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1824

NEW YORK STATE GEOLOGICAL ASSOCIATION

TROY
MAY 1961

33rd Annual Meeting

GUIDEBOOK TO FIELD TRIPS

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RENSSELAER POLYTECHNIC INSTITUTE

Troy, N. Y.

May 12-13, 1961

PREFACE

Geologic studies in Rensselaer and Columbia Counties began in the infancy of American Geology. It is especially noteworthy that our host, Rensselaer Polytechnic Institute, played a vital role in the development of this then new science. The founding of the Rensselaer School (1824) by Stephen Van Rensselaer, Patroon of Albany, was a distinct departure from the conventional classical institute of higher learning of that day. This school of science (the idea of an engineering school came later) claimed the unique innovation of having science taught by personal contact in laboratory, field, and by classroom functions in which students lectured while professors listened! That geology was highly regarded is evidenced by the Rensselaer circular of 1827 which reads, "....it is now required that each student take two short mineralogical tours to collect minerals for his own use, for the purpose of improving himself in the science of mineralogy and geology." Into this promising environment, as Director of the Rensselaer School, came Amos Eaton, who had studied science under Benjamin Silliman and law under Alexander Hamilton.

In 1820-22, Van Rensselaer sponsored the first commissioned geological survey in this country, that of Albany and Rensselaer Counties. Amos Eaton was Geologist-in-charge with Joseph Henry, who was later to achieve fame in his own right, as his assistant. In the same year, Chester Dewey prepared a structure section from Troy, N.Y. to Williamstown, Mass. Again, under the patronage of Van Rensselaer, Eaton executed Governor DeWitt Clinton's far-sighted plan to make an agricultural and geological survey along the Erie Canal. This extraordinary accomplishment included a cross-section of the rock formations from Buffalo on the west to Williamstown on the east. Eaton further displayed his versatility by authoring textbooks on botany, zoology, and chemistry, as well as geology---thereby demonstrating his keen perception for related sciences. No more fitting tribute could be bestowed than that by his favorite student, James Hall, who said, "If we with great means do what he did with small, we shall deserve well of coming generations."

An impetus to geologic investigation was given in 1836 by the creation of the N.Y. Geological Survey, with the appointment of not one but four "State Geologists", all energetic men of equal authority and (it was hoped) equal competency: W. W. Mather, First or southeastern District; E. Emmons, Second or northern District; T. Conrad, Third or central District; L. Vanuxem, Fourth or western District. Conrad was selected for his reputation in conchology and because the New York rocks were known to be full of fossils and none of the other three knew anything about them. It soon became obvious that Conrad was overwhelmed with the business of identifying fossils and in 1837 the Survey was reorganized. Conrad was named first State Paleontologist, Lardner Vanuxem transferred to the Third District, and James Hall assumed responsibility for the Fourth. The fruit of this colossal endeavor was the monumental Geology of New York in four parts, which even today, forms the basis for any stratigraphic studies within the State.

The geological bibliography of the Troy area boasts the names of many of the pioneers of American Geology. Aside from Eaton, there were J. D. Dana, T. N. Dale, C. D. Walcott and Ebenezer Emmons, about whom we shall have more to say.

D. W. Fisher

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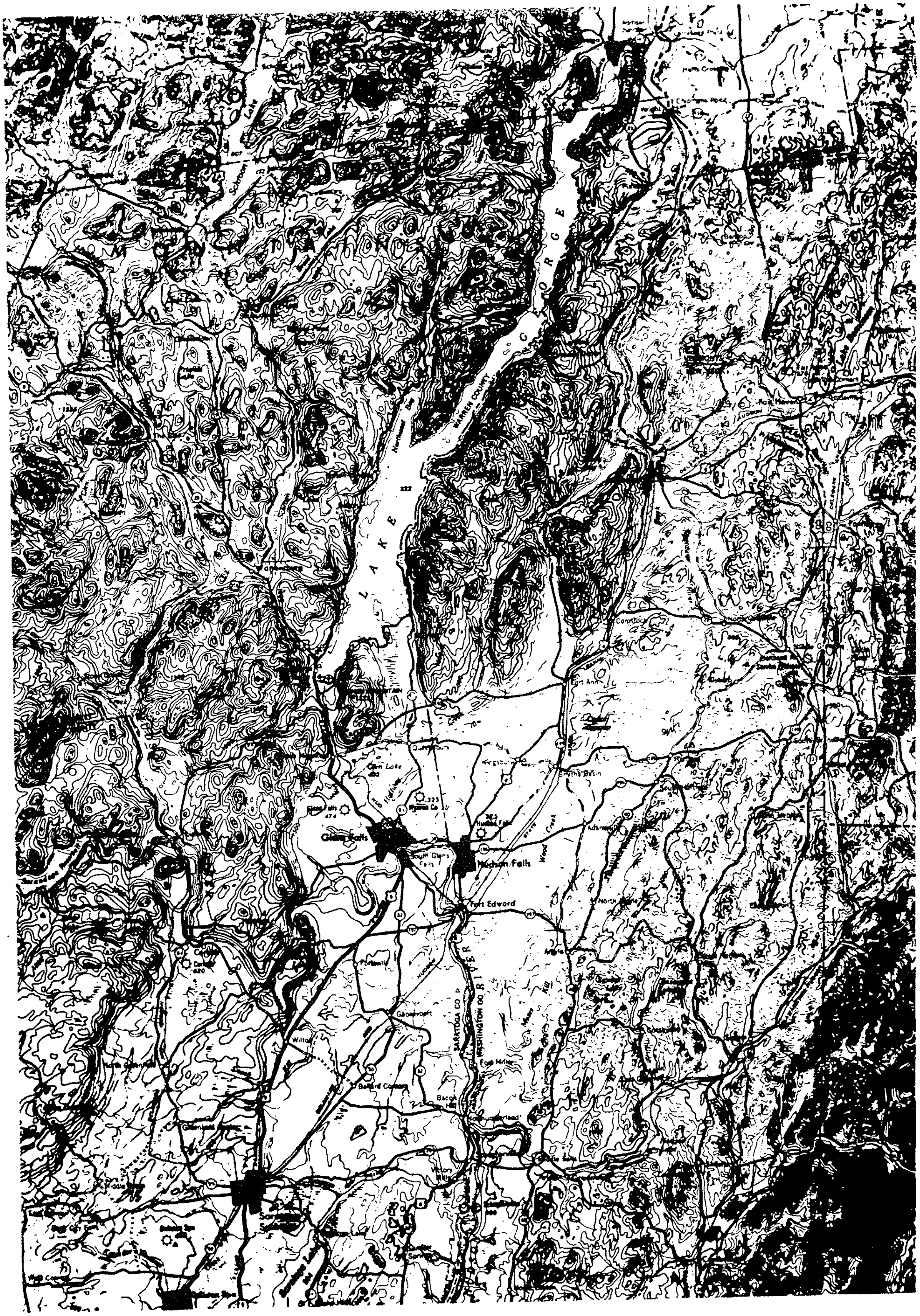
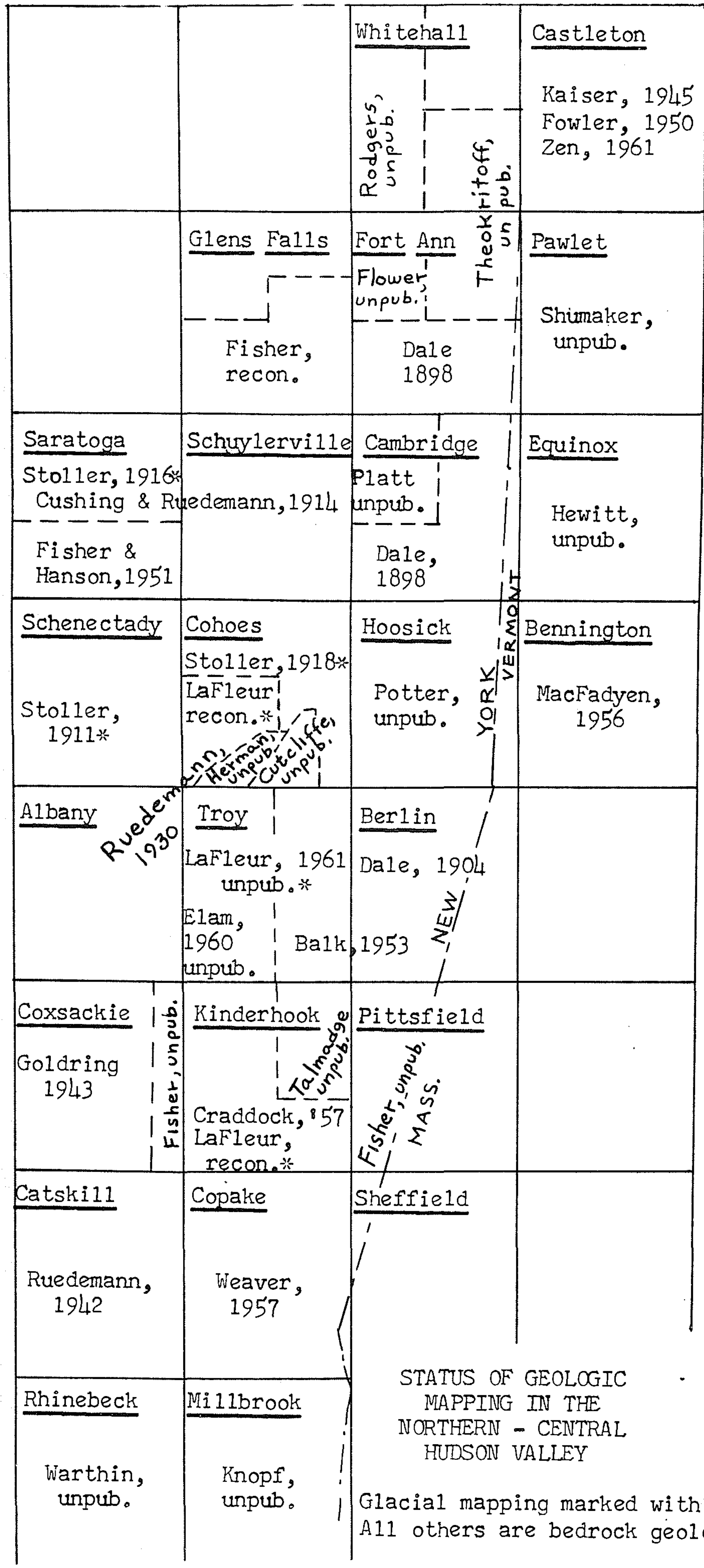
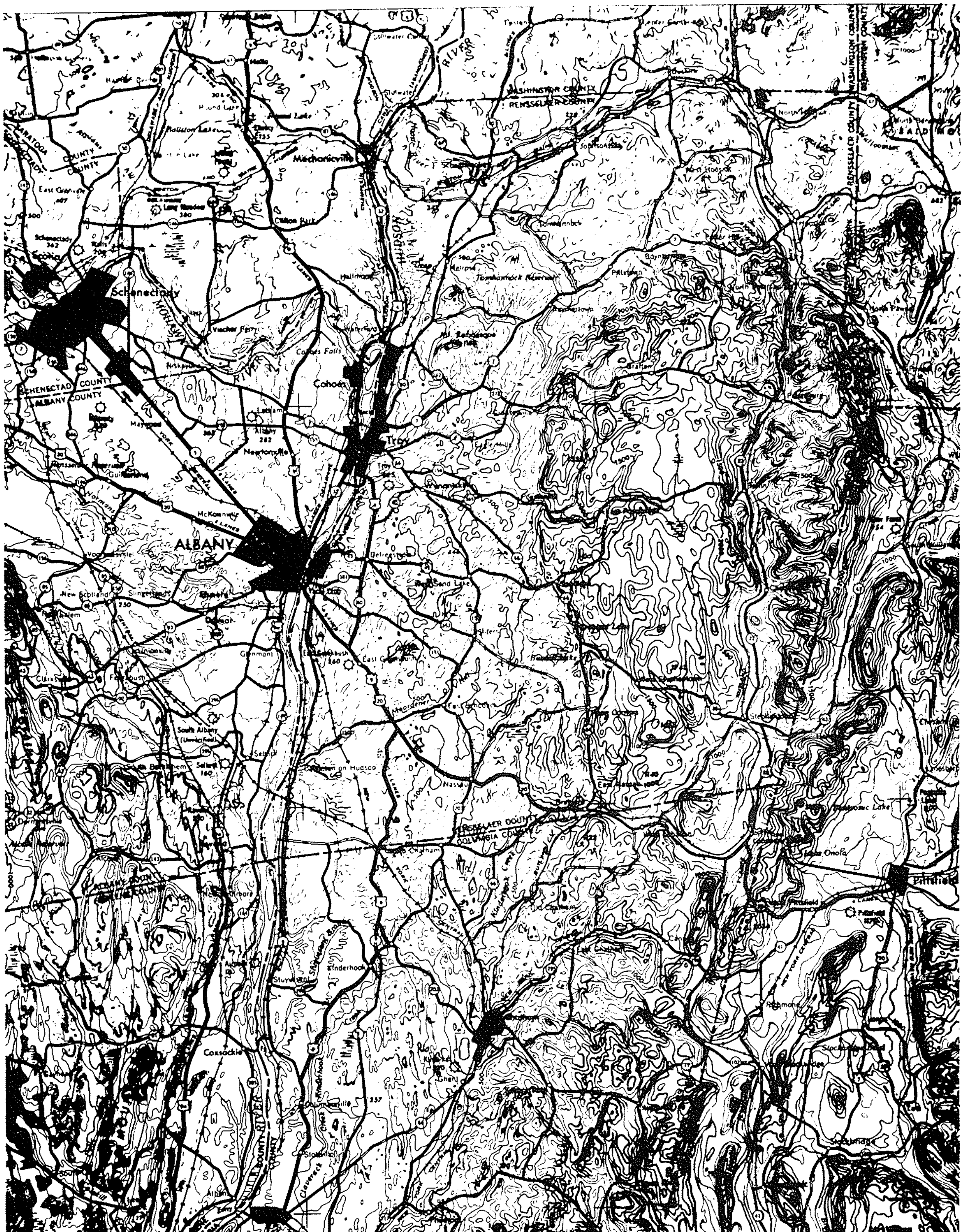


Northern Hudson - Southern Champlain Valleys
(Portion of the Glens Falls
1:250,000 sheet. U.S.G.S.)



STATUS OF GEOLOGIC MAPPING IN THE NORTHERN - CENTRAL HUDSON VALLEY

Glacial mapping marked with *. All others are bedrock geology



Central Hudson Valley - Southern Taconics - Northeastern Catskills

(Portion of the Albany 1:250,000 sheet. U.S.G.S.)

TRIP A

GLACIAL FEATURES IN THE VICINITY OF TROY, N. Y.

by Robert G. LaFleur

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INTRODUCTION

During the past 60 years, the Hudson-Champlain Valley has periodically received the attention of several glacial geologists. This valley, the longest and most continuous north-south lowland in the northeast, was considered a valuable area for field study because it connected the terminal moraines of Long Island with the St. Lawrence Valley. For many years workers believed that a continuous record of Wisconsin ice withdrawal northward from Long Island was indicated by the many kame terraces, deltas, and lacustrine clays exposed throughout the Hudson Valley.

The north-south trend of the valley also proved ideal for the study of glacial rebound, and this phenomenon occupied an important place in the works of Peet (1904), Woodworth (1905), and Fairchild (1918).

Only recently (Flint, 1953),(MacClintock, 1954) have the deposits between the Hudson Highlands and Glens Falls been assigned to the Cary Substage, younger than the Tazewell Long Island moraines. (See Plate I) This assignment has invalidated the correlation of Lake Albany and the Mohawk delta with Lake Iroquois, a supposition basic to the early descriptions of regional history. In effect, the time during which the Hudson Valley was deglaciated has been considerably shortened from original concepts, although many local details are still valid.

Among the controversial problems was the nature of the water bodies which formed during ice wastage. Most workers accepted the importance of a pre-glacial Hudson gorge as a topographic low capable of retaining a long N-S tongue of ice in the valley contemporaneous with the lacustrine deposition. Peet and Woodworth were impressed by the evidence for a definite northward receding ice margin defending expanding fresh water lakes, while Cook postulated the superglacial accumulation of much of the valley deposits upon and next to a large saucer-like block detached from any south-facing regional block or lobe.

Fairchild, by not conceiving of a possible southern barrier isolating the valley from the Atlantic, postulated the marine invasion of the Hudson-Champlain region and related all of the depositional landforms throughout the valley to this sea-level strait. By passing his "ideal marine plane" through the average of the summit elevations of deltas, terraces and beaches, he determined the rebound value for the region to be 2.25 feet per mile, a figure too low by comparison to the 4.2 feet per mile value determined in the Connecticut Valley (Flint 1953).

Progress in the understanding of the glacial history of the Hudson Valley has been hampered by the lack of mapping. The only quadrangles which have received attention are the Schenectady (Stoller, 1911), Saratoga (Stoller, 1916), Cohoes (Stoller, 1918), and the Troy (LaFleur, 1960) 15 minute sheets.

HISTORICAL REVIEW

Early papers by Peet (1904), Woodworth (1905) and Fairchild (1918) were devoted to regional analyses of the Hudson-Champlain Valleys. Peet was the first to recognize the rebounded condition of the crust as indicated by the gradual climb of delta and terrace summits northward. He also called attention to no fewer than 15 places between Catskill and Glens Falls where the ice margin was indicated by distinct "morainic phenomena". His examples in the Troy area are the Schodack Terrace, Loudonville Moraine, and the Sycaway Terrace. Peet presumed that all of the Hudson Valley deposits dated from the withdrawal of a single Wisconsin ice sheet and hence assigned too long an interval to the Hudson waters, equal to the duration "of Lake Maumee, Whittlesey, Warren, Dana, and part of Iroquois."

Woodworth (1905) followed with a classical paper on glacial deposits and history of the Hudson-Champlain Valley, much of which is still valid. He called the "Hudson waters" of Peet by the name Lake Albany, following the application by Ebenezer Emmons and Asa Fitch (1849) of the name Albany to the clays of this area. In Fitch's words, "As neither its geological age or name is well settled, I prefer designating it the Albany clay". Woodworth correlated Lake Albany in part with Lake Iroquois, defining the former as a fresh water lake defended by the ice margin and progressively enlarging northward until the ice margin receded far enough to clear the Mohawk Valley for outflow of central New York waters (Lake Iroquois). At this time Lake Albany "properly came into existence". Woodworth also noted evidence for a readvance of ice into the Fort Edward area, and cited the several terraces of the Hoosic delta as evidence for the stages of lowering of Lake Albany.

