTERNATIVE INTERPRETATIONS OF THE POCONO-CATSKILL CONTACT



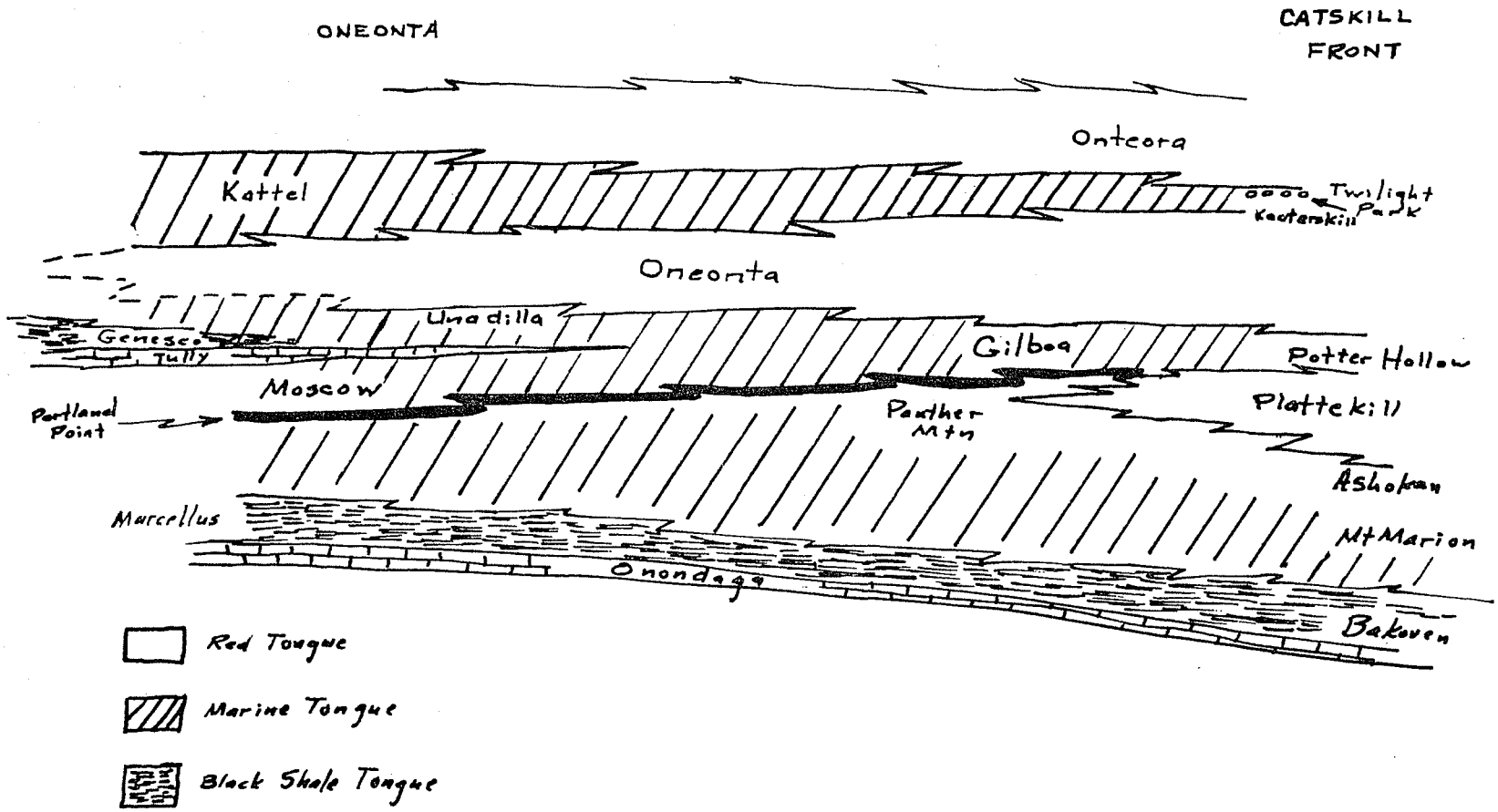
(Suggested by Weller, 1960, Stratigraphic Principles and Practices, Harper Bros., p. 399, fig. 156.)



(Suggested by Ashley, 1938, Am. Assoc. Petroleum Geologists Bull., v. 22, p. 422, fig. 5.)

PLATE VII

MARINE - NONMARINE FACIES RELATIONSHIPS



THE FRANKLIN STERLING MINERAL AREA

by
Helen A. Biren, Brooklyn College

TRIP E

Introduction

The area which we shall visit is a limestone region lying in the New Jersey Highlands, which is part of the Reading Prong. It extends in a northeasterly direction across the northern part of the state.