Fairchild in 1912 accepted and restated the genesis of Lake Albany as postulated by Woodworth, and in the Mohawk Valley defined Lakes Schoharie and Amsterdam. He assigned the 340' Mohawk delta to Lake Albany and discriminated two periods of Mohawk Valley river flow: (1) the Glaciomohawk which drained: the later Lake Vanuxem, the free drainage succeeding Vanuxem, the restored Vanuxem, and Lake Warren; and (2) the Iromohawk which drained Lake Iroquois. Fairchild recognized that the relation of Lake Albany to the glacial Mohawk is not clear and suggested that it was probable Lake Albany endured to the close of Iroquois time.

Stoller in 1911 published his mapping of the Schenectady quadrangle, followed by the Saratoga sheet in 1916, and by the Cohoes sheet in 1918. His was the only mapping attempted in the Hudson Valley until very recently.

Fairchild in 1914 and 1918 rejected Woodworth's original conception of the Hudson waters, and assumed that all water-level-indicating features such as beaches and deltas were built in a body of sea level water extending from New York City to Canada, accompanying the receding ice margin. He passed an "ideal marine plane" through the summit elevations of the beaches and deltas and arrived at a figure of 2.4 feet per mile as a rebound value for the Schenectady-Saratoga area.

Stoller (1918), on the Cohoes quadrangle, recognized the presence of a series of water levels to the north of Troy and assigned them to stages in the lowering of Lake Albany. He did not side completely with either Woodworth or Fairchild on the genesis of these waters, and was more concerned with evaluating local conditions. He promoted Woodworth's conception of a narrow ice block occupying a sharply defined preglacial Hudson gorge contemporaneous with the deposition of clays between the ice and the shore in early Lake Albany time. Stoller separated the terraced lacustrines into (a) constructional surfaces (minimum elevation 300 feet) formed while ice occupied the central gorge; (b) construction surfaces marking the upper limit of fine sedimentation in the center of the valley following the melting of the ice block in the gorge (minimum elevation 240 feet); (c) fluvial erosional surfaces marking pauses in the lowering from the 360-foot maximum (200-foot upper level near Mechanicville, and 100 foot lower level, also near Mechanicville). He inferred that the Iroquois-Mohawk drainage emptied into Lake Albany through the Anthonykill channel at Mechanicville when the lake waters were at the lower 100-foot terrace level. He rejected Fairchild's marine strait on the grounds that (a) no evidence exists indicating rising water levels following the cutting of the erosional terraces by existing waters, and (b), the marine strait would have to occupy a very narrow channel.... "at Mechanicville not greater than approximately the space between the 100 foot contour lines on the opposite sides of the valley; that is a breadth not greater than that of the present valley bottom".

In 1922 Stoller restated a 360-foot level for the maximum development of Lake Albany in the Cohoes latitude and correlated the 300-foot Malta sand delta and the 310-foot Saratoga delta with stages in the lowering of Lake Albany.

In the first of several papers, Cook (1924) treated the hypotheses explaining the disappearance of ice from eastern New York, and was impressed with the lack of concentrically arranged recessional moraines as compared with those of the Erie Lobe in Ohio and Indiana. He proposed that the portion of the ice sheet south and east of the Adirondacks wasted by the stagnation vertically of an overthickened block, a condition invited by a saucer-like crustal downwarp of a moderately rugged area. Cook also considered that the ice in the Hudson Valley was thicker than elsewhere and as a result lingered until after the termination of lacustrine conditions. He promoted Woodworth's concept of an ice block in the Hudson Valley contemporaneous to part of Lake Albany and extended this concept by suggesting that the Hoosic and Battenkill deltas (Cohoes and Schuylerville sheets) were built over blocks of ice at the time of maximum development of Lake Albany. He was led to this conclusion by not encountering any levels coincident with the terraces of the Hoosic delta elsewhere in the Hudson Valley. Cook opposed the concept of a well-defined southward-facing ice margin, connected to live ice, retreating northward as melting progressed. Of particular importance was the following observation:

> "This much is evident; all of the clays in the valley north of Rondout do not belong to a single water body which may be called Lake Albany; some of them were laid down in ponded water marginal to the ice tongue filling the main valley and parts of the smaller valleys tributary to it." (p.174)

Cook also believed that...."There is much to suggest that Lake Albany was combered with ice, both floating and anchored in the gorge, that cobble-covered ice formed the bed of its outlet for many miles and that this protected ice in the lower valley existed contemporaneously with the buried masses in the upper valley already mentioned, as long as this "lake" endured." (p. 174)

Brigham (1929) discussed the glaciation of the lower Mohawk Valley, but his work did not extend east to the Troy area. He estimated the maximum thickness of ice over the Capital District to be 3700 feet, to permit glaciation westward through the Mohawk Valley, ascending to near the 1600 foot level of the plateau at Cedarville in Herkimer County.

Cook (1930) in Ruedemann's "Geology of the Capital District" called attention to the moraine on the Troy quadrangle (Albia-Burden Lake moraine of this paper) and considered the Schodack terrace to be totally an ice-margin deposit, continuing to the south through the Kinderhook sheet. Cook did not recognize any beaches, especially along the Schodack terrace, and therefore eliminated from consideration ice-free conditions for Lake Albany.

Rich (1935) mapped the glacial deposits of the Catskills and was the first to recognize drifts of two different ages, which were later correlated by Flint (1953). Rich's mapping borders on the Hudson Valley, some 30 miles south of Troy.

Chapman (1937) discussed the deglaciation and lake stages of the Champlain Valley and, pertinent to the Troy area, he (1) dismissed completely Fairchild's marine invasion from the south, (2) proposed that no tilting (rebound) of the region occurred from early Coveville time until the marine invasion from the north, and (3) proposed a gentle uplift and tilting during the final stages of Lake Albany.

Cook added chapters on the glaciation of the Berne (1935), Catskill (1942), and Coxsackie (1943) quadrangles, all to the south and west of the Troy area, but he did not map any of these areas. Cook repeated his hypothesis of ice stagnation and selected local deposits and landforms as evidence. He continued to reject the ice-wall theory of retreat, and emphasized the importance of superglacial drift accumulations and ice-contact topography. He assigned the clays to a series of lakes and times of deposition rather than a synchronous "Lake Albany", but did not attempt to arrange water bodies in either a geographical or chronological order.

Chadwick (1944) cited evidence for the presence of an ice block lingering in the Hudson Valley beneath Lake Albany waters in the Catskill area and also considered the possibility of progressing wave-or bulge-type rebound holding in the waters of Lake Albany at the south. He cited the northward deflection of part of the clay plain in the Catskill area as evidence for a 4.5 foot per mile rebound value instead of the 2.25 foot per mile value measured on the shorelines in the same area.

Cook (1946), in a paper on ice-contact deposits, selected landforms from the Troy area as examples. He cited the large hill east of Rensselaer (in the present paper, Plate II, called "Rensselaer Delta") as an example of a "smooth rounded" type of ice contact, in which an arch-shaped overhang of ice has determined the curvature of the hill on the upstream side. He illustrated the Schodack terrace as an ice-contact deposit with an ice roof overhang bordering the terrace along its western edge.

Cook (1946) coined the words "kame-complex" and "perforation deposit", and applied them to features which he had observed near Urlton on the Coxsackie quadrangle.

The most recent regional synopsis has been provided by Flint (1953) and his conclusions are summarized as follows:

1. The lacustrine clays and silts of Woodworth's Lake Albany are not overridden by readvancing ice between Newburg and a point a few miles south of Glens Falls, but are overridden farther north.

2. "They are not covered with outwash but are the latest glacial deposits in the valley." (p. 902)

3. Lake Hackensack and Lake Albany lacustrines are distinct, separate sedimentary bodies, although Antevs (1928) correlated Lake Albany varves at Newburg with those in the Connecticut Valley.

4. Outwash covering undisturbed Lake Hackensack clays suggests an ice margin at the Hudson Highlands prior to Lake Albany.

5. Lake Hackensack is correlative with the retreat of Tazewell ice; Lake Albany dates from the retreat of the Cary ice margin.

6. There is a discrepancy in the rate of northward rise between the 4.2 feet per mile value for the Connecticut Valley, and 2.25 feet per mile for the Hudson Valley, as measured from sediment summits between Newburg and Glens Falls.

7. The possibility of Cary readvance, at any latitude, between Glens Falls and Newburg is eliminated.

8. The readvance of ice near Glens Falls dates from the Mankato substage.

9. Lake Albany was drained in Cary rather than Mankato time, to permit marine invasion in the deglaciated St. Lawrence lowland.

10. The Mohawk discharge into the Hudson Valley dates from Lakes Whittlesey and Vanuxem (late Cary) rather than Mankato.

11. The two drifts of the Catskills may possess substage value;...

    "the younger drift in the Catskill Mountains district is the Cary drift, and ....the subdued topography and the weathering of the older drift are a record of the Brady interval." (p. 904)

12. A rising lake level, not yet recognized, prior to Chapman's Lake Vermont, accompanied the receding Mankato ice north of Glens Falls.

13. The Lake Vermont Glens Falls delta may cover the evidence of Mankato advance west of Glens Falls.

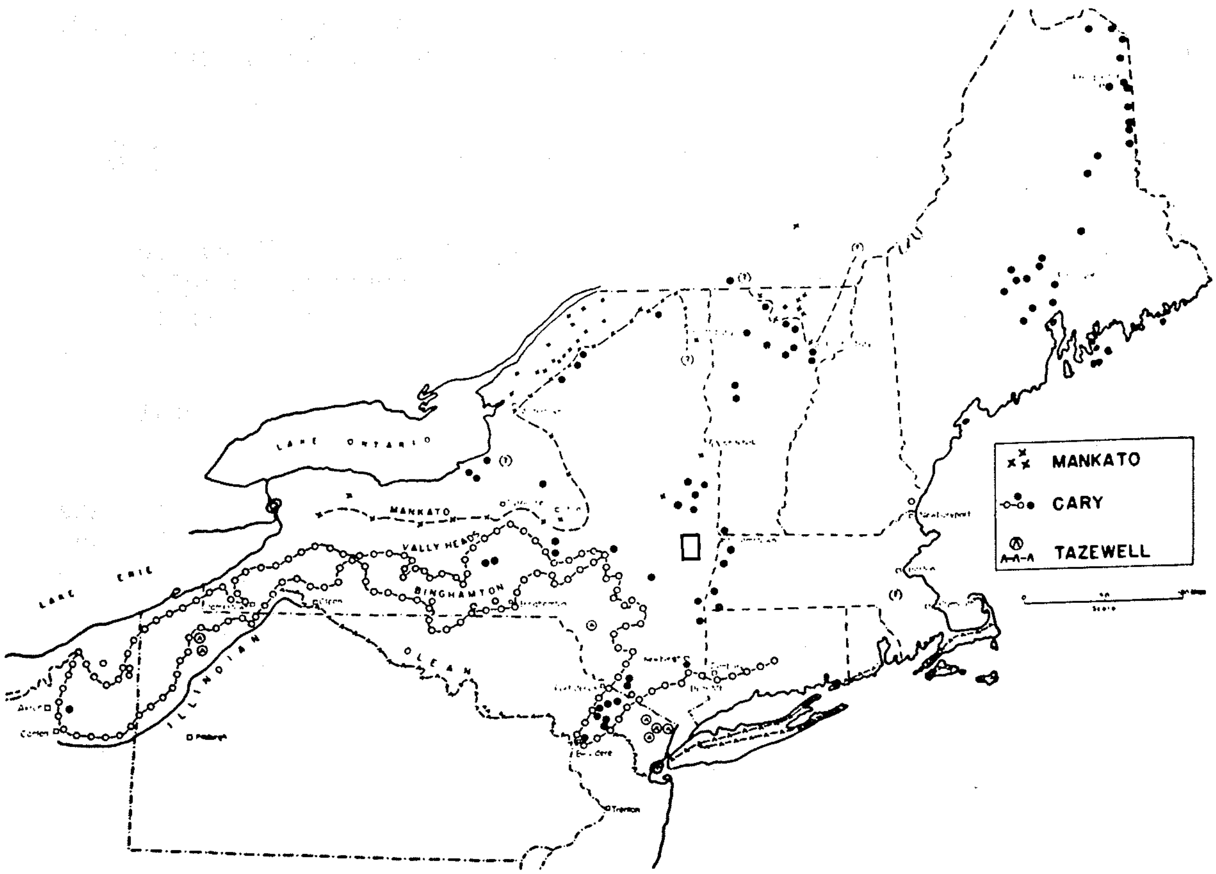
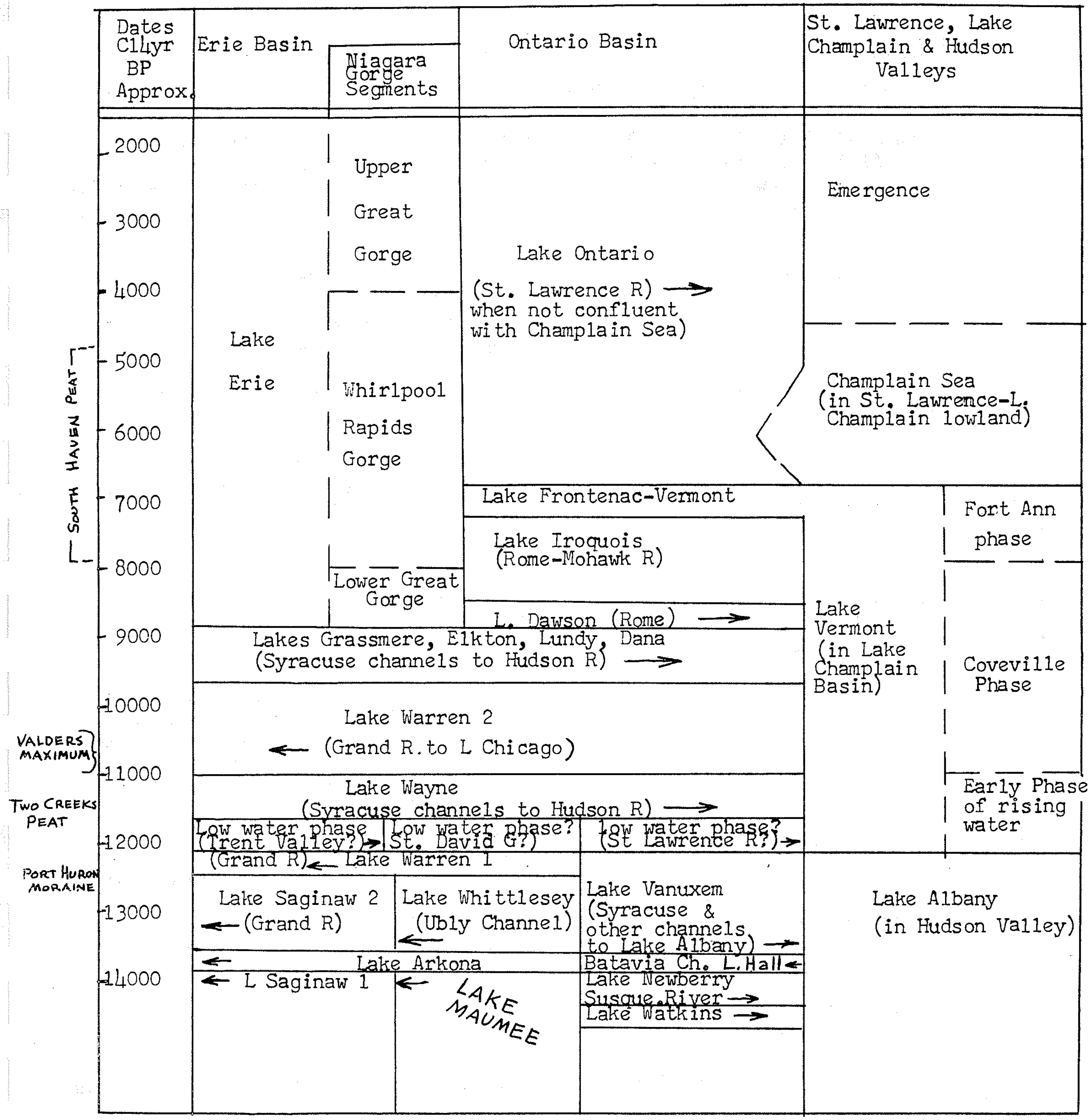


PLATE I. Map Showing Carbonate Leaching Test Localities And Proposed Drift Correlations. From MacClintock (1954). Troy Quadrangle Indicated By ▯.

MacClintock (1954) correlated drift by depth of carbonate leaching, and for the Hudson Valley postulated that the younger Catskill drift of Rich is Cary in age. Plate I is his map. Note the abundant sample localities indicating Cary age surrounding the Troy area and also the two localities near Glens Falls and Saratoga with a Mankato age designation. The extent of Mankato advance into eastern New York has not been established.

The present author (1960) has mapped the Troy quadrangle, and the "Sequence of Events" chart, Plate II, and the remainder of this discussion are based on this work.



"SEQUENCE AND MUTUAL RELATIONS OF THE LATE-WISCONSIN GREAT LAKES". Eastern part of table, from Flint (1957).

GENERALIZED SEQUENCE OF EVENTS

DECREASING AGE →

CARY SUBSTAGE

Episode	Features on Troy Quadrangle
Dissection of lacustrines by present Hudson River.	
"Lake Albany" lowered to 180'	Glacial rebound of 340' Lake Albany beach
? "Lake Albany" lowered to 230'	Minor beaches west of Rt. 4 and B & A R.R.
"Lake Albany" lowered to 310'	Highland Ave. sand - Griswold Hgts. delta at Troy, 310' summit. 310' Wynantskill terrace
? Lake Albany max. 340'	Blooming Grove and Schodack terrace beach ridges, Defreestville beach, Frear Park beach, Troy Airport 340' summit sand delta of the Wynantskill
Rising water from ice-free Mohawk (?)	Clays exposed on Spring St. & Highland Ave., Troy
Rensselaer-Albany Interval Possible lowering of lake levels to about 320'.	Ice-margin deltas north of Troy on Cohoes sheet. Clay deposition (?) in Troy area Rebound-induced deflection of upland drainages southward.
Lake Rensselaer 300' + (350'?)	"Rensselaer delta" east of Rensselaer, clays south of Rt. 381. Ice-border gravels (?) along Rt. 4
Lake Hampton 350'	"Hampton Park delta", kettle fillings on Schodack Terrace @ East Greenbush. Clays and sands west of Couse and south of Sherwood Park. Superglacial portion of 380-360 cobble-gravel terrace in North Greenbush.
Lake Schodack 330'	Foresets of Schodack terrace. Clay & gravel bottomsets west of terrace front.
Schodack Terrace	Several continuous stages of gravel deposition as ice margin withdraws NW from Rt. 9 vicinity.
Albia-Burden Lake (and other) upland kame moraines	esker delta complexes
Emergence of Rensselaer grit plateau as a nunatak. High-level kames & deltas around edge. Stagnation and downwasting of ice toward west and north from western edge of plateau.	
Formation of drumlins. Cary ice bifurcated at Helderbergs, sending the Mohawk lobe westward into Herkimer County. The Hudson lobe extended south to the Highlands (?) and southeastward into the Berkshires.	

Pre-Cary erosional topography on Taconic rocks (and earlier drift?). Local relief frequently exceeded 200'.

GEOMORPHIC SETTING

The Troy quadrangle lies near the geographic center of the Hudson-Champlain lowland at its junction with the Mohawk Valley and displays the record of a single Late Wisconsin glacial advance and stagnation of probable Cary age. The surficial deposits are underlain by severely deformed Cambrian and Ordovician rocks of the Taconic sequence, mapped by Ruedemann (1930) and more recently by Elam (1960, unpublished; western half).

A relief of over 1500 feet extends from the tidewater Hudson River, bordering the area on the west, to the rugged plateau maintained by the Rensselaer graywacke on the eastern edge. Preglacial erosion developed a sharply defined topography with local relief frequently exceeding 200 feet on north-south trending structures in the less resistant shales and sandstones west of the Rensselaer escarpment. Drumlins are common throughout the area, with average summit elevations rising eastward from 450 feet near the Hudson River to 950 feet at the base of the escarpment. Some drumloid masses of thick bouldery till occur on the Rensselaer plateau but typical drumlins are restricted to lower elevations. Much of the western quarter of the quadrangle is underlain by lacustrine sediments heretofore assigned to Lake Albany, and by gravelly deltas and kame terraces, marginal to ice blocks lying in the Hudson preglacial channel. Beaches of Lake Albany extensively alter granular deposits from Frear Park in Troy south through Defreestville to the Schodack terrace. Postglacial gullying of the lake clays has severely dissected the westward-sloping plain bordering the Hudson River on the east.

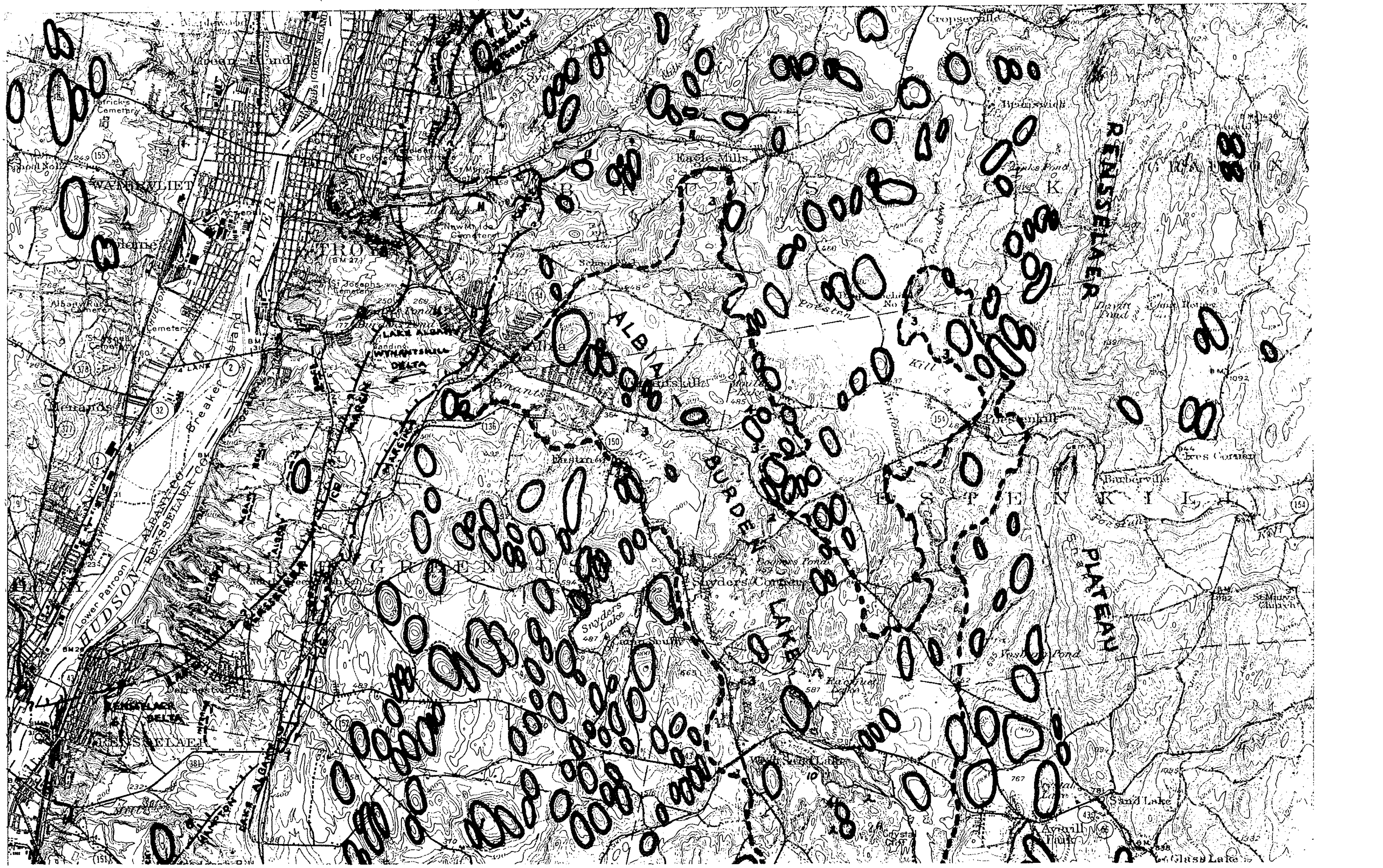
Two distinct topographic trends are developed. Ice advanced from N20W as indicated by drumlin axes. Where drift is thin the Taconic structural grain is dominant, striking N-S to N15E. The Troy area received the southeastern advance of ice as the main advance split at the Helderbergs, sending the Mohawk Lobe westward.

ICE ADVANCE FEATURES

Drumlins

Much of the Troy area west of the Rensselaer plateau is covered by clusters of drumlins. See Plate II. They are particularly abundant along Rt. 43 between West Sand Lake and Defreestville. The trip route will cross this area.

Composition of the drift closely reflects underlying bedrock. The trend of major Taconic lithologies nearly coincides with the direction of ice advance, making the evaluation of distance of transport of bedrock fragments by moving ice a difficult one. Generally the till is rich in clay, shale, and siltstones, and poor in carbonates. Near the base of the Rensselaer plateau some patches of till have a brownish or reddish color from the high content of red shale. On top of the plateau, the drift is generally thin and contains boulders of graywacke, some of huge proportions. Where the till is calcareous, it has been leached to a depth of about 5 feet, but the limestone content of the drift generally is low and irregular, and dating by the depth of leaching has its limitations.


TROY
HUDSON
RIVER
RENSSELAER
PLATEAU
ALBANY
BURDEN
LAKE
Cropseyville
Brunswick
Eagle Mills
Wynantskill
Poestenkill
Barberville
Snyders Corner
Snyders Lake
West Sand Lake
Sand Lake
Averill Park
Glass Lake
Crystal Lake
Defreestville
RENSSELAER DELTA
LAKE ALBANY
WYNANTSKILL DELTA
Menands
WATERVLIET
Lower Patroon
Breaker Island

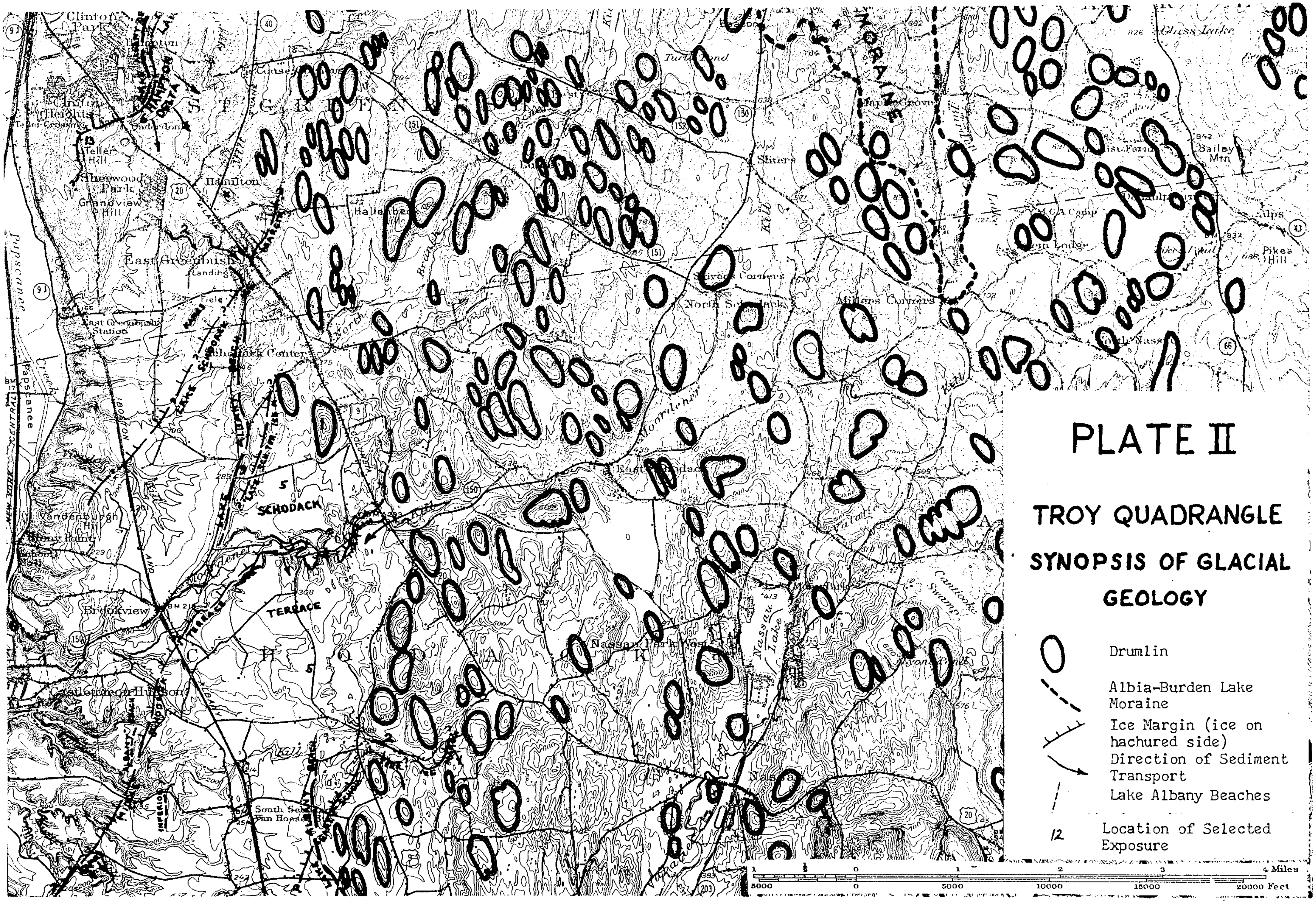


PLATE II
TROY QUADRANGLE
SYNOPSIS OF GLACIAL GEOLOGY
Drumlin
Albia-Burden Lake Moraine
Ice Margin (ice on hachured side)
Direction of Sediment Transport
Lake Albany Beaches
Location of Selected Exposure
4 Miles
20000 Feet
SCHODACK
TERRACE
East Greenbush
Brookview
Castleton-on-Hudson
Nassau Lake
North Schodack
Millers Corners
Bailey Mtn
Pikes Hill

STAGNATION FEATURES

The Albia-Burden Lake Moraine

A continuous gravel moraine extends for 8 miles from Burden Lake north and west to Poestenkill and Albia. (See Plate II)

Isolated kames, kame complexes, eskers, and esker deltas are well developed throughout this area. Fundamental to the formation of this moraine was the ability of the ice block to temporarily maintain local base levels by withholding its runoff waters. Downwasting progressed northward (downhill) through a minor preglacial valley which joins the Hudson Valley south of Troy. Periodic halts in the retreat of the margin (acceleration in melting of the whole block while the margin is along any given line) produced semimentation both in front of the margin and in crevasses leading to the margin. As evidenced by the maximum length of the eskers which feed the ice-margin outwash, the ablation zone, as far as sedimentation is concerned, extended upstream no more than 2 miles from the margin. This distance seems to be rather consistent throughout the length of the moraine, and also is appropriate to the ice margins of the more central Hudson Valley.

Within this moraine, summit elevations of eskers and esker deltas decrease (750 feet to 400 feet) progressively from SE to NW. Temporary locations of the ice margin are indicated at the following locations: one mile NW of Maple Grove; one mile WNW of Crystal Cliff; at West Sand Lake; one mile NW of Racquet (Reicherts) Lake; at Coopers Pond-Pine Bowl Speedway; and at Pawling Sanitarium - Moules Lake, where the ice margin can be traced into the Poestenkill valley along Route 354 and thence southeast along the Newfoundland Creek valley.

Apparently there was no barrier to surface water communication between the Poestenkill Valley and the ice margins listed above. Trend of differentially eroded bedrock is favorable, and a large area of bare rock with patches of gravel extends from near Racquet Lake NE to Newfoundland Creek. If one can presume that summit elevations of ground-laid outwash lying at the same elevation are built under the same local base levels and hence are nearly contemporaneous, then various portions of the moraine can be correlated. A paucity of outwash levels from 820' to 620' exists for the Poestenkill Valley while several levels within that range occur toward the Burden Lake end of the moraine. Consequently a northward retreat of the ice margin would have covered 3 miles between Burden Lake and West Sand Lake, while at Poestenkill the margin was withdrawing only one mile westward between Brookside Cemetery at Barberville and Poestenkill.

For the vicinity of the Albia-Burden Lake moraine it may be stated that the ice frequently presented a discernible south-facing margin and, as is further shown in the section on Hudson Valley lacustrine stages, this tendency was maintained at least through the time of the Newtown Road delta, on the Cohoes sheet to the north of the Troy area. This would seem to refute Cook's (1924) preference for a detached ice block in the middle Hudson Valley, apparently unrelated in its melting to any general northward withdrawal of the ice margin.

As may be noted from the $7\frac{1}{2}$ minute topographic sheets and also in the field, both the longer eskers with their usual periodic sags and the shorter single-segment eskers rise to their outwash termini by as much as 60 feet. This suggests that the eskers did not accumulate in subglacial tunnels but rather that they have collapsed from an englacial or superglacial position from which they fed the outwash plain as base-level controlled, ice-fracture-directed streams. Those longer eskers which followed crevasses in the ice parallel to original ice advance generally rise less to the outwash summit than do those shorter forms which follow directions at near 45 degrees to ice advance. The preferred interpretation is that the long eskers are deposited in early-opening crevasses, exposed to the sky, with sagging caused by differential collapse where the esker is locally laid over ice. Sedimentary structures of several long eskers indicate they are largely ground laid with foreset bedding being common.

The shorter eskers may have accumulated in late-opening crevasses immediately next to ice margin.

The Schodack Terrace

The Schodack terrace, named for its prominent development through the Town of Schodack, is an extensive area of gravel and sand, bordered on the north by an esker-fed kame complex near the village of East Greenbush, and merging 8-10 miles to the south with the similar but larger Kinderhook terrace. The Schodack terrace was first recognized by Peet (1904), and Woodworth (1905), who called it a kame-terrace with an ice-contact along its western edge. This designation was also followed by Fairchild (1918), and Cook (1930). In 1946, Cook attributed the rounded and smoothed western edge to contact with an ice margin which overhung part of the terrace toward the east.

Jahns and Willard (1942) noted similar ice-margin terraces in the Connecticut River Valley and pictured them as forming by stages beginning along ice margins but ending in delta foreset deposition into glacial lakes standing in front of the ice margin. The Schodack terrace appears to duplicate this sequence. In several pits, collapsed gravels are overlain by delta topset and foreset beds. West of the terrace edge, interbedded clays and sandy gravels encountered in water wells are probably the bottomset equivalents to the delta stage.

The western edge of the terrace rises from a gullied clay plain and has been altered by beaching of waters assigned to Lake Albany. Prominent beach ridges occur where the terrace faces westward or slightly north of west. Where southeast-trending borders are present, beaches are not so well developed. The western edge does not, in most places, reflect an ice contact, overhanging or otherwise, and the sediments beneath the beach are mainly westward-dipping delta foresets.

The terrace surface is gently rolling and frequently pitted by kettle holes. Its maximum elevation is 350 feet near the eastern edge where it is bordered by drumlins, and it slopes to about 320 feet near the beached western edge. Angular eskers are exposed within the terrace along the Moordener and Vlockie Kills and attain summits of 350 feet. Southeast of Brookview, between the Moordener and Vlockie Kills, the western edge of the terrace is indented by reentrants which are aligned parallel to the eskers exposed elsewhere on the terrace. Beaching between these points is slight and the reentrants could be unaltered ice contacts. South of the Vlockie Kill, the western edge is straight and capped by beach ridges. From south to north, the average terrace summit increases by about 10 feet, but it could easily have rebounded by that amount. The part of the terrace south of the Moordernkill probably is older than that part to the north, as evidenced by the eskers which feed the terrace at an ice contact along which this creek now flows. (See Plate II for locations of probable ice margins.) This suggests that the Kinderhook terrace to the south began to form before the Schodack terrace, as a south-and east-facing ice margin in the Hudson Valley progressively wasted northward. The "early", "middle", and "late" terrace ice margins are examples.

HUDSON VALLEY LACUSTRINE STAGES

The Lake Albany Problem

Originally it was suggested by Peet (1904) and Woodworth (1905) that the Hudson ice block defended lake waters on the south, and as its margin melted northward an increasing area was presented for the accumulation of lacustrine sediments, chiefly clay. These successive water bodies (or growing single body) have been called by the general and collective term Lake Albany. Mapping in the Troy area indicates that this concept of ice withdrawal is valid, and also that it is necessary to recognize the sequential lake stages that comprise the total "Lake Albany".

Two ice-margin deltas are found on the Troy quadrangle isolated from the kame terraces to the east. ("Hampton Delta"and"Rensselaer Delta"of Plate II). Reconnaissance of the Cohoes and Kinderhook sheets to the north and south has revealed other places at which the receeding ice margin also remained for a time long enough to deposit frontal gravel deltas with fine-grained bottomsets into standing lakes.

In addition to the two deltas on the Troy sheet, there are (1) numerous kame-terrace-delta deposits along the eastern edge of the main Hudson Valley which date from both deltas, and also from more southern positions of the ice margin; and (2) continuous and well-formed beaches which extend from the Kinderhook area north to the Schuylerville sheet. These beaches modify the western edges of both the kame-terraces and mid-valley deltas, and as a long fetch is required for the beach development, an ice-free condition for the Central Hudson-Eastern Mohawk Valleys during the later lake stages is indicated.