The rocks are Precambrian "crystallines" with narrow belts of infolded and infaulted Paleozoic sedimentary rocks. Major longitudinal faults slice the fold structures, so that the area has been described as a series of fault blocks extending from south of the Sterling Mine to Big Island, N. Y.

For many years the Franklin Limestone yielded enough zinc to make New Jersey a leading producer of this commodity. Mining has steadily decreased in this area, and in 1955 the Franklin Mine was shut down permanently, so that mineral specimens are derived mainly from surface dumps and quarries. Some twenty million tons of ore were removed from Franklin before it was shut down.

Prior to mining, the ore outcropped in two synclinal folds completely within the limestone, which pitched to the northeast at an angle of about 25° with the horizontal. In these two horseshoe shaped bodies were developed the Franklin and the Sterling Mines. This zinc ore is unique in its lack of sulfides and lead minerals, and in the occurrence of franklinite and zincite as substantial ore minerals.

The limestone has produced nearly 200 species of minerals, some 33 of which were first found in Franklin, and about 30 of which have never been found elsewhere.

The emphasis for this trip will be on mineral collecting, and no attempt will be made to demonstrate the many complex mineralogical and geological problems still unsolved here.

History

A very brief history of the area may be of interest. The earliest records go back to about 1640, when Dutch miners in the Minisink Valley prospected the Sterling ore.

Originally this was a pig iron center, the first forge built at Franklin about 1770. The unsuspected zinc and manganese prevented successful smelting, so the industry came to a standstill by 1820.

Between 1820 and 1850, Dr. Samuel Fowler, his son Col. Samuel Fowler, and a number of other scientists, studied the ores and recognized their composition and properties.

In 1841 the N. J. Zinc and Copper Mining and Manufacturing Co. was chartered, and in 1850 the ore bodies were successfully exploited, the principal product being zinc oxide. In 1854, the company started roasting franklinite for zinc oxide, and smelting the residue for manganiferous iron.

From this time on there was continuous expansion; in 1880, the Trotter shaft was sunk into the pegmatite and the pneumatolytic zones; the Buckwheat area near Mine Hill was opened and stripped; and in 1888, electromagnetic concentration of ore resulted in the production of zinc oxide and spiegeleisen from the franklinite, and zinc from the willemite. In 1896, the Parker shaft was opened, and many new species were found.

Much litigation among the various companies had interfered with production, but in 1897 all the properties were consolidated in the present New Jersey Zinc Co., and the mines were continually productive until 1954 when the Franklin Mine could no longer be worked profitably, and was completely shut down in 1955. The Sterling Hill Mine at Ogdensburg is still expanding.

General Geology

Franklin is located in a zone of Precambrian rocks flanked by Paleozoic inliers. The zinc ores, as well as some iron ores, occur exclusively in Precambrian rocks, generally classified as metasedimentary, igneous and metavolcanic types. A detailed study of the Precambrian geology of this area is to be found in Baum (1957).

The Franklin Marble, which contains the ore, is a crystalline white limestone and dolomite, sometimes siliceous, and characterized by the presence of blocks and bands of dark gneiss which were broken and displaced by the deformation of the marble.

West of the Franklin Marble has been mapped a zone called the "Pochuck Gneiss," which more recently has been described on the basis of mineral assemblage, rather than as a unit formation.

To the east of this area the Precambrian Bryam gneiss outcrops. Baum (1957) divides this into three major types, based on grain as well as mineralogical criteria.

The pegmatites found in the the Precambrian rocks have been divided into sodic and potassic types. The contact zones of these pegamtites are the locale for many of the rare mineral species found in this region.

The Kittatinny Limestone is a thick dolomitic series of early Cambro-Ordovician Age, which outcrops to the north and east of Franklin Pond. The Kittatinny is separated from the Precambrian rocks by longitudinal faults which trend northeast. In the graben at Franklin Pond the Kittatinny shows some post-Ordovician folding, but this is not indicated in the Precambrian rocks.

Origin of the Ore

Many hypotheses concerning the origin of the ores in this area have been advanced, but so far no single hypothesis has satisfactorily explained all the peculiarities present. Pinger (1948) has reviewed and discussed these hypotheses, which come under the following general headings:

1. Igneous injection.
2. Sedimentary ore deposited in the limestone and later metamorphosed.
3. Contact metamorphism due to injection of the pegmatites.
4. Replacement from magmatic solutions.

The hypothesis which comes closest to fulfilling the conditions observed is that of replacement of favorable horizons in the limestone by a primary oxide ore, since elimination of sulphur after emplacement is difficult to explain. Sampson (1957) has given additional detail of features and facts which must be considered in the formulation of a theory of origin.