It is further necessary to define as accurately as possible those lake stages which coincide with the unblocking of the Mohawk Valley, in order to extend Hudson Valley correlations westward. The Albany-Troy-Schenectady area is critical to this problem.

The determination of glacial rebound values for eastern New York depends upon the dating of the beaches and other deposits on which measurements are made. There is abundant evidence in the Troy area that rebound was in progress during the ice-margin and ice-free lake stages. The grouping of all the valley deposits together and the averaging of the depositional summits has produced a total value of 2.25 feet per mile for the region, which is too low.

The sedimentary relationships also call for more precise definition of Lake Albany. The bulk of the clay can be related to the ice-margin lake stages more easily than it can be equated to the ice-free lakes. Deltas, some of them very large, cover clay in many areas. Frequently, as at the Schodack terrace and at the Hampton and Rensselaer deltas, clays are interbedded with silts, sands and gravels in bottomset relationship. Sand-and gravel-free clays elsewhere probably represent more distal bottomset occurrences of ice-derived sediment. Westward from the main Lake Albany beach, silts and pebble gravels have been carried lakeward over earlier clays, suggesting perhaps a minimum of clay was deposited in "later Albany"time.

Sequence of Glacial Lakes

ICE MARGIN STAGES

Three of many successive Hudson Valley lakes are recognized as having ice margins on the Troy quadrangle.. It is presumed that open waters extended to the south away from these margins, and that to the north, the Hudson lowland was filled by ice to a greater degree than at the Troy latitude during this time. (See Plate II)

The lakes are named Schodack, Hampton and Rensselaer in order of decreasing age. These are given names for the purpose of reference and description of local deposits. Further mapping is necessary to establish the degree of applicability of each. They are important to recognize, however, because it is likely that at some time during the existence of or shortly after these stages, the Mohawk was opened to eastward runoff by near final stagnation of the Mohawk Lobe.

Lake Schodack

Lake Schodack is postulated (1) to account for the delta foreset beds which dip generally westward along the western edge of the Schodack terrace, and (2) to collect the interbedded clay, sand and gravel which is encountered in water wells drilled along the terrace edge. The mid-valley position of the ice margin at this stage is not exactly known, but Strong (personal communication) of Hall, Inc., Delmar, N.Y., has postulated the western limit of gravel aquifers beneath the clay to pass due south from Grandview Hill. The persistent bedrock hogback beneath clay over which the streams entering the present Hudson now fall, nearly coincident with Strong's aquifer border, may have provided a logical place for the ice margin to linger during Lake Schodack time. A water level of 330 feet above present sea level would accomodate the delta beds and also permit filling of some of the kettles along the terrace edge shortly thereafter, but the dating of these kettle-fillings is uncertain. They may date from a later stage of Lake Albany, as evidenced by the increased thickness of beach gravels into contemporaneously collapsing shoreline kettles. Apparently Lake Schodack did not extend an eastern marginal embayment much farther north than Couse, where remnants of pebble gravels at 330 feet are exposed at the intersection of Routes 4 and 151. As yet no isolated marginal delta, supplied from the ice alone west of the Schodack terrace, has been found.

Lake Hampton

Lake Hampton, with a postulated water level of 350 feet is named from the prominent ice-margin delta upon which Hampton Park in East Greenbush is located. The delta summit corresponds to this level and about 10 feet of channeled topset beds overlying foresets are exposed in a gravel pit atop Hampton Park. The north end of the delta is defended by Rysedorph Hill, a small but bulbous knob of Rysedorph Conglomerate which served as a nunatak in the Hampton ice margin, probably inviting accelerated ice melting on its downstream side.

East of the delta along Mill Creek, sands which are traceable up the delta slope interfinger with clay, indicating open water in an embayment east and probably northeast of the delta. The near-level-bedded cobble gravels, which are continuously exposed from near Albia south to Defreestville at an elevation of 380-360 feet, terminate in delta foresets exposed in a pit at the intersection of Routes 4 and 381. These beds are in nice adjustment to a 350 foot level of Hampton lake water and are assigned to that body. Possibly these 380 foot gravels could be assigned to Lake Rensselaer, which follows, but relationships in the Wynantskill delta area are contrary to this association.

Lake Rensselaer

Immediately east of the City of Rensselaer, a drumlin-shaped hill nearly one mile long, surrounded by clay, attains an elevation of 300 feet. This hill, called the Rensselaer delta, contains southward-and southeastward-dipping pebble gravel foresets and bottomsets. Connected with this delta beneath, and exposed in the gully to the northwest, and through Rensselaer to the Hudson River, is the southeastern extension of the Loudonville moraine. The clays south of the delta, exposed along Mill Creek contain at least 50 percent sand, and may represent cyclical (turbidite?) bottomsets of the delta. There is no evidence that any of the delta is superglacial and no slump structures are encountered in the pit along its southwest flank. In the pit at the east end of John St., 2000 feet east of School 2. in the City of Rensselaer, slumped cobble gravels are exposed at 100-140 feet and may have collected under more superglacial conditions prior to the retreat of the ice margin to the north edge of the Rensselaer delta. Such a sequence would duplicate that of the later Newtown Rd. delta on the Cohoes sheet.

The level of Lake Rensselaer cannot be established exactly, but a northward retreat of 2 miles of the Hampton ice margin is indicated. A lake level of at least 300 feet is required, but as the Rensselaer delta has no topset beds, and as the lower 350-foot level gravels to the east adjacent and inferior to the 380-foot river gravels through North Greenbush are well-beached and altered by later waters, the upper limit of the lake can only be estimated to be near or slightly lower than the 350 foot Lake Hampton level. Further work is needed in Albany County before the significance of Lake Rensselaer and its ice margin can be established. This episode may have been the first one in which Mohawk water played an active part. The Loudonville moraine slightly antedates the Rensselaer delta and the geographic setting and large volume of the former suggests an unusually heavy influx of superglacial drainage into the ablation zone, possibly more from the west than previously. It would not be suprising if the ice-contact deposits of the Loudonville moraine dated from Lake Hampton, while the terminal Rensselaer delta represents the end of the retreat of the ice margin through the Hampton ice ablation zone.

Post-Rensselaer-Pre-Albany Interval

Well-defined frontal deltas are not found north of the Rensselaer delta on the Troy sheet. Gravels are exposed at Waterford and along Newtown Road in Saratoga County on the Cohoes sheet. The Newtown Road deposit is deltaic with a northerly source only on the final stages and is interlobate in early stages.

The channeled topset beds of the Newtown delta are overlain by congeliturbate clays. The summit of the Newtown deposit lies now at 350 feet and if rebound is taken even as a conservative $2\frac{1}{4}$ feet per mile, the delta's position - 13 miles north of the Hampton Park delta, at an identical elevation - would place the original summit level at a maximum of 320 feet if water levels had remained constant. While the value or the nature of rebound has not been established, the summit level of the Newtown Rd. delta suggests a general lowering of lake levels following Lake Rensselaer time. It is also likely that the ice margin became less continuous during this interval, under the influence of added drainage from the Mohawk. Further speculation on this interval is not warranted until more mapping is done to the north. Part of the clays north of the Rensselaer delta latitude belong to this interval, but how much is not presently known. The next recognizable episode is that represented by the persistent shore line of a redefined Lake Albany.

ICE-FREE STAGES

Lake Albany

The name Lake Albany is redefined and assigned to the broad, ice-free water body which produced the continuous beach with frequent storm ridges from south of the Troy sheet northward beyond the limits of the Cohoes quadrangle. This is the level (320 feet on the south edge to 340 feet at the north edge of the Troy sheet) Stoller has assigned to the maximum development of Lake Albany, which attained according to him a level of 360 feet on the Cohoes sheet, and to which the Hoosic delta summit was concordant. In the present writer's opinion, the use of the Lake Albany designation should be restricted to this level and episode.

At full development, Lake Albany received, in the Troy area, the discharge from the Wynantskill and Poestenkill Creeks where a 25-50' sand delta beneath the Troy Airport was constructed. (Wynantskill delta of Plate II). Discharge from the Mohawk (Lake Vanuxem?) presumably was responsible for the extensive sands exposed between Albany and Schenectady known as the Mohawk delta. Much of this deposit was later wind-worked into what is locally called the "Colonie blow sand".

Small patches of sand occur east of the Hudson as erosional remnants above the clays, and occasionally the sand contains rafted cobbles. Dunes in the Troy area are rare. Sand and pebble silt carried westward from the Lake Albany beach covers the earlier clays, particularly west of the Schodack terrace where sand thickness frequently exceeds 10 feet. How much clay was deposited in the redefined Lake Albany is not known but the deltaic materials laid over the clays suggest that, at least along the shore, coarse material dominates. It appears that most of the clay should be assigned to the earlier ice-margin lakes. Some clay in North Albany is clearly superglacial.

Lower Stages of Lake Albany

The Lake Albany ice margin at the time of the beach formation stood at least as far north as the northern edge of the Cohoes sheet but the degree to which the upper Hudson Valley was deglaciated at this time is not now known. Presence of deltas in the Schuylerville,area particularly that of the Battenkill, standing at levels inferior to the 360' Hoosic delta - 320' Albany beach, (at the Schodack latitude) may indicate 1) the ice filled the valley north of the Hoosic at this time preventing open-lake deltas from forming, or that 2) the inferior deltas record stages of sedimentation which occurred only during the lowering of Lake Albany. Minor beaches and deltas inferior to the Albany beach occurring at 310', 230', and 180' in the Troy area may prove correlative to some of these northern deltas. The Cohoes-Saratoga-Schuylerville area contains more evidence for the lower Albany stages than does the Troy area. Bedrock nickpoints occur in all the streams entering the Hudson south of Troy. The Hoosic delta terraces may provide the best data, as Woodworth (1905) and Stoller (1918) both pointed out.

SELECTED EXPOSURES

1. Drumlins. Dozens occur between the Wynantskill and Moordenerkill in the towns of North Greenbush, East Greenbush, and Schodack. Long axes trend about N20W. See Plate II.

2. Eskers. Many occur throughout the Alben-Burden Lake moraine. The most typical are at Moule's Lake, Coopers Pond, and West Sand Lake. Two others feed the Schodack Terrace at East Greenbush and along the Vlockie Kill. Esker deltas are extensively excavated 2 miles ESE of West Sand Lake.

3. Kames. Exposed along Rt. 66 SE of Wynantskill, south of Eagle Mills, and E. of the Wynantskill at West Sand Lake. Solitary kames occur one mile north of Poestenkill.

4. Ice contacts. Several ice contacts cross the Albia-Burden Lake moraine. Three (in order of sequence) occur (1) north of Sheer Rd., (2) one mile SE of West Sand Lake, and (3) along Rt. 154 at Moule's Lake. All of these contacts are fed by eskers some of which are a mile in length.

5. Schodack Terrace. Extensively developed through the Town of Schodack. Kamey in part with large kettles and a few short eskers. Deltaic sediments exposed along the western edge.

6. Ice-margin deltas. Exposed at Hampton Park and one mile east of Rensselaer. Extensive gravel pits at both localities. Expecially good bottomset structures at the latter.

7. Superglacial kame terrace and ground-laid ice-border outwash gravels are extensively exposed in a pit south of Williams Rd., North Greenbush. Terrace is continuous south to Defreestville where it terminates in a small delta.

8. Lacustrine varved clays with interbedded sands underlie a large area west of Rt. 4 and the Boston and Albany tracks. Good exposures are limited but occur along the entrance road to the paper company just north of Castleton, along Mill Creek north of Rysedorph Hill, and along Spring Street where about 35 feet of clay overlying gravel is exposed in a pit.

9. Beaches. The Lake Albany beach is well developed, with frequent storm ridges, at (1) one mile SE of South Schodack, (2) along the W edge of the Schodack terrace between Brookview and East Greenbush, and (3)from Defreestville E of Rt. 4 north along Blooming Grove Rd. Gravel pits provide cross-sections through the beach at all of these locations.

10. Peat bogs are common throughout the area. Peat is presently being dug from a bog one mile SE of West Sand Lake.

11. River terraces are best developed along the Poestenkill between Eagle Mills and Troy, and also along the Wynantskill in Albia.

12. Post-glacial rock gorges with falls are found on the Poestenkill near Pawling Ave. in Troy, on the Wynantskill along the Airport Rd. in Troy, and on Mill Creek along Rt. 151 near Rensselaer.

13. Promontories at Teller Hill near Sherwood Park, at Rysedorph Hill, and at Prospect Park in Troy offer panoramic views of the Hudson Valley.

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NOTES ON TRIP A

TRIP B
SOME ASPECTS OF TURBIDITE SEDIMENTATION IN THE VICINITY OF TROY, NEW YORK

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INTRODUCTION

In the course of geologic field work in the vicinity of Troy, New York, much interest and controversy have been evolved locally on the subject of deep water flow sediments, generically called turbidites. Numerous and highly varied types of turbidites are exposed within the immediate environs of Troy. Complicating factors in field mapping are the Logan Line thrust fault and the sharp local folding both of which produce tectonic breccias and otherwise complicate the definition and identification of stratigraphic units.

The following section outlines the history of the concept of turbidite sedimentation and briefly describes the two main types of turbidites which are to be seen on this trip.

HISTORICAL REVIEW OF TURBIDITES

Since the beginning of this century there has been a growing interest in the apparently anomalous occurrences of "shallow water" coarse grained sands, conglomerates, and breccias in association with deep water sediments and faunas.

The papers on the Deepkill by Rudolph Ruedemann first showed the coarse grained and brecciated character of a significant part of these sediments (1901). Later he argued strongly for the pelagic and deep water environment of the pure graptolite faunas of the Normanskill, Deepkill and Schaghticoke (Ruedemann 1926) and (1934).

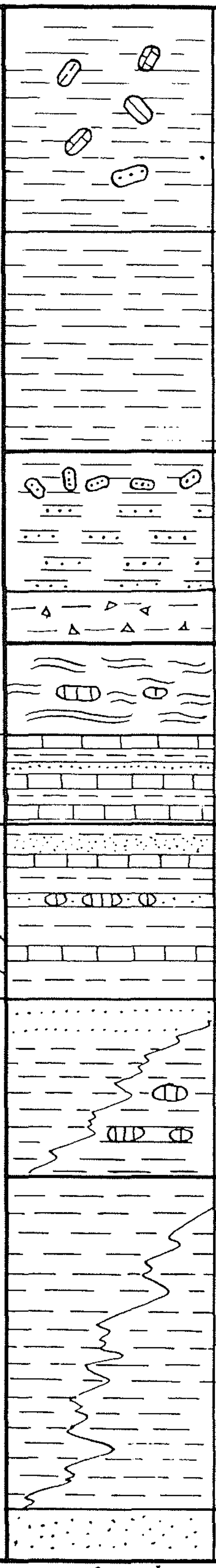
The work of Manley Natland (1933) demonstrated conclusively the presence of deep water assemblages of foraminifers in association with sands and conglomerates of the Pliocene of the Los Angeles Basin, California.

Archanguelsky and Strakov (1938) followed a correlative line of thought in the sterile deep basin of the Black Sea and concluded that recent sediment from large areas of the shelf south of the Crimea had become unstable due to earthquake shocks and had slid off into the deeper parts of the basin. Archanguelsky (1927) also noted the presence of a layer of sand between two layers of abyssal deposits and commented that "This fact is extremely strange and suggests an idea of some very rapid catastrophic changes in conditions attending the transportation of the material". (p. 280)

Daly (1936) postulated that submarine canyons had been cut by mud-laden submarine streams during periods of glaciation when sea level, and hence base level were lowered.

FIGURE 1.

STRATIGRAPHIC SECTION
TROY AREA



ORDOVICIAN	Middle	SNAKE HILL	Gray shale with blocks of graywacke, limestone, chert, and black shale up to 600 ft. long.	Mega breccia
ORDOVICIAN	Middle	SNAKE HILL	Gray shale and subgraywacke.	Subgraywacke
ORDOVICIAN	Middle	NORMANSKILL	Alternating graywacke and shale. Cataclasite near thrust fault.	Graywacke
ORDOVICIAN	Middle	NORMANSKILL	Chert and shale.	Graywacke
ORDOVICIAN	Middle	DEEPKILL	Chert, porcelanite, and flow bedded shale, brecciola.	Brecciola Black shale and Flow shale
ORDOVICIAN	L.	DEEPKILL	Ribbon limestone with sedimentary boudinage, graptolitic black shale, thin bedded silt & occasional graded sandstone conglomerate and brecciola.	Brecciola Black shale and Flow shale
CAMBRIAN	Upper	U€	Black clay shale, limestone, brecciola, calcareous sandstone.	Brecciola Black shale and Flow shale
CAMBRIAN	Lower	TROY-SCHODACK	Black shale, limestone, brecciola, green shale.	Brecciola Black shale and Flow shale
CAMBRIAN	Lower	METTAWEE	Purple and green shale.	
CAMBRIAN	Lower	BOMOSEEN	Massive grit	

Vertical scale - 1" = approx. 500'

Gould (1951) investigated subsurface currents in Lake Mead where heavy mud-laden flood water from the Colorado River flows below the clear water of Lake Mead with an initial velocity of 0.7 miles per hour, decreasing to 0.2 miles per hour 100 miles "downstream".

It remained for Keunen and Migliorini (1950) to demonstrate experimentally the process of turbidite deposition. They were able to illustrate further, by field observation in the Apennine Mountain arc, the competence of submarine currents to transport great masses of coarse clastics under water. Some of these sediment-laden currents appear to have originated as landslides on the upper continental slopes. As the mud and rock fall and slide down the steep slope, the flow incorporates an increasing amount of water, and gathers speed as it becomes less viscous. The carrying power of such a mud-laden stream of density 2.0 is theoretically 14,000 times the carrying power of pure water; experiments have demonstrated 9,000 times the power (Keunen lecture, 1950).

A flow of this type was triggered by earthquakes on November 18, 1929, from the Grand Banks (Heezen and Ewing, 1952). It flowed several hundred miles and snapped many transatlantic cables in its path. The greatest speed, calculated by the time of successively broken cables was 60 miles per hour. The speed was still 50 miles an hour 200 miles from the flow's source in 15,000 feet of water and on a comparatively gentle slope of 25 feet per mile. Where the bottom slope decreased to 4 feet to the mile, 400 miles from source, the flow was still moving 15 miles per hour.

Kuenen (1952) calculated the mass of this flow as being approximately 16 to 40 inches thick over an area of 100,000 square miles. This has been corroborated by Ericson, (1953) and Heezen, Ericson and Ewing (1954).

Other such flows are known in several places; for instance 30 miles south of Bermuda at a depth of 3 miles (Ericson, Ewing and Heezen, 1954), and at the mouth of the Magdelena River in Columbia (Heezen 1955). Extensive sedimentary studies have been made in the Black Sea and it has been found as noted above that south of the heavily faulted area adjacent to the Crimea, recent sediments have slid off of three quarters of the outer portion of the continental shelf. Studies in that area have emphasized the importance of faulting as a trigger action for such slides, and also the importance of a slippery layer to act as a skid plane. (Archanguelsky and Strakov, 1938).

Gentle currents similar to those in Lake Mead, but on a much greater scale, may be responsible for thin layers of sand and silt that are interbedded with deep-water clay over much of the abyssal plains of the North Atlantic. These sands have been studied by Ericson, Ewing, Wollin and Heezen (1961) in 230 cores. Ericson et al. noted that these sands never occur as patches on isolated highs but apparently do flow over low mounds that lie in the path of a flow. It is conceivable that flow after flow of sand could be brought into an area in such rapid succession that no abyssal clay would be deposited, resulting in a considerable thickness of laminated, fine-grained sand or silt.

It seems probable that these gentle currents may originate as submarine streams draining submarine deltas such as the delta in 14,000 feet of water at the mouth of the Hudson River Canyon; or they may be the fines from more

(continued on Page B6)

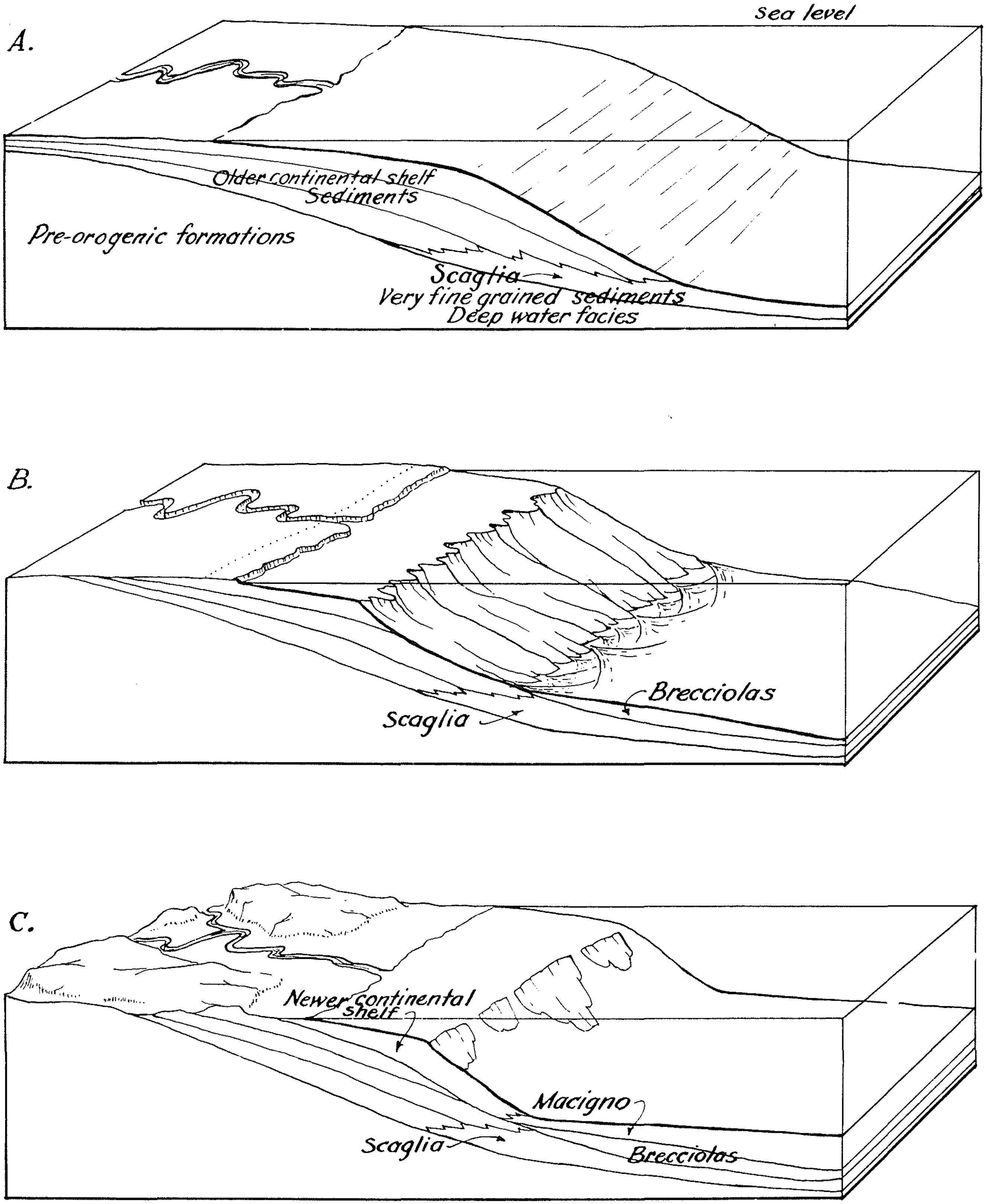


FIGURE 2.

HYPOTHETICAL DEPOSITION OF BRECCIOLAS AND MACIGNO
after Kuenen and Migliorini - Journal of Geology, March, 1950

EXPLANATION OF FIGURE 2
(after Kuenen and Migliorini)

"Block diagrams illustrating the sedimentation of the brecciolas and the macigno......vertical scale is some twenty times the horizontal."

"Diagram "A" shows the phase immediately preceding the sedimentation of the brecciolas. No irregularities are shown along the base of the continental shelf, to avoid unduly complicating the drawing. The sea would be slowly retreating because of the growth of the continental terrace." [The scaglia appears to be the starved-basin deep-water equivalent of limestone-shelf deposits from which brecciolas were formed.]

"In "B" the littoral zone has been raised some 30 meters. This has brought about the erosion of the continental shelf by waves and of the slope by turbidity currents, and the deposition of brecciola fans at the foot of the slope.......Where the channels were closely spaced the individual fans would overlap laterally, whereas no brecciola would be deposited between widely spaced channels.......In the phase shown, the destruction of the terrace is well under way but has not yet reached its maximum."

"In "C" the mainland has been uplifted by orogenic deformation, and its rejuvenation is in progress.......the new continental terrace, which has already buried the submerged remains of the older one, is growing, a littoral plain is forming behind it, and the sea is retreating. Slumping along the unstable slope is bringing about the deposition of the macigno by turbidity currents."

"......In sections that have not been too disturbed tectonically, the contact between the brecciolas and the macigno is perfectly regular and concordant. In some places the two formations actually merge into each other by repeated alternations. But, notwithstanding this perfect sedimentary continuity, typical macigno sandstones always make a sudden first appearance in a brecciola and shale alternation. From this evidence the following deductions may be made: (1) At a given moment during the deposition of the brecciola formation there was a sudden influx of another type of sediment, consisting mainly of arenaceous material. The new type of sediment, which gave rise to the deposition of the macigno, obviously resulted from the erosion of a different source area than that from which the material of the underlying complex was drawn. (2) The conditions determining the sedimentation of the brecciola formation persisted for some time after the beginning of the macigno sedimentation. (3) The changeover to macigno sedimentation was not accompanied by any appreciable tectonic disturbance in the area of sedimentation."

"It should be remarked that the upper surface of the brecciola fans, which were deposited by swiftly moving suspensions, slopes out to sea and is uneven, whereas that of the macigno, which was deposited by a suspension that spread out on the bottom of the sea floor, is practically horizontal and even. Consequently, the brecciola formation thins out, whereas the macigno thickens in a seaward direction."

turbulent flows originating on the upper continental slopes; or, again, some of them may originate from the flood waters of rivers entering the ocean or large gulfs particularly in areas of locally narrowed continental shelves such as the Mississippi River.

Daly (1936) suggested that such mud-laden currents would be formed on a vast scale during glacial stages when wave base was lowered by lowering of sea level. Similar currents could be produced tectonically by uplift of the continental shelf with consequent lowering of wave base (Archanguelsky 1927). Occasional great storms might produce similar results without lowering of sea level or raising of the continental shelf. Such storms could produce bottom currents in a seaward direction to carry some of the storm-roiled sediment over the edge of the continental slope where it would form a turbidity current with resultant deposition on the lower slope or the abyssal plain (Kuenen and Migliorini, 1950) and (Rich 1950).

TYPES OF FLOWS

There is a tendency to classify turbidity currents into two groups, typified by the fast and slow flows described above. Actually there must be many kinds of flows in addition to the two types described. Also it seems probable that there are a wide variety of depositional types produced below wave base, comparable in variety perhaps to those produced above it.

Probably one of the best known types of turbidites are the brecciolas which were described from the Apennine Mountain arc by Migliorini in co-authorship with Kuenen (Kuenen and Migliorini, 1950). The name brecciola was applied to sedimentary "little breccias", in which the fragments are preponderantly limestone. It has been found that there are other "little breccias" in the Troy area, some of which are composed of sand in a sand matrix, lime fragments in a sand matrix, lime fragments in a dolomite matrix, lime fragments in a clay matrix, and clay fragments in a clay matrix. It seems reasonable to include these also in the brecciola facies of the turbidite clan.

TRIP STOPS AND DESCRIPTIONS OF EXPOSURES

The purpose of this trip is to examine deep water sedimentary rocks in the field. Of the many assemblages that there are of such rocks, two are particularly well developed in the Troy area. One of these is composed of brecciolas and associated rocks; the other is the group of rocks that make up the euxinic assemblage.

Schodack Brecciola Assemblage

Stop 2. See Figure 3. Four brecciolas are described which apparently belong to the Schodack (West Castleton) Formation. These are typically developed at the following locations: School 14, west edge of playing field at 13th St. and College Ave.; Sage Avenue, 250 feet west of 15th Street; R. P. I. Campus, east end of football field; and Troy High School, northwest corner of athletic field.

All four occurrences appear to be distinctive, and they are not noticeably lenticular like the brecciolas of the upper and lower Deepkill some of which lens out across the outcrop. The Sage Avenue brecciola occurs at four localities one-half mile apart, and is clearly recognizable at each locality. The Troy High School sequence of brecciolas occurs in two extensive outcrops, approximately 800 feet apart, at both of which it possesses the same distinguishing characteristics. All four brecciolas are sharply distinct from one another, except that all are ten to twenty feet thick without marked lenticularity. They differ in this respect from the Deepkill brecciolas, which are inches thick and sharply lenticular. The brecciolas described by Migliorini in the Apennines appear to be closer to the Deepkill variety than to those of the Schodack. The Grand Banks brecciola of 1929 was calculated to be 16 to 40 inches thick. By comparison, the Schodack brecciolas are unusually large, although not to be compared to the Rysedorph megabreccia facies of the Snake Hill (Middle Ordovician) (J. G. Elam, 1960 unpublished).

A. School 14 locality (North of College Age. along an extension of 13th Street at west edge of playground of School 14.)

One hundred feet of outcrop extends north-south, strikes N25E and dips 45° southeast with the top of the section to the southeast as judged by graded bedding. The south end of the outcrop is a pale, gray-green quartzite, poorly sorted and mostly fine grained.

The MATRIX is a brownish purple, fine grained sandstone or siltstone with frequent coarse, round, sand grains and some clay, much calcareous dust and small calcareous fragments, many blobs of clay varying from black to light gray, and also with frequent light gray calcareous granules.

The FRAGMENTS are coarse-grained, light-gray, massive, and fossilferous limestone varying in shape from irregular to round to tabular. Average size is 2"-5" with some longer dimensions up to 18". There are also a few large slabs the largest of which is two feet thick and eight feet long. The general orientation of fragments is subparallel to the boundaries of the main flow. Abundant small clay blobs about 2" across are also found, along with some dense light gray limestone fragments and a few sandy fragments. At the north end of the outcrop the ratio of pebbles to matrix is about 30:70 varying to 20:80 near the middle, and dropping to 10:90 at the south end of the brecciola outcrop. This indication of grading suggests the beds are right side up with the top to the south east.

Deepkill Euxinic Assemblage

Stop 1. The first stop will be at the type locality of the Deepkill, one-quarter mile east of Grant's Hollow, ten miles north of Troy on Route 40.

The upper Deepkill is separated from the lower by a covered interval of 800 feet, and its rocks comprise a different assemblage from the euxinic lower Deepkill. The upper Deepkill is a series of mud flows, clay-in-clay brecciolas, a few lime-in-clay brecciolas, porcelanites, and thin beds of chert. Near the bottom of the section there is a small amount of graptolitic black shale and dark gray limestone. This part of the Deepkill is mentioned because its proximity makes it available for those who may be more interested in spending a half-hour on this additional sedimentary type than in collecting graptolites and turbidites from the lower Deepkill.

Both the top and the bottom of the lower Deepkill are covered. The part of the section which is exposed is made up of black shale, gray shale, light gray thin bedded siltstones in banks one to four feet thick, and various types of brecciolas and graded beds.

This assemblage appears to be produced by two sets of factors. First, the underlying euxinic chemical environment dominated by H_2S affects Eh much more than pH (Krumbein and Garrels 1952). This permits the accumulation of lime mud at one time and sapropelitic black mud at another depending on alternating chemical controls that are related to tectonic activity on the basin margin. An example is the Black Sea where the lime muds overly sapropelitic ooze (black organic shale) and the two are separated by a thin layer of terrigenous sand (Archanguelsky 1927). The second set of factors are those which produce turbidites of various kinds, brecciolas and graded beds of one kind or another depending on the speed of flows from the upper parts of continental slopes triggered by faulting or by overloading of metastable shelves. More gentle currents from continental shelves would bring a steadier supply of sand and silt to build the banks of thin bedded siltstones.

When turbidity flows were in action and diluted the euxinic environment, then lime muds or organic ooze would not be present as pure rock types, but when the flows died down the euxinic deposits would form the dominant rock type with alternation from lime to mud to organic ooze, and with an occasional turbidite flowing into the depositional area from one side of the basin or the other.

The faunal evidence as analyzed by Ruedeman fits well with the postulated euxinic environment. The predominant fossils are graptolites which are thought to be pelagic or pseudopelagic (i.e. living attached to seaweed). Other fossils are rare and are thin shelled chitinous forms which appear to be well adapted to a pseudopelagic environment. Other bottom dwelling types are wanting in the shales, silts, and calcilutites.

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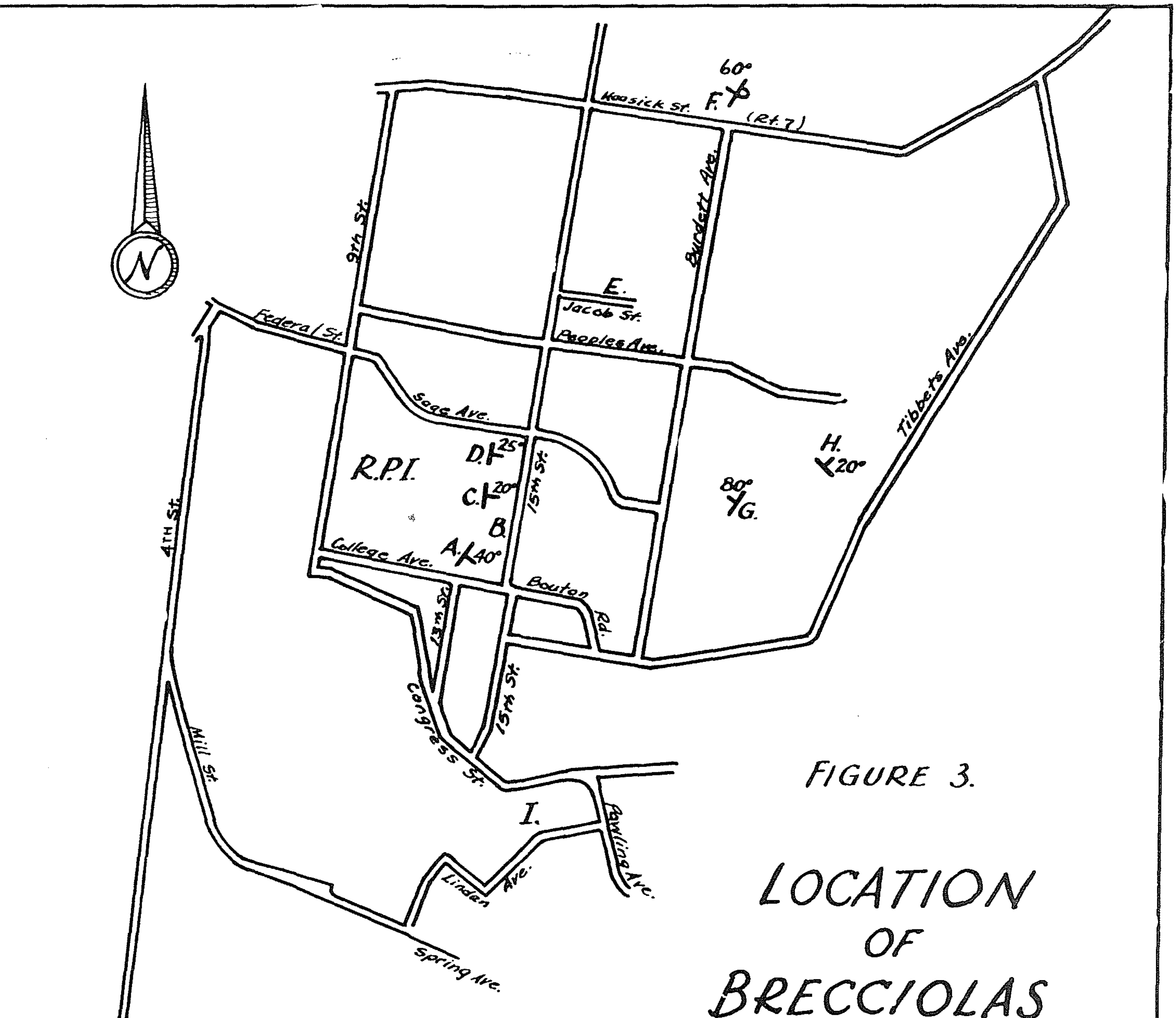

FIGURE 3.

LOCATION OF BRECCIOLAS

A. School 14, College Ave. and 13th Street.
B. Sage Ave. brecciola, 15th St. occurrence.
C. Campus brecciola at east side of playing field.
D. Sage Ave., 250 ft. west of 15th Street.
E. Brecciola north side of Beman Park.
F. Dunn Garden Apartments, Hoosick St. and Burdett Ave.
G. Troy High School playing field.
H. Between Rensselaerwyck and Troy High School playing field.