The minerals which could be considered "rare and interesting" rather than ore minerals, are generally interpreted as "contact" minerals, formed by the interaction of hydrothermal solutions with limestone or dolomitic host rock. The host rock supplied calcium and magnesiu, the magmatic solutions brought in silica, water, and rare elements like boron, fluorine, and beryllium. (See Montgomery, Picking Table, June 1960.)

Route Stops

On the accompanying sketch map (taken from Pinger, 1948) numbers have been placed to locate the areas which we shall visit.

Below is a brief note on each location, but specific information concerning details of the mineral descriptions, paragenesis and associations can be best obtained from the paper by Palache (1935).

Stop No. 1, Sterling Hill:

The Lord Sterling Pits, the earliest known workings (1770) outcropped in the legs of a syncline in the Franklin Limestone, which pitches northeast at an angle of about 50° from the horizontal. Details of the structure are quite complex. About 1913 a shaft was sunk and extensive underground development started.

The ore appears to have followed definite stratigraphic horizons in the folded structure, since the banding of the Franklin Limestone and the complex folding of the ore veins appear to conform. Pegmatites are not present with the ore, so fare minerals are fewer than at Franklin. Minerals reported from this area (other than the common species listed on the chart) include: Chalcophanite, McGovernite, Mooreite, and Roepperite.

Stop No. 2, Farber Quarry:

The Farber Quarry (formerly the Bigelow Quarry) on Cork Hill Road at the Franklin-Ogdens rg line is the only active local quarry.

In this white limestone may be found tremolite in fluorescent crystals, pyrite crystals and calcite, chondrodite, norbergite, magnetite, dolomite, edenite, fluorite, graphite, hematite, phlogopite and scapolite.

Stop No. 3, Slag Heap:

Along the east side of Cork Hill Road are large dark boulders which represent slag from the old Franklin Furnace. Many minerals are present in some of the boulders, and the "vesicles" in the slag show a variety of fillings representing secondary mineralization.

Stop No. 4, B. Nicol Quarry (Formerly the Fowler Quarry):

This was the largest quarry in the area, and was active at the turn of the century as a source of flue for the blast furnace.

It is requested that visitors stay clear of the buildings of the Cellate Corporation, and do not smoke in the vicinity of the buildings or drums.

Recent visits to this quarry have yielded specimens of amphibole, apatite, arsenopyrite, chondrodite, diopside, edenite, fluorite, graphite, magnetite, phlogopite, pyrite, pyrrhotite, pyroxene, quartz, scapolite, spinel and green and brown tourmaline.

Stop No. 5, Furnace Quarry:

This is an abandoned quarry in the white limestone which has yielded many metamorphic minerals, including arsenopyrite, edenite, fluorite, graphite, norbergite, pyrite, pyrrhotite, rose quartz, sphene, spinel and tourmaline.

Stop No. 6, Buckwheat Dump:

In 1852 the eastern leg of the syncline was discovered, and was stripped to form the Buckwheat open cut. Much of the overburden was removed to the dump.

The accompanying key lists 50 minerals which are likely to be found there. Since the town of Franklin turns the dumps over at intervals, fresh materials are exposed, so that there is a likelihood that a variety of species will be available.

In the sheds at the foot of the dumps some long and short wave ultraviolet lamps will be available for determining fluorescent phenomena. Accompanying this paper is a chart describing the fluorescence of Franklin

minerals, as observed and as reported in the literature. Not all samples of a given mineral will display the described fluorescence, but it is certain that Buckwheat will yield some fluorescent material.

Stop No. 7, Mine Replica:

The mine replica is an authentic duplicate of a typical working space in the abandoned Franklin Mine, and a display of fluorescent minerals under ultra-violet light. This is an optional trip and involves a 50-cent admission charge. Since only a limited number can be accommodated at one time, arrangements for this visit will be made while the rest of the group is collecting at the various quarries.

This trip also offers a good view of the Buckwheat open cut.

Lunch:

Lunch will be at the Village Inn on Route 23 (sandwiches, homemade pie, coffee - $1.00). Please make your reservation in advance at the registration desk.

Acknowledgments

The Franklin-Ogdensburg Mineral Society have cooperated generously with the committee, and we want to thank both Mr. William Spencer, their president, Mr. Frank Edwards, secretary-treasurer, and all the members and experts on Franklin minerals who have kindly given their time to aid the group in identification of specimens.