B. Sage Avenue locality - 15th Street occurrence.

The outcrop is buried beneath the buildings along 15th Street in the vicinity of the 15th Street Lounge. Large boulders 4' by 6' were blasted from an old quarry wall and moved by bulldozer to their present location between the South Parking Lot and the tennis courts. There is one predominant type (TYPE 1) of rock, which makes up about 90% of the boulders and there are several subsidiary types.

TYPE 1. FRAGMENTS: About 80% of the fragments are coarse grained, fossiliferous, light gray, limestone, averaging 4" to 6" in size, irregular to subspherical in shape, with no linear distribution, and with no noticeable grading. Since the occurrence is a pile of boulders there are no observable stratigraphic relationships. Minor constituents are small fragments of light gray, dense limestone and sandstone of which the former is more abundant.

MATRIX is a brown-weathering dolomite mud with numerous medium- to coarse, rounded sand grains. About 20 to 50% of the matrix is composed of light gray, dense, calcilutite fragments averaging $\frac{1}{4}$" in diameter. These give the matrix the appearance of a pebble conglomerate.

The relative abundance of matrix and fragments is variable from boulder to boulder but the general average is about 60% fragments, not counting the $\frac{1}{4}$" calcilutite fragments that appear to make up a considerable part of the conglomeratic matrix.

SPECIAL FEATURES OF TYPE 1. The coarse grained fossiliferous limestone fragments with brown weathering dolomite cement are closely similar to the outcrops on Sage Avenue, 250 feet west of 15th Street (Location D) where the bed is well exposed along a joint face. It also outcrops in Beman Park near Samaritan Hospital at the west edge of the parking lot. This was one of S. W. Ford's fossil localities (1876). Walcott also collected Lower Cambrian fossils (Elliplocephala asaphoides zone) from the calcarenite fragments at the Beman Park locality. The calcarenites in the boulders at the 15th Street occurrence of the Sage Avenue brecciola probably are as good a locality for collecting fossils from this zone as we will see on this trip.

Similar features of matrix fragments are seen in the upper brecciola at Hoosick Street and Burdett Avenue (section buried), now represented by boulders in the rubble pile to the west of the Dunn Garden Apartments. These three occurrences appear to lie on strike and are probably correlatable.

C. R. P. I. Campus locality (12' brecciola outcropping on R. P. I. campus east of football field)

The general dip of 20° to the east places this brecciola beneath the "Sage Avenue brecciola". It is underlain by greenish-gray clay with interbeds of dolomitic, fine-grained sandstone two to three inches thick and six to ten feet apart. The brecciola is overlain by greenish-gray shale with thinly interbedded siltstone or very fine grained sandstone. The interval from the top of the "campus brecciola" to the base of the "Sage Avenue brecciola" appears to be 15 to 30 feet, with the latter being the younger of the two.

MATRIX is dark gray, flow-streaked mudstone. No evidence is seen of stratigraphic differentiation, graded bedding, or direction of flow.

FRAGMENTS are predominantly (80%) coarse grained light gray, fossiliferous limestone, ranging in size from 2" to 1½ feet, irregular in shape and with no preferred orientation. There are a few small fragments of dense light gray limestone, about one per cent by volume. Medium grained, rounded sandstone makes up about 20% of the fragments with irregular distribution and no preferred orientation.

FRAGMENTS & MATRIX: Relative percentage of fragments to matrix is 40:60 to 50:50. Evidence of scour is seen in the presence of green clay blobs in the lower part of the flow. Load casts are also present in the form of green clay injected into the base of the brecciola.

STRATIGRAPHIC CORRELATION: This brecciola is lithologically closely similar to the lower brecciola at Dunn Garden Apartments (Hoosick & Burdett). It also falls in the same succession of beds and is thought to be stratigraphically equivalent.

G. <u>Troy High School playing field.</u> (Sequence at the east end of the track and playing field north of Troy High School on Burdett Avenue.)

Strike of these beds is N15E, dip is 75 west; top of the stratigraphic section is to the west. The brecciola sequence is made up of three members with eleven submembers. It is overlain by thin bedded, fine grained sand and shale with a possible thickness of 200 feet. The brecciola sequence is underlain by brown weathering green claystone with dark gray wispy interbeds, having a possible thickness of 300 feet. The thickness of the brecciola sequence is approximately 90 feet. The Troy High School outcrop is the most extensive and gives the best picture of both the brecciola and the beds associated with it.

Brecciola Sequence (in descending order)

Bed 3b; Mostly covered but with occasional patchy outcrops of dense, light gray limestone fragments in a dark gray clay matrix. A large outcrop that is probably stratigraphically equivalent occurs at the southeast corner of Burdett Avenue and West Peoples Drive. This outcrop has a ratio of fragments to matrix of about 15:85; the fragments are uniformly light gray, dense limestone, 2" to 3" thick, 8" long, and randomly oriented. The matrix is uniform dark gray claystone.

3a: Thin bedded light gray dense limestone, interbedded with thin beds of dark gray shale. Unit is regularly bedded but slightly disturbed, giving the appearance of layers being slightly pulled apart in sedimentary boudinage. This occurrence, which is 2 feet thick and over 8 feet long, may be a large mass that slid or flowed some distance without turbulence, or it may have slid only a few inches or feet, but enough to cause the disturbance noted. Similarly bedded limestone in a similar stratigraphic position occurs about 500 feet to the east across the High School playing field.

Bed 2e. Three feet of tan weathering green claystone with numerous black wispy streaks that show flow bedding.

2d. One and one half feet of light gray, dense limestone fragments in a dark gray matrix with 10:90 ratio; fragments are 2 by 6 inches and randomly oriented.

2c. Two and one half feet of tan weathering green claystone.

2b. One foot of green clay blobs (1" to 2") in maroon weathering clay matrix; ratio 20:80.

2a. Seven feet of green clay with black wispy interbeds and one interbed of coquina one inch thick with worm borings, giving supporting evidence of top and bottom.

Bed 1d. Four feet of light gray dense limestone and black shale fragments in a rusty, medium-grained, rounded sand matrix with a 20:80 ratio. Fragments and trains of fragments are subparallel to the margins of the flow. A small percentage of the limestone fragments are granular and fossiliferous. A few others are light brown and well-bedded. Average size of limestone fragments is 3 by 6 inches.

1c. One foot thick, similar to above but with sand and clay matrix 50:50, and showing an increase in the percentage of limestone fragments to matrix, to about 40:60.

1b. Black shale boulder one foot thick and eight feet long, oriented parallel to the margins of the brecciola.

1a. Brecciola bed five feet thick; ratio of limestone fragments to clay matrix is 80:20. Orientation of fragments is sub-parallel to the boundaries of the brecciola. The limestone fragments are mostly dense light gray limestone, granular fossiliferous light gray limestone, and light brown well-bedded limestone in a ratio of 60:20:20. The matrix is dark gray clay.

SYNOPSIS OF MAIN BRECCIOLA MASS (Beds 1a-1d)

GRADED BEDDING. The sand matrix shows incipient grading above bed 1c which is mixed sand and shale. The main mass of the flow 1a-1d shows marked increase in the abundance of limestone fragments downard through the flow.

OTHER CRITERIA OF TOP AND BOTTOM.

Worm borings: as noted under 1a.

Scour: the basal portion of 1a shows many wispy blobs of green clay that appear to have been scoured from the underlying green clay beds while they were unconsolidated.

STRATIGRAPHIC DIFFERENTIATION.

MATRIX: The sand and clay matrices appear to be well differentiated stratigraphically.

FRAGMENTS: The fragments are less well differentiated than the matrix but they do show a notable differentiation from the top to bottom. Toward the top of the bed, the limestone pebbles are mostly calcilututes while at the base the pebbles contain about 10% of calcarenites. The pebble-to-matrix ratio is perhaps 20:80 toward the top, increasing to 80:20 toward the base. At the top of the main brecciola the matrix is nearly pure sand; this changes gradationally downward to sandy clay and to nearly pure in clay in the base of the flow.

Correlation of separate outcrops on the west and east sides of the athletic field is satisfactory. On the west side the units are oriented from top on the west to bottom on the east; on the east side the orientation of the same sequence has the top on the east and bottom on the west. In spite of this structural complication the correlation of the various brecciola units can be made in some detail.

NOTES ON TRIP B

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TRIP C

SILURIAN AND DEVONIAN ROCKS OF THE CENTRAL HUDSON VALLEY

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INTRODUCTION

Limestones, shales, sandstones, and conglomerates comprise the Silurian and Devonian sequence of the Hudson Valley. Only the youngest portion of the Late Silurian is represented (Rondout Formation), whereas most of the Early and all of the Middle Devonian is present. Late Silurian (Cayugan Series) rocks are thin, and rest unconformably upon folded and eroded Middle Ordovician shales and sandstones. The Early Devonian rocks are divided into the Helderbergian and Ulsterian Series (Rickard, in press), and consist of limestones in the lower part and shales and sandstones in the upper portion. The overlying Middle Devonian sequence (Erian Series) begins with the Onondaga Limestone and continues above into marine and non-marine shales and sandstones of the Hamilton Group. Fossils are common throughout most of the Silurian-Devonian sequence of the Hudson Valley. Marine assemblages are particularly rich in the Helderberg limestones, the Onondaga Limestone and the lower, marine portion of the Hamilton. Plant fragments are the only abundant fossils in the non-marine rocks near the top of the sequence.

STRATIGRAPHY

UPPER SILURIAN AND LOWER DEVONIAN

Introductory Statement

Extensive detailed geologic mapping on a scale of 100 feet and 50 feet to the inch by Dunn, Cutcliffe, and LaBrake in the South Bethlehem-Ravena area and the Port Ewen-East Kingston area, and analyses of thousands of feet of diamond drill cores have provided new detailed information about the Cayugan and Helderbergian formations in the Hudson Valley. An outgrowth of the work has been a division of the Manlius, Kalkberg, and New Scotland formations into new, economically usable key beds and members. Simultaneously, L. V. Rickard (in press) has studied the same series on a regional basis and has redefined and subdivided several formations. Plate I is a tabulation of the geologic formations from previous authors and indicates the new stratigraphic units suggested by Rickard (in press), and Dunn, et al., (unpublished), as seen at East Kingston, Broncks Lake and Ravena.

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Stratigraphic Summary for the Ravena Area, New York

Age	Series	Formations	Members	Lithologies
MIDDLE DEVONIAN	ERIAN	Hamilton Group	Kiskatom	Shale to sandstone
			Ashokan	Sandstone
			Mount Marion	Shale to sandstone
			Stony Hollow	Shale
			Bakoven	Shale
		Onondaga	Nedrow	Limestone
			Edgecliff	Limestone
LOWER DEVONIAN	ULSTERIAN	Schoharie	Leeds	Calcareous mudstone to limesto
			Carlisle Center	Calcareous mudstone
		Esopus		Shale to sandstone
		Glenerie		Quartz sandstone
	HELDERBERGIAN	Becraft		Limestone
		New Scotland		Calcareous mudstone to limesto
		Kalkberg	Broncks Lake	Limestone
			Hannacroix	Limestone
		Coeymans	Ravena	Limestone
		Manlius		Limestone
Late SILURIAN	CAYUGAN	Rondout		Limestone
Middle ORDOVICIAN		Normanskill		Shale to sandstone

Rickard has suggested that part of the Rondout Formation (the Crysler Member) and the Manlius Formation be placed in the Devonian and that the Crysler Member be made the base of the Helderbergian Series. He also has defined the Thacher Member of the Manlius and the Ravena Member of the Coeymans. He has redefined the top of the Kalkberg and suggests that the Kalkberg be given formational status.

J. R. Dunn, assisted by W. E. Cutcliffe and R. LaBrake, has described six key beds within the Manlius Formation that have proven to be mappable units throughout the central Hudson Valley. The Kalkberg Formation has been subdivided into four units on the basis of lithologic and faunal criteria. Faunal, lithologic, and chemical data obtained by Dunn support Rickard's redéfinition of the top of the Kalkberg Formation. The New Scotland Formation has been described in detail from numerous cores, and several key beds have been noted. A facies change from predominantly calcareous mudstone to silty limestones occurs from north to south.

Upper Silurian

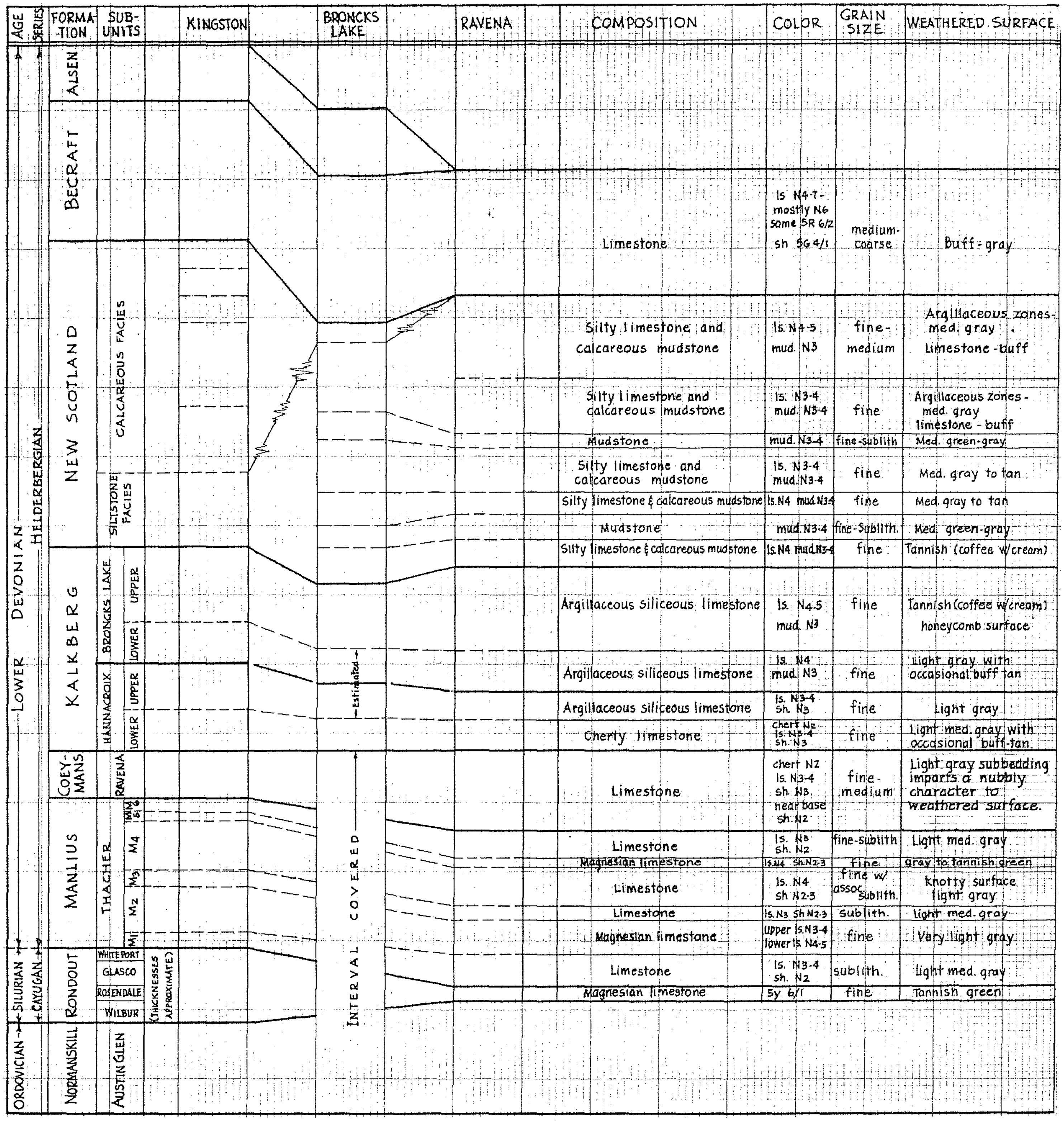
Rondout Formation

The name Rondout was first applied by Clarke and Schuchert (1899, pp. 874-876) to magnesian limestones in the vicinity of Rondout which were used for the manufacture of natural cement. Rickard (in press) defines the Rondout Formation as the buff-weathering, greenish-gray, magnesium limestone which is subjacent to the Manlius Formation throughout New York State. Because no specific type locality was recommended in the past, Rickard suggests that the exposures in the abandoned gravel pit 0.5 miles south of Wilbur, New York be taken as the standard reference section. He notes that other equally good sections are present at the abandoned cement mine in East Kingston and along the road south of the West Shore railroad bridge at Wilbur. The Rondout of southeastern and eastern New York is considered by Rickard to be Upper Silurian (Late Cayugan). The Crysler Member of central New York is placed in the Devonian (Early Helderbergian).

The Rondout, as presently defined in the central Hudson Valley, is the buff-to gray-weathering, magnesian limestone which lies between the contorted Ordovician shales, siltstones, and graywackes and the ash-gray-weathering, blue-gray, predominantly thin-bedded limestone of the lowest Manlius Formation. Fresh Rondout Limestone has a greenish cast, particularly in the more magnesian zones. These zones in all cases are fairly high in ferrous iron and in pyrite and hence weather characteristically to a buff color. Locally, the Rondout is rich in the corals *Halysites catenularia* and *Cladopora rectilineata*.

In the vicinity of Rosendale and Kingston, the Rondout is divided, from bottom to top, into the Wilbur Limestone (3-15 feet), the Rosendale Dolomitic Limestone (17-27 feet), the Glasco Limestone (10 to 15 feet), and the Whiteport Dolomitic Limestone (9-14 feet). The Rondout is 37feet thick at Wilbur, 40 feet at Fourth Lake, and almost 50 feet at Rosendale according to Rickard (in press). Diamond drill cores indicate a thickness of about 28 feet at East Kingston. A thickness of approximately 30 feet

SUMMARY OF LATE CAYUGAN AND HELDERBERGIAN



COLOR CODE

REFERENCE: ROCK COLOR CHART
GEOLOGIC SOCIETY OF AMERICA, N.Y., N.Y.

N2 - Grayish Black	N5 - Medium Gray	5G4/1 - Dark Greenish Gray
N3 - Dark Gray	N6 - Medium Light Gray	5Y6/1 - Olive Gray
N4 - Medium Dark Gray	N7 - Light Gray	5R6/2 - Pale Red

STRATIGRAPHY IN THE CENTRAL HUDSON VALLEY

TOPOGRAPHIC EXPRESSION	BEDDING	COMMON FAUNAL SPECIES	SPECIAL CHARACTERISTICS
Slope			
Cliff } slope	Massive (1-2' beds) Lower 10" - 8-16" of Limestone with ½-6" shale	Abundant fossils - *Spirifer concinnus*, *Gypidula pseudogaleata*, *Atrypa reticularis* and *Uncinulus campbellanus*	Becraft <25% shale, crystalline limestone frequently a coquinoid. New Scotland contact is transitional. Base is last typical gray New Scotland limestone with first green-gray Becraft shale superjacent.
Slope	Limestone 2"-10" beds Mudstone ½-2" at top to 12-15" near base	Transitional Becraft fauna *Leptaena rhomboidalis* immediately below contact. Lower part of zone, *Streptelasma strictum* abundant.	New Scotland >25% mudstone generally ≈60%. Limestone, crinoids, with slight Becraft texture. Three fossiliferous blue-gray-black chert bands, one above, two below Becraft contact.
Cliff } slope	Limestone 1-4" beds Mudstone 12-36" beds	Abundant large brachiopods, "*Eospirifer*" *macropleura*, *Leptaena rhomboidalis*, *Leptostrophia becki*, *Strophonella leavenworthana*.	Main cliff former
Slope	Limestone 2-6" beds, Mudstone 6-12" beds	*Leptostrophia becki* (?)	Fossils jumbled, small olive green pebbles.
Slope	Limestone 2½-10" beds Mudstone 16" beds	Some large brachiopods, abundant small rugose corals. Few algal swirls. *Streptelasma strictum*	Limestone zones weather with ½" wide vertical scars, seldom outcrops.
Slope	Limestone 4-8" beds, Mudstone 4-19" beds	Large bryozoa whorls & algal reef pods in crystalline limestone.	Lithology similar to above unit.
Slope	Limestone 2-6" beds Mudstone 6-12" beds	*Platyceras ventricosum*, *Rhipidomella oblata* (?)	Fossils contorted. Associated limestone sublithographic in 8-13" beds. Olive green pebbles.
Slope	Limestone 1-2" beds Mudstone 8-12" beds	Lowest *Eospirifer macropleura* and abundant brachiopods.	Great increase in SiO_2 & Al_2O_3; decrease in CaO relative to lower unit.
Slope } cliff	Limestone 4-8" beds Mudstone 4-6" beds decreasing to ⅛-¼" beds near base.	Abundant rugose corals. Few bryozoa whorls in lowest beds with relatively abundant brachiopods. Both decrease vertically.	3-4 layers of concentration of chert lenses near base of zone. Small nodules through lower half. Subbedding gives "tennis net" appearance.
Slope	Limestone 2-4" beds Shale ¼-½" beds	Abundant encrusting bryozoans. *Dicoelosia varicus*, *Lingula rectilatera*	Euxinic zone with pyrite and small calcareous fossil tests at base.
Slope	Massive (1-2') subbedding shale streamers (1-3")	Small *Gypidula coeymanensis*, siliceous Crinoid stems, *Dicoelosia varicus*.	Lithology like Coeymans. "Tennis net" weathering.
Cliff	Massive (1-12") bedded with chert	Transition fauna - similar to Coeymans. *Gypidula* smaller, less common.	Abundant chert, otherwise like Coeymans.
Cliff	Thin bedded (1-2") for a few feet near the top & bottom. Massive (2-3') thru the main part with associated shale streamers.	*Gypidula coeymanensis* most common. *Atrypa reticularis* and *Uncinulus mutabilis* Large (½") siliceous crinoid stems.	Massive homogenous limestone with well developed vertical jointing. A few nodules of chert in upper beds. Contact transitional.
Slope	Limestone 2-6" beds Shale ⅛-¼" beds	Few *Tentaculites gyracanthus*. *Stromatopora baretti*.	6-12" reef frequently in zone.
Slope	Millimeter	Generally absent.	Well developed in Ravena & west, intermittent to the south.
cliff	Irregular	Main reef builder *Stromatopora* (*Syringostoma*) *barretti*.	Interval immediately above & below well developed reef - light gray sublithographic limestone.
Slope	Limestone 2-6" beds, shale ⅛-¼" beds	*Tentaculites gyracanthus*	Fossils recrystallized to sparry calcite.
Cliff	Millimeter	One foot zone in middle of unit with abundant *Tentaculites gyracanthus*.	Polygonal mud crack structures. Color lightens beneath fossil zone.
Slope	2-4" Limestone bedded by ⅛-¼" shale Near base limestone 8-14" thick.	*Tentaculites*, "*Spirifer*" *vanuxemi*, *Leperditia alta*, and "*Orthoceras*" *rudis*.	"*Orthoceras*" *rudis* in small 2" zone immediately above Rondout contact in Ravena - small reef occasionally within zone. Contact conformable.
Slope	Millimeter to 1-8"	Absent in Ravena, Abundant & varied species in Kingston.	Radical facies change from Catskill to the south.

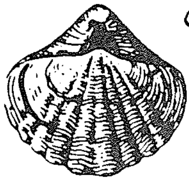
NOTE: Description of New Scotland is for Ravena Section.

PLATE Ic

By W.E.Cutcliffe
Checked by J.R.Dunn

Vertical Scale 1" = 50'
March 1961

a.



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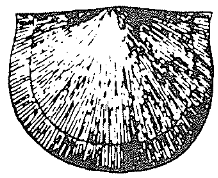

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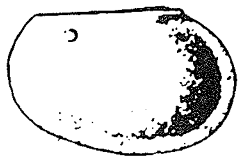
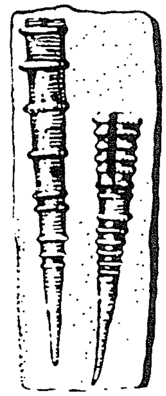
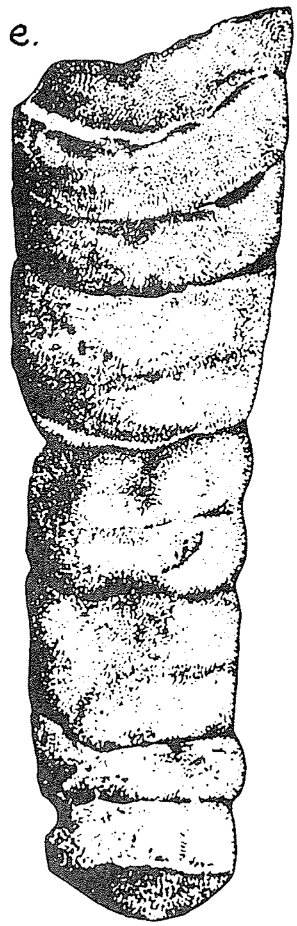




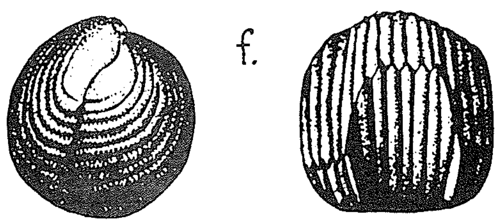
d.

e.



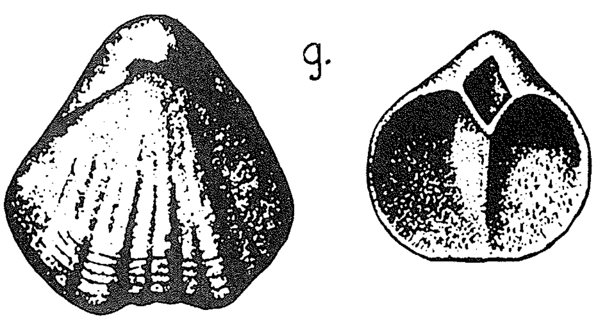
MANLIUS WATERLIME FOSSILS:
a. "*Spirifer*" *vanuxemi*, x 2¼. b. *Stropheodonta varistriata*, x 1⅛. c. *Leperditia alta*, x 3.
d. *Tentaculites gyracanthus*, x 3.
e. "*Orthoceras*" (*Anastomoceras*) *rudis*, x ¾.

f.

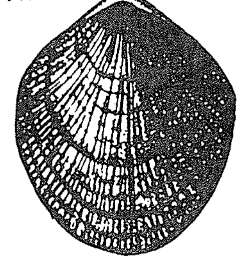


COEYMANS LIMESTONE FOSSILS:
f. *Uncinulus mutabilis*, x 1⅛.
g. *Gypidula coeymanensis*, x 1⅛.
h. *Atrypa reticularis*, x 1⅛.

g.



h.



(Rickard, in press) is maintained northward to Catskill. The thickness in the Thacher Park and Ravena area is generally less than 10 feet but is variable. Cores at Ravena and South Bethlehem (western part of Callanan quarry) indicate 2 to 8 feet of Rondout magnesian limestone, but at the northern part of the Callanan Road Improvement Company quarry at South Bethlehem (Stop 1A) the Rondout Formation is 12 (?) feet thick.

Lower Devonian

Manlius Formation

The name Manlius was first used by Vanuxem (1840, p. 376) for limestone in the vicinity of Manlius, New York. Apparently it was first applied to rocks which are now known as the Cobleskill, Rondout, and Manlius Formations, but most subsequent applications of the name have restricted its use to only the last of these. The Manlius Formation is subdivided from bottom to top into the Thacher Member (Rickard, in press), and the Olney, Elmwood, Clark Reservation, and Jamesville Members (Smith, 1929). The Olney and higher members were to found pass laterally into the Coeymans Formation in the Richfield Springs quadrangle (Rickard, in press).

The only member of the Manlius Formation present in the central Hudson Valley is the Thacher. According to Rickard, the Thacher is not a part of the type Manlius as defined by Smith (1929). The Thacher consists of interbedded "ribbon" limestone and more massive biostromal units consisting of stromatoporoid remains. It has been subdivided by Dunn into 6 units, and these units have been utilized for detailed geologic mapping at South Bethlehem, Ravena, Coxsackie, East Kingston and Port Ewen. Plate I summarizes the units as seen at East Kingston and Ravena. The submembers are tentatively called M-1 through M-6. Of particular interest is the fact that the M-5 unit has a typical Rondout lithology, i.e., it is greenish gray, somewhat pyritic, weathers to a buff color and is magnesium rich. M-6, a medium bedded, frequently biostromal layer, is at the top of the Thacher.

The Thacher Member of the Manlius is 52 feet thick at the type locality at Indian Ladder in Thacher Park, 52 to 55 feet at Ravena and South Bethlehem, 50 feet at Broncks Lake, 52 feet at East Kingston, and 50 to 55 feet at Wilbur, Rondout, and Glasco southeast of Kingston (Rickard, in press). The fauna of the lower Thacher consists of *Tentaculites gyracanthus* (Eaton), *Howellella vanuxemi* (Hall), a brachiopod, and *Leperditia alta* (Conrad), and *Howellella vanuxemi* (Hall), among others. The stromatopore which is the major reef-former presumably is *Syringostroma barretti* (Girty). About 80 fossil species have been reported from the Thacher.

Coeymans Formation

The name Coeymans was first suggested by Clarke and Schuchert (1899, pp. 874-875) for the "Lower-Pentamerus" limestone of Hall, Vanuxem and others. The name was applied in some cases to include certain overlying strata, but subsequent usage by Ruedemann (1930), Goldring (1935),(1943), and Chadwick (1944) has restricted the Coeymans Formation to the essentially non-cherty units below the Kalkberg Formation and above the upper biostromal layer of the Manlius Formation. The Ravena (new, Rickard 1961) is the only member of the Coeymans Formation which occurs in eastern New York. The Ravena Member of the Coeymans Formation is a homogeneous, bluish, medium gray, medium to coarse-grained limestone which forms prominent, massive ledges below the cherty Kalkberg Formation. It normally weathers to a slightly lighter gray than the overlying Kalkberg. Bedding planes are 1 to 12 inches apart and irregular enough in detail so that attitudes are difficult to obtain. The Ravena Limestone is characterized faunally by Gypidula coeymanensis (Schuchert) and large crinoid stems which, toward the top of the member, are silicified.

Rickard (in press) considers the upper contact of the Coeymans with the Kalkberg Formation to be gradational. Dunn identifies the top of the Coeymans in the Hudson Valley by the first occurrence of layers of chert nodules occurring about 12 inches apart. Johnsen (1958, p. 10) places this contact in the same position. Generally speaking, this selection places one or two nodular zones within the Coeymans Formation. However, in the absence of a more definitive contact the base of the closely spaced chert layers is quite adequate because: (1) this produces more uniform thicknesses for the Coeymans within a given area; (2) the base of the chert layers can nearly always be seen and is therefore readily mappable; (3) the increase in chert coincides with an increase in the silica content of the limestone, from less that 10% to about 25% - a point of considerable economic importance. This selection of the top of the Coeymans produces somewhat greater thicknesses for the Coeymans at Ravena than earlier reported. Based on many drill cores, Dunn recognized 26 to 30 feet. Johnsen observed 32 feet of Coeymans at Ravena. Typical thicknesses (Rickard, in press) for the Coeymans formation in the Hudson Valley are: Rosendale area 15 to 20 feet; Catskill quadrangle 10 to 15 feet; Ravena 20 feet; Indian Ladder in Thacher Park, 36 feet (50 feet according to Goldring 1935, p. 101).

Over 80 species of fossils have been reported from the Coeymans formation. Among the most common are: the brachiopods Atrypa "reticularis" (Linnaeus), Stropheodenta (Brachyprion) varistriata (Conrad), Gypidula coeymanensis (Schuchert), Uncinulus mutabilis (Hall), Camerotoechia semplicata (Conrad), Leptaena "rhomboidalis" Wilckens) and Rhipidomelloides oblata (Hall). The most common trilobites reported are Odontochile micrurus (Green) and Synphoroides pleuroptyx (Green).

Kalkberg Formation

In 1908, Chadwick (pp. 346-348) proposed the name Kalkberg for the cherty limestones in the lower part of the New Scotland Formation of Clarke and Schuchert (1899, pp. 874-878), with the apparent intention of giving the Kalkberg the status of a member. The name has been used primarily for the lower member of the New Scotland Formation although Hartnagel (1912, pp. 56-60) separated the Kalkberg from the New Scotland, giving them equal status. In the opinion of Rickard (in press) because "......the Kalkberg is much more extensive in central New York than the restricted New Scotland and contains a lithology and fauna distinct from strata above and below, it should be raised to formational rank and used only in that sense."

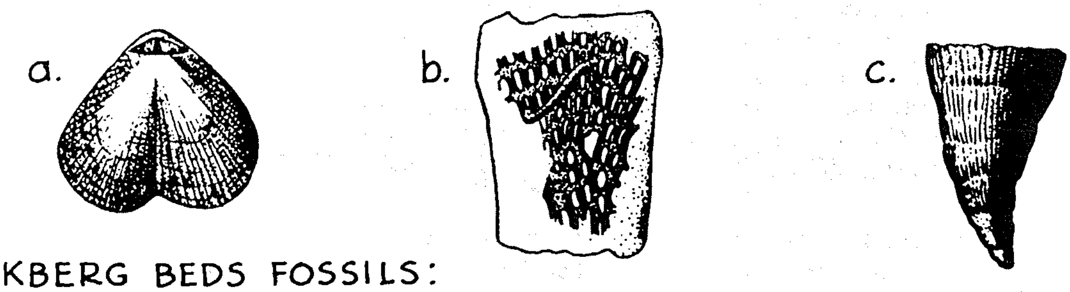
Chadwick placed the type locality of the Kalkberg at Austin's Glen on Catskill Creek where Rickard (in press) refers 54 feet of limestone to this formation. Earlier authors describing this section recognized only 40 feet of Kalkberg and put the remaining part into the New Scotland or "Catskill shaly". Rickard's redefinition of the top of the type Kalkberg permits a clearer lithologic differentiation by placing all of the less shaly, medium to massive limestone units together. Faunal distinctions are also sharper - the Kalkberg includes the Dicoelosia (formerly Bilobites) varicus (Conrad) zone, and generally lacks Eospirifer macropleurus. (Conrad).

Independently, Dunn, working on cores and chemical analyses form East Kingston, South Bethlehem, and Ravena, arrived at a similar position for the top of the Kalkberg Formation. Criteria for separation were found to be not only faunal and lithologic but also chemical. Passage from Kalkberg, as now defined, into New Scotland is characterized by a change from less than 30% SiO_2 to nearly 50% SiO_2 and several percent Al_2O_3 or, stated lithologically, from siliceous limestone to calcareous mudstone.

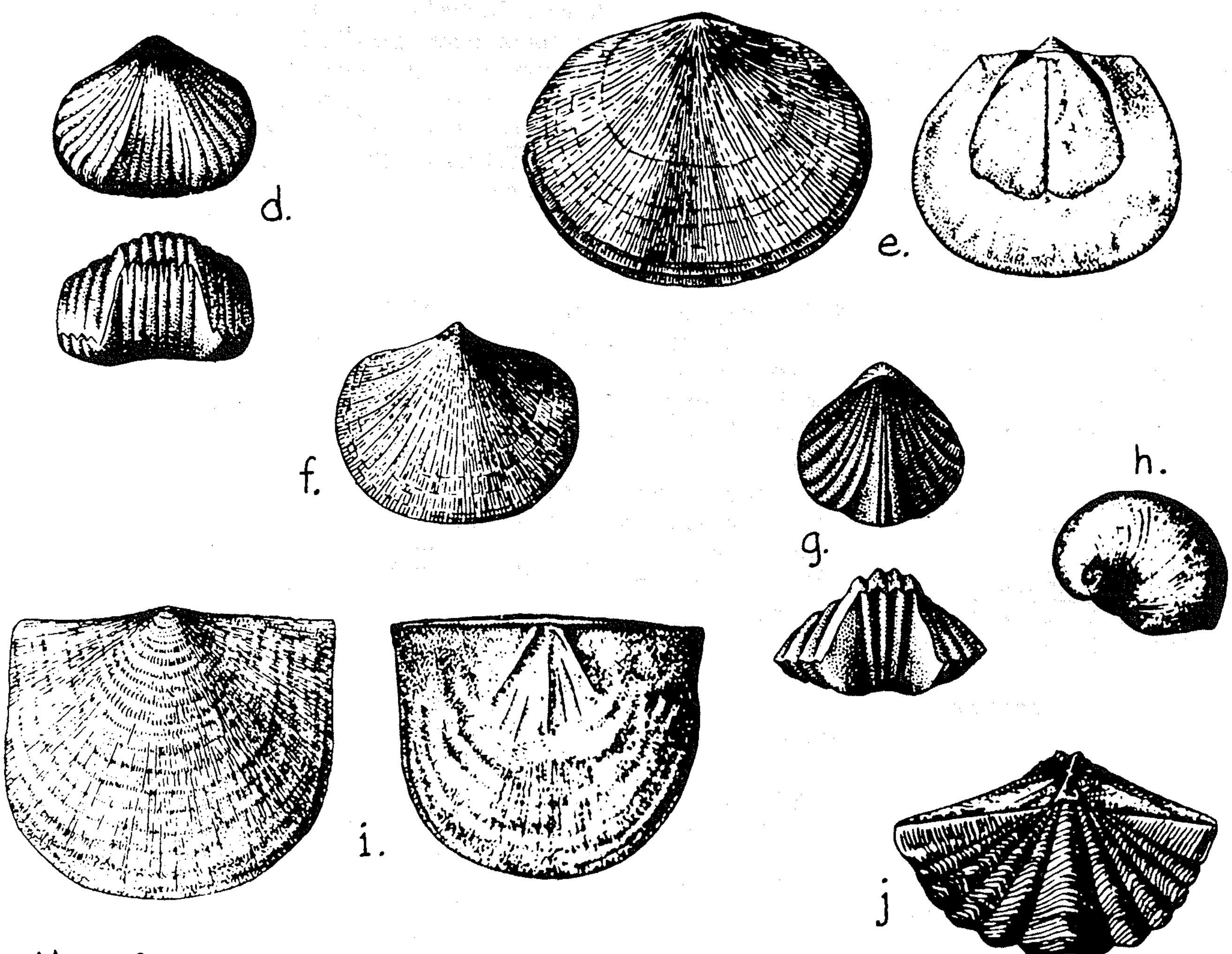
It is here proposed by Dunn that the Kalkberg Formation within the Hudson Valley be subdivided into two units which have been studied and differentiated in cores and in the field both in the Ravena-South Bethlehem area and the East Kingston area. The names here proposed are Hannacroix (lower and upper) for the lower unit and Broncks Lake (lower and upper) for the overlying unit. These two members have structural, faunal, and lithologic distinctions, but, aside from a slight upward increase in Al_2O_3 (from about 2% to 3.5%), the chemical composition of both members is very similar.