We wish also to thank Mr. R. Provost of Cellate, Inc., for permission to visit the B. Nicol Quarry, and Mr. F. M. Dunn for permission to visit the Farber Quarry.

Bibliography

A complete bibliography with annotations is given in the U.S.G.S. Prof. Paper 180, "The Minerals of Franklin and Sterling Hill, Sussex Co., N. J." by Charles Palache, 1935.

New Mineral species are frequently discovered and described, old species restudied for further detail or validation. This material usually is available in relatively short papers in the following publications:

American Mineralogist - Journal of the Mineralogical Society of America. Editor, L. S. Ramsdell.

Franklin Digest - a booklet published annually by the Franklin Mineralogical Association, Box 408, Middleburgh, N. Y. This specializes in reprinting important papers on Franklin Mineralogy.

Notes on Minerals of Franklin and Sterling Hill, N. J. A quarterly published by John S. Albanese, P. O. Box 221, Union, N. J.

Rocks and Minerals - A bimonthly magazine edited by Peter Zodac, Box 29, Peekskill, N. Y.

The Picking Table - A publication of the Franklin-Ogdensburg Mineralogical Society, Inc., Box 146, Franklin, N. J.

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Brief Key to 50 Common Minerals
(as found in Franklin-Sterling area)

LUSTER - METALLIC

Color	H	Streak	Disting. Properties	Name
Black	6	Black	Octahedrons or massive; no cleavage; strongly magnetic.	Magnetite
	6	Brown	Rounded octahedrons or massive; no cleavage; weakly magnetic.	Franklinite
Gray	1	Black	Folia; greasy feel; flexible; marks paper.	Graphite
	$2\frac{1}{2}$	Gray	Isometric-cubes; perfect (100) cleavage.	Galena
	6	Red-brown	Tabular crystals; no cleav.; parting good.	Hematite
Blue-gray	1	Blue-gray	Hexagonal folia, flexible; marks paper; heavier than graphite.	Molybdenite
Silver white	6	Gray-black	Prismatic striated xls.; massive; imperf. cleav.	Arsenopyrite
Brass-yellow	$3-3\frac{1}{2}$	Greenish-black	Usually hairlike xls., in cavities; not plentiful in Franklin.	Millerite
	4	Greenish-black	Usually massive, tarnished bluish, cleav. imperfect; yellower and softer than Pyrite.	Chalcopyrite
	$6\frac{1}{2}$	Brown-black	Pyritohedrons, cubes, massive; no cleav.	Pyrite
Bronze-yellow	4	Gray-black	Usually massive or "drops" hexag.; no cleav.; tarnishes brown; magnetic	Pyrrhotite
Bronze-brown	3	Gray-black	Tarnishes purple; usually compact; no cleav.	Bornite
Copper-red	3	Red, metallic	Usually dendritic, wires; malleable	Copper

LUSTER - NON-METALLIC

Color	H	Streak	Disting. Properties	Name
Colorless-to-white	2½-3	-	Irregular platy elastic flakes; perf. cleavage.	Muscovite
	3	-	Usually opaque; cleavage rhombic; may be pink, brown; effervesces in dilute HCl; fl. red.	Calcite
	3	-	Usually cleavages - perfect - or massive; heavier than calcite. Fl. pale blue.	Barite
	3½-4	-	Usually crusts on other minerals. Rare, fluor-yellowish cream.	Aragonite
	3½-4	-	Curved rhombic xls.; massive granular; good cleavage.	Dolomite
	4	-	Earthy white films; good cleav.; fl. cream.	Smithsonite
	5	-	Usually translucent - transparent; often cox-comb xls. Good cleav.	Hemimorphite
	6	-	Usually columnar or fibrous; fl. blue.	Tremolite
	6	-	Rare color. May fl-green; cleav. imperf.	Willemite
	6	-	Usually massive; good cleav.; twin planes.	Albite
	7	-	Many small vitreous colorless xls. in pockets.	Quartz
Yellow	5.5	-	Massive, honey colored, opaque.	Chondrodite
	5.5	-	Massive, honey colored. Fl. (at Franklin) buff.	Norbergite
	7	-	Yellow brown, wedge shaped xls.; massive; Fl. red	Axinite
Brown	2½	-	Usually brown, may be green; massive, compact, fibr.	Serpentine
	2½	-	Irregular elastic plates, blackish-brown	Biotite
	2½-3	-	Hexagonal, bronze colored elastic platy xls.	Phlogopite
	3-5½	Yellow-brown	Mustard colored powdery alteration product.	Limonite
	4	Yellow	Usually massive resinous luster, yellow-brown.	Sphalerite

LUSTER - NON-METALLIC (Cont'd)

Color	H	Streak	Disting. Properties	Name
Brown (cont'd)	5-6	-	Orthohombic; massive; conchoidal fract.	Bementite
	6	-	Usually massive, imperf. cleav.; fl. green.	Willemite
	7	-	Good dodecahedrons, or granular massive, may be black (polydelphite). No cleavage.	Garnet (spessartite)
	8	-	Isometric xls - octahedrons. Imperf. cleav.	Spinel (Gahnite)
Gray	6	-	May be massive gran; tetragonal prismatic xls; good cleav.; may fl. orange or yellow.	Scapolite
	$6\frac{1}{2}$		Var. of olivine; granular-massive; good cleavage.	Tephroite
Gray-Green	5		Hexagonal, prismatic xls; good termin. fl. yellow-orange - pinkish.	Apatite-Svabite
	6		Monoclinic, prismatic xls; good (110) cleav.	Diopside
	9		Hexag. prisms, good basal cleav.	Corundum
Green	2		In tiny plates or folia- flexible-deep green.	Chlorite
	4		Usually massive, compact, apple-green.	Malachite
	4	Yellow	Resinous, translucent- fluor. orange.	Sphalerite-cleiophane
	6	-	Imperf. cleav. Fluor. green.	Willemite
	6	-	Good cleav. - 2 directions; Triclinic.	Amazonstone
	6-7	-	Massive, granular, crystalline, medium green.	Epidote
Blue	4	-	Usually massive, granular, light to medium blue.	Azurite

LUSTER - NON-METALLIC (Cont'd)

Color	H	Streak	Disting. Properties	Name
Pink	3½-4	-	Massive, granular, good rhombic cleav., opaque.	Rhodochrosite
	5.5-6	-	Triclinic - bright pink prismatic xls; massive, granular	Rhodonite - bustamite
	6	-	Salmon-pink. Good cleav. - 2 directions.	Microcline
	9	-	Hexagonal barrel-shaped xls, basal cleavage.	Corundum (ruby)
Red	4-4½	Orange	Xls rare; usually grains or plates. 1 cleavage.	Zincite
	6	-	Brownish-red, imperfect cleavage. Fl. green.	Willemite
Purple	4	-	Comes in all shades - white, cubic xls, good triangular cleav. faces. Streaks in ls.	Fluorite
Black	6	-	Greenish black, silky luster, columnar xls, prismatic cleavage; wedge shaped.	Amphibole - edenite
	8	-	Isometric xls - octahedrons; imperfect cleavage.	Spinel - gahnite

FLUORESCENT FRANKLIN-STERLING MINERALS

Name	Daylight Color and Characteristics	Iron Arc.	Short Wave	Long Wave
RED FLUORESCENCE				
Corundum	red or green - in ls.	-	weak red	bright red
Rhodonite	pink to brownish pink	-	-	pink to deep red
Calcite	white-pink cleavages		bright red	purple-red
Mooreite	white (may have been mis-identified)		red	
Axinite	yellow, or xlized man-ganaxinite	-	dull red	pale red
Sphalerite	light greenish brown	-	pale red	bright orange
PURPLE FLUORESCENCE				
Barylite	white plates in hedyphane, with willemite	lavender		
Hardystonite	white to pink grains in ls.	violet	violet	purple to none
ORANGE FLUORESCENCE				
Pectolite	colorless or white	yellow	yellow-orange	same
Sphalerite	vitreous green-brown-cleiophane	-	rose-orange	bright orange
Clinohedrite	amethystine-white, vitreous	orange	orange	pale yellow - none
Wollastonite	white, silky, bladed	-	bright orange	pale orange
Svabite	gray apatite	-	yellow-orange	none
YELLOW FLUORESCENCE				
Tourmaline	brown, yellow, green, prisms		yellow	-
Scapolite	white, gray, translucent xls	-	pale	yellow-orange
Cerussite	colorless, white - mainly Sterling	-	pale	bright yellow
Norbergite	honey colored in ls.	-	buff	-
Phlogopite	bronze mica with calcite	-	dull yellow	
Calcium larsenite	white, opaque, greasy luster	lemon-yellow	bright lem. yel.	pale yellow
Willemite	small crystals from Sterling Hill		gold to lemon yel.	-

Name	Daylight Color and Characteristics	Iron Arc.	Short Wave	Long Wave
	GREEN FLUORESCENCE			
Willemite	massive, resinous, colorless, red, green, black		bright yel. gr.	duller green
Fluorite	gray to purple, compact granular	blue	blue-green	blue-green to none
Apatite	crystals-prisms, translucent blue		pale green	-
Levco phoenicite	brown-purplish red, isolated grains or massive granular		yellow-green	dull green
	BLUE FLUORESCENCE			
Hydrozincite	white powdery alteration; films, crusts	-	blue to blue wh.	faint white
Hedyphane	small brilliant white to buff xls. Not confirmed.	grayish blue		
Diopside	colorless to gray, basal parting, twinned	-	creamy blue	-
Anorthite	gray tabular crystals in pegmatite	-	pale blue	-
Tremolite	gray or white xls in ls., some fibers		pale greenish blue	-
Thomsonite	var. calcio thomsonite, radial aggregates of fine needles	-	none	pale blue
Nasonite	white, rectangular blocks greasy luster		blue (not confirm.)	
Margarosanite	white, rhombic cleav., colorless, lamella masses	pale violet-blue	pale violet-blue	
Calcite	white, Franklin ls.		bright blue	
	WHITE-CREAM FLUORESCENCE			
Smithsonite	white crusts and coatings	-	-	yellowish cream
Barite	white, transparent, colorless, plates	-	pale bluish cream	pale blue
Amazonstone	green microcline	-	blue-white	-
Aragonite	white films and crusts	-	white	white
Pectolite	gray-white to colorless, massive	yellow	chalky orange	white

VALIDATED FRANKLIN-OGDENSBURG MINERAL SPECIES

As of February 1961, some 176 species (exclusive of varieties) of F-O minerals have been validated by Professor C. Frondel. Others are being investigated. The order of listing follows Dana, except for the silicates.

Species found only at Franklin or Sterling are marked with an asterisk.

native elements

1113 Silver
1114 Copper
1115 Lead
1211 Arsenic
1242 Graphite

sulfides

2321 Chalcocite
243 Bornite
2611 Galena
2621 Sphalerite
2631 Chalcopyrite
2642 Greenockite
2651 Pyrrhotite
2653 Niccolite
2655 Millerite
26.10 Realgar
2911 Pyrite
2922 Gersdorffite
2931 Loellingite
2933 Rammelsbergite
2934 Pararammelsbergite
294 Marcasite
2951 Arsenopyrite
2961 Molybdenite
2.10.11 Skutterudite

3242 Tennantite

oxides

411 Cuprite
413 Water
4213 Manganosite
4221 *Zincite
4411 Corundum
4412 Hematite
4413 Ilmenite
4511 Rutile
4514 Todorokite
453 Brookite

hydroxides

6111 Brucite
6112 Pyrochroite
613 Manganite

multiple oxides

7122 Goethite
7211 Spinel
7213 Gahnite
7216 Magnetite
7217 *Franklinite
7221 Hausmannite
7222 *Hetaerolite
7223 Hydrohetaerolite
761 *Chalcophanite

unlisted oxides

Birnessite
Hydrohausmannite
Woodruffite

halides

9.2.1 Fluorite

carbonates

14.1.1.1 Calcite
14.1.1.3 Siderite
14.1.1.4 Rhodochrosite
14.1.1.6 Smithsonite
14.1.3.1 Aragonite
14.1.3.4 Cerussite
14.2.1.1 Dolomite
14.2.1.3 Kutnahorite
16.1.1 *Loseyite
16.1.3 Hydrozincite
16.1.4 Aurichalcite
16.1.6 Malachite
16.1.11 Azurite

borates

26.1.1 Fluoborite
26.1.5.1 *Sussexite
26.1.6 *Roweite
27.1.2 *Cahnite

sulfates

28.3.1.1 Barite
28.3.1.2 Celestite
28.3.1.3 Anglesite
28.3.2 Anhydrite
29.6.3 Gypsum
29.6.6.1 Hexahydrite
31.1.3 *Mooreite
31.1.4 *Torreyite
31.3.2 Ettringite

phosphates, arsenates

38.2.1.2 Manganberzeliite
40.2.4.2 Brandtite
40.2.15.2 Erythrite
41.1.2 *Holdenite
41.1.4.1 *Chlorophoenicite
41.1.4.2 *Mg. Chlorophoenicite
41.2.4 Allactite
41.5.2.1 Descloizite
41.6.3.3 Sarkinite
41.7.7.1 Fluoapatite
41.7.3.1 Svabite
41.7.3.2 Hedyphane

Quartz

Orthoclase
Hyalophane
Microcline
Anorthoclase
Albite
Anorthite

Diopside
Hedenbergite
*Jeffersonite
Johannsenite
Schefferite
Augite

Rhodonite
Bustamite
Wollastonite
Pectolite

Anthophyllite
Cummingtonite
Tremolite
Edenite
Riebeckite
Hastingsite

Cuspidine

Barysilite
Nasonite
Margarosanite
Barylite
*Roeblingite

Grossularite
Almandite
Spessartite
Andradite

Glauchochroite
Forsterite
Hortonolite
Tephroite

*Larsenite
*"Calcium Larsenite"

Willemite

Friedelite
Manganpyrosmalite
*Schallerite

*McGovernite

Scapolite

*Hardystonite

Idocrase

Zircon
Thorite

Sillimanite
Kyanite

Datolite

Zoisite
Epidote
Allanite
*Hancockite

Axinite

Prehnite

Norbergite
Chondrodite

*Leucophoenicite

Kentrolite

Hemimorphite
*Clinohedrite

Tourmaline

Xonotlite
Ganophyllite
Apophyllite
Heulandite
Stilbite
Chabazite
Natrolite
Thomsonite

Muscovite
Biotite
Manganophyllite
Phlogopite

Stilpnomelane

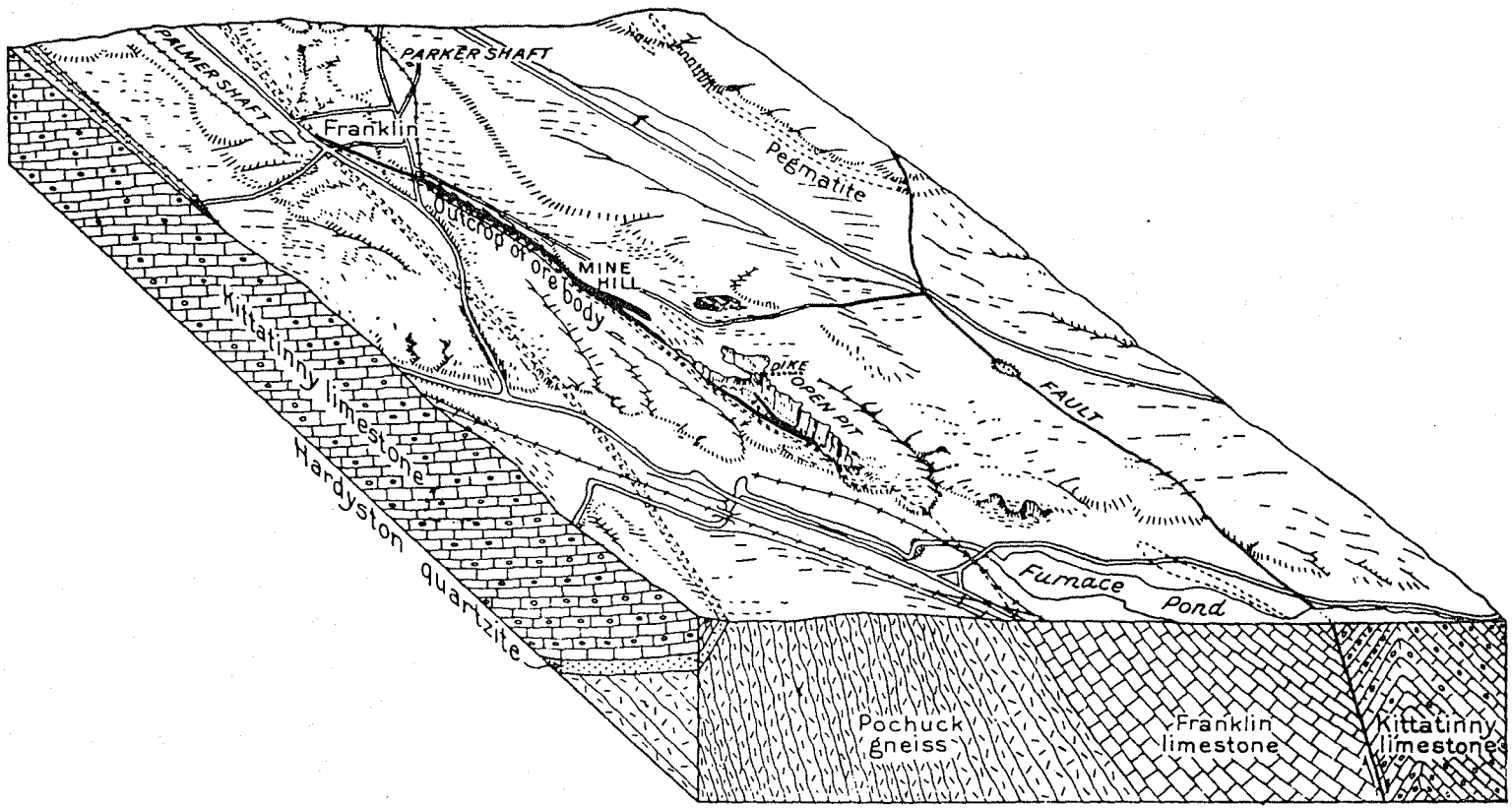
Antigorite
Bementite
Chrysotile

Zimalsite

*Hodgkinsonite
*Gageite

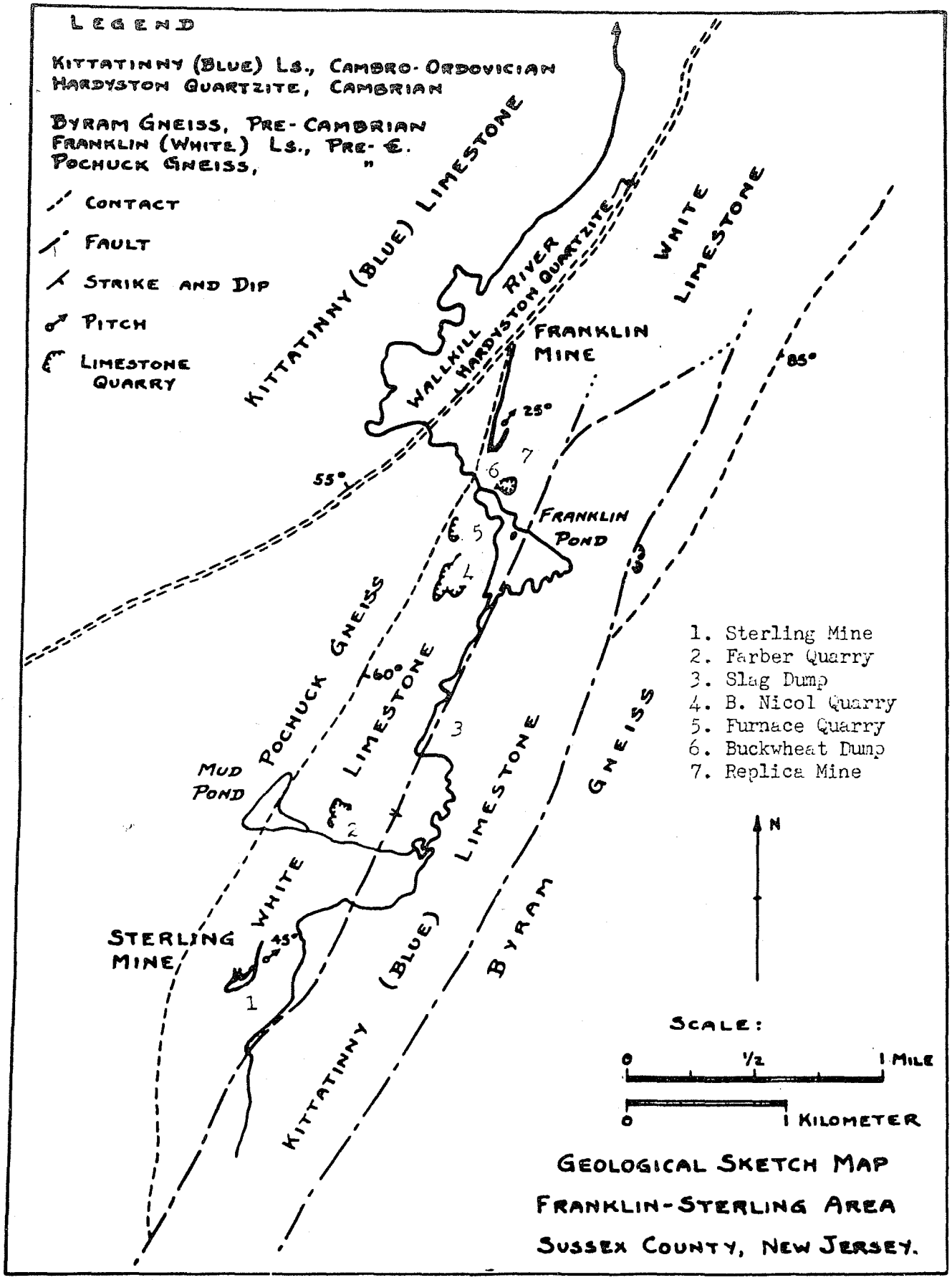
Sphene

Yeatmanite



Block diagram illustrating the general relations of the ore deposits at Franklin, the geography of the surface, and the contacts in the vicinity of the ore

From: Internat. Geol. Congress XVI, Guidebook 8, p.7



From: Geological Society of America, Guidebook, 1948