The lower Hannocroix is fully exposed in the field at many places from Albany to Kingston, because it is the principal ledge-forming unit west of the Hudson River. The lower Hannacroix is a bluish-gray, chert-rich limestone at the base of the Kalkberg, which, except for the chert, is very similar to the Coeymans Formation. It is fine grained, except for recrystallized fossils, and massive in appearance with bedding planes 4 to 12 inches apart. Nodular chert layers are spaced approximately 8 to 14 inches apart. The predominant species are large silicified crinoid stems, the brachiopods Dicoelosia varicus (Conrad), Gypidula coeymanensis (Schuchert) and Atrypa "reticularis" (Linnaeus). Typical thicknesses of the lower Hannacroix are 11 feet at Ravena and on Hannacroix Creek, 14 feet at Catskill, and 15 feet at East Kingston.

The upper Hannacroix is a fine-grained, fairly massive, gray limestone with anastomosing argillaceous subbedding and is the unit above the last layer of chert of the lower Hannacroix. Bedding planes are several inches to two feet apart. Although it contains none of the distinctive layers of chert nodules of the lower Hannacroix, it still contains about 25% SiO_2. This silica occurs as silt, fine chert replacements, and as a component in the clay fraction. On weathered bedding planes the rock is laced with thin shale stringers giving it a "tennis-net" appearance. In the absence of chert, this unit looks very similar to the Coeymans Formation, but is finer grained and contains only a few small shells of Gypidula coeymanensis (Schuchert). Other typical fossils are: Dicoelosia varicus (Conrad), Atrypa "reticularis" (Linnaeus), and Eatonia medialis (Vanuxem). The top of the Hannacroix is recognized by the first appearance of a dark gray, euxinic shale which contains pyritic nodules and small brachiopods. Typical thicknesses of the upper Hannacroix are 10 feet at Ravena and South Bethlehem, 14 feet at Catskill, and 14 to 18 feet at East Kingston.



KALKBERG BEDS FOSSILS:
a. Bilobites varicus, ×3. b. Fenestrella compressa, ×1½.
c. Streptelasma (Enterolasma) strictum, ×1⅛.



NEW SCOTLAND BEDS FOSSILS:
d. Uncinulus abruptus, ×1⅛. e. Rhipidomella oblata, ×1⅛, ×1½.
f. Isorthis perelegans, ×1⅛. g. Stenoschisma formosum, ×1⅛. h. Platyceras ventricosm, ×1½. i. Leptostrophia becki, ×1⅛, ×¾. j. "S" perlamellosus, ×1⅛.

The lower part of the Broncks Lake Member consists of fine-grained, blue-gray limestone beds, one to three inches thick, interbedded with calcareous shale layers, about 1 to 2 inches thick. This unit is not often exposed, but when it is, the hard limestone layers weather away from the argillaceous beds which become soft and friable on long exposure. At the base is a black, euxinic shale, 2-3½ feet thick, which contains small calcareous fossils. In the lower Broncks Lake, fossils are abundant, the most characteristic ones being large colonies of encrusting bryozoans and the brachiopod Dicoelosia varicus (Conrad). The large crinoid stems of Mariacrinus stoloniferous, Hall and the brachiopods Uncinulus abruptus, Hall, Rhipodomelloides oblata (Hall), and Kozlowskielina perlamellosua (Hall) are abundant. The lower Broncks Lake is 15 feet thick at Ravena and South Bethlehem, 14 feet at East Kingston and 16 feet at Catskill.

The upper Broncks Lake is a fine-grained, blue-gray limestone which differs lithologically from the lower part by 1) its more massive bedding (a few inches to a foot or more thick), 2) its argillareous material is less obvious, 3) the occurrence of one to three chert layers near its base, and 4) its characteristically pitted weathered surface. Faunally, the unit was observed to contain a few Dicoelosia and bryozoan whorls only in the lower 4 to 5 feet. Lingula rectilatera (Hall) is common but has not been observed in the lower Broncks Lake. Typical thicknesses in the Hudson Valley are: 25 to 30 feet at Ravena, 24 feet at South Bethlehem, 23 feet at Broncks Lake, and 27 feet at East Kingston.

New Scotland Formation

The term New Scotland was first applied by Clarke and Schuchert (1899, pp. 874-878) to the "Catskill or Delthyris shaly limestone" of early workers (Hall, 1893, pp. 8-13, Darton, 1894, pp. 406-407). Clarke and Schuchert probably included the Kalkberg Formation in their original definition of the New Scotland. Rickard (in press) and Dunn, et al., (unpublished) separate the Kalkberg and the New Scotland strata into two formations.

The New Scotland Formation consists primarily of alternating medium gray, sublithographic to fine grained, impure limestone, and dark gray calcareous mudstone with varying amounts of chert and pyrite. Toward the top of the New Scotland some of the limestone layers become similar to the Becraft Limestone as calcite crystals increase in size to medium and coarse grain. At all areas in the central Hudson Valley where the contact is exposed, the lowest New Scotland, in gross chemical composition, is not a limestone. Rather, it is primarily a calcareous mudstone or siltstone in which the total carbonate is 45% or less. The top of the New Scotland Formation is taken arbitrarily at the lowest appearance of green shale and the highest occurrence of typical fine-grained, gray New Scotland limestone. The change coincides with a sudden increase in lime content in the South Bethlehem, Alsen and Kingston areas.

Significant facies changes occur in the Hudson Valley area. At Ravena and South Bethlehem the New Scotland Formation is a calcareous mudstone throughout its entire thickness. At Broncks Lake only the upper 6 feet can be called a limestone. At East Kingston the New Scotland is mostly limestone with but 27 feet at the base being argillaceous or silty. An additional change in the New Scotland Limestone is a notable increase in the content of silt in the Kingston area and a corresponding decrease in the alumina content. Judging from chemical analyses, the New Scotland Limestone is basically a limy siltstone or silty limestone at Kingston, but in the Albany area, although still silty, the clay content increases approximately by a factor of 2. According to Rickard (in press) the New Scotland formation also changes character to the west in the Schoharie and Canajoharie quadrangles. Here it is lower in clay content and gradually becomes more similar to the Kalkberg Formation.

Several valuable marker beds in the New Scotland have been noted in the central Hudson Valley, particularly in the South Bethlehem to Broncks Lake area. Plate I shows their position and gives a short description of their characteristics.

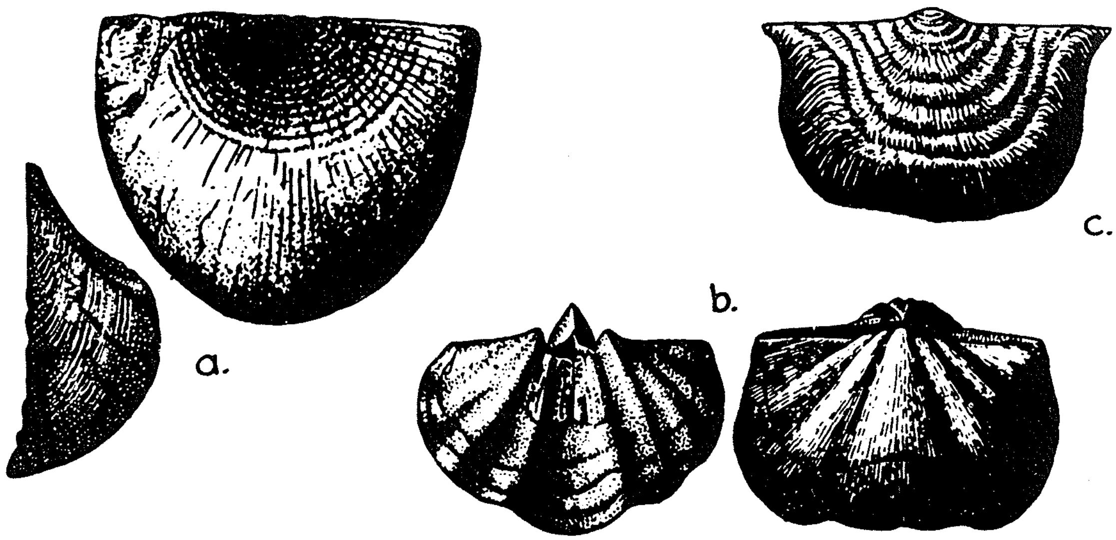
The brachiopods Kozlowskielina perlamellosa (Hall), Eospirifer macropleurus (Conrad), Leptaena "rhomboidalis" (Wilckens), Leptostrophia beckii (Hall), Howellella cycloptera (Hall), and Strophonella punctulifera (Conrad) are common. Bryozoans, trilobites, pelecypods, ostracods and platyceratid gastropods have also been noted. In all, over 300 species have been reported from the Kalkberg and New Scotland formations.

New New Scotland Formation is 65 feet thick (Rickard, in press) in the Helderbergs. Core data at South Bethlehem and Ravena indicate a thickness of 98 feet and approximately 92 feet is present at Broncks Lake. It is 98 feet thick at Austin's Glen (Rickard, in press), and about 100 feet at East Kingston.

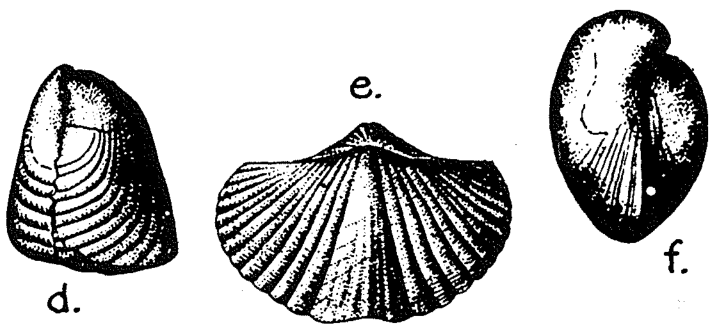
Becraft Formation

The name Becraft was given by Darton (1894) to the exposures of the coarse grained limestone occurring above the New Scotland Formation on Becraft Mountain near Hudson, New York. The Becraft Formation consists of very coarse-grained, light gray, tan, reddish, or nearly white limestone with green or gray shale partings. Locally chert occurs near the base and also near the top, and at Ravena minor quartz sandstone lenses have been observed near the top. It weathers to a light gray and is a prominent ledge former. Bedding planes are 3 to 6 inches apart at the base and over a foot apart in the upper portion. Appearance in outcrop is massive; bedding planes are irregular and difficult to see. The Becraft Formation has a thickness of 13 to 27 feet in the Albany area, 40 to 65 feet in the Ravena to Alsen area, and 35 to 50 feet in the Kingston area.

Fossils are abundant and crinoid stems are most common. The brachiopods Atrypa reticularis, (Linnaeus), Gypidula (?) pseudogaleata (Hall), Leptaena "rhomboidalis" (Wilckens), Meristella princeps (Hall), Schizophoria multistriata (Hall), "Spirifer" concinnus (Hall), and Howellella cycloptera (Hall) are among the most common.

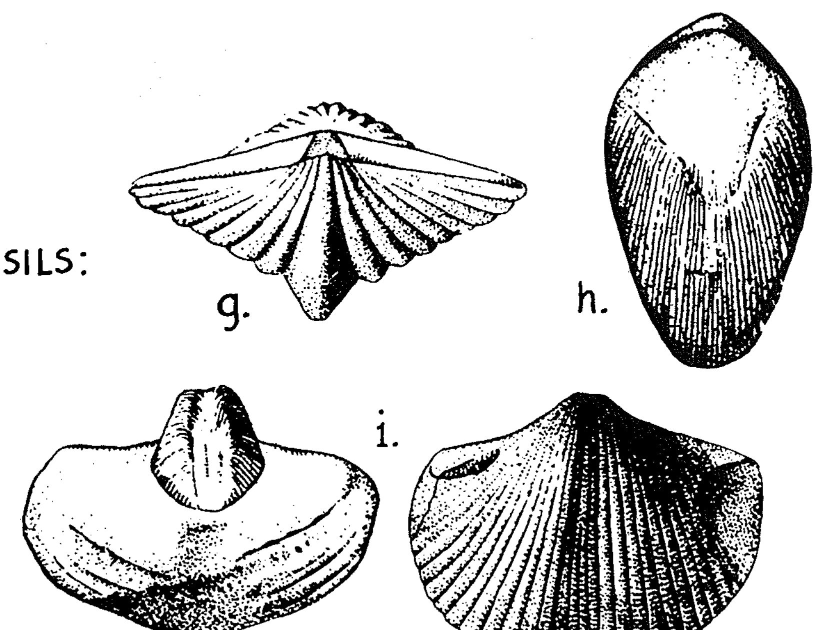


NEW SCOTLAND BEDS FOSSILS: a. *Strophonella leavenworthana*, x 1⅛. b. "*S*" (*Eospirifer*) *macropleura*, x ¾. c. *Leptaena rhomboidalis*, x ¾.



BECRAFT LIMESTONE FOSSILS:
d. *Uncinulus campbellanus*, x 1⅛.
e. "*Spirifer*" *concinnus*, x 1⅛.
f. *Gypidula pseudogaleata*, x 1⅛.

GLENERIE LIMESTONE FOSSILS:
g. "*S*." *murchisoni*, x 1⅛.
h. *Rensselaeria ovoides*, x ¾.
i. "*Spirifer*" *arenosus*, x ¾.



Alsen Formation

The Alsen Formation was named by Grabau (1919). He gave the name to cherty limestones which lie above the Becraft Formation in the central Hudson Valley. The Alsen Formation, in the Ravena-South Bethlehem area, and the Port Ewen Formation (above the Alsen) from the Catskill area south are the youngest formations of the Helderbergian Series.

The Alsen is a medium-grained, medium to dark gray, cherty limestone with interbedded argillaceous material. It is similar in appearance to the lower Hannacroix Member of the Kalkberg Formation. Aside from its stratigraphic position, the Alsen differs from the Kalkberg in having fewer layers of chert, being somewhat coarser grained, and containing Spirifer concinnus and Monotrypa tabulata. According to Rickard (in press) the Alsen is absent from the Coxsackie quadrangle to West Berne (northwest). Rickard measured 24 feet in the Broncks Lake section, 35 feet at Austin's Glen, and 20 feet in the Kingston area. Core data from East Kingston also indicate a 20 foot thickness for the Alsen in that area. At Ravena, however, some confusion exists in some cores where Alsen-like limestone is present beneath Glenerie quartzite (Oriskany) along with massive chert of uncertain identity. The limestone might reasonably be Alsen. The chert could be Alsen, Port Ewen or Glenerie.

Glenerie Formation

The name Oriskany Sandstone was applied by Vanuxem (1937) to a nearly pure, fossiliferous quartz sandstone exposed at Oriskany Falls in east-central New York. This sandstone is represented in the Hudson Valley by cherts and siliceous limestones containing Oriskany fossils, for which Chadwick (1908, p. 348) proposed the name Glenerie. The Glenerie varies in thickness throughout the Hudson Valley from less than 5 to over 50 feet, generally thickening to the south. Its fossils are usually silicified and many excellent collections have been made from these beds. The most common brachiopods are: Eatonia peculiaris (Conrad), Hipparionyx proximus (Vanuxem) Leptocoelia flabellites (Conrad), Leptostrophia oriskania (Clarke), Rensselaeria ovoides (Eaton), Costispirifer arenosus (Conrad), and Acrospirifer murchisoni (Castelnau). The trilobites: Homalonotus vanuxemi (Hall), Phacops logani (Hall) and Synphoria stemmata (Clarke) have also been found.

Esopus Formation

The Esopus Shale or Grit, overlying the Glenerie Formation, is the "Caudagalli grit" of Vanuxem (1842) and other early workers, so called from the markings Taonurus cauda-galli (Vanuxem) on the bedding planes which resemble a rooster's tail. The Esopus, because of its soft, argillaceous nature forms gentle slopes between the terraces maintained by the Becraft-Glenerie below and the Schoharie-Onondaga above. It is relatively barren of fossils except for a few brachiopods and the Taonurus markings whose origin is disputed. Taonurus has been described as a worm burrow, "fucoid", or seaweed or wave-mark of a peculiar type. Recently Laskowski (1956) has submitted evidence that these markings represent plant remains. The Esopus is about 150 feet thick in the Coxsackie quadrangle and will be seen at Stop 3.

Schoharie Formation

This formation, the youngest of the Lower Devonian units recognized in eastern New York, has been subdivided into several members. The lower 20-30 feet, known as the Carlisle Center Member, consists of laminated and flaggy calcareous mudstones or siltstones with a sparse fauna. The overlying Leeds Member is about 25 feet thick. It is composed of calcareous mudstones and siltstones which grade upward into cherty, argillaceous limestones, weathering buff. Fossils are more common in the Leeds Member. The most common Schoharie fossils are the brachiopods: *Atrypa impressa* (Hall), *Chonetes hemisphericus* (Hall), *Elytha fimbriata* (Conrad), *Leptaena "rhomboidalis"* (Wilckens), *"Spirifer" macrus* (Hall), *"S." raricosta* (Conrad); the trilobite: *Synphoria anchiops* (Hall) and various gastropods, cephalopods, corals and conularids.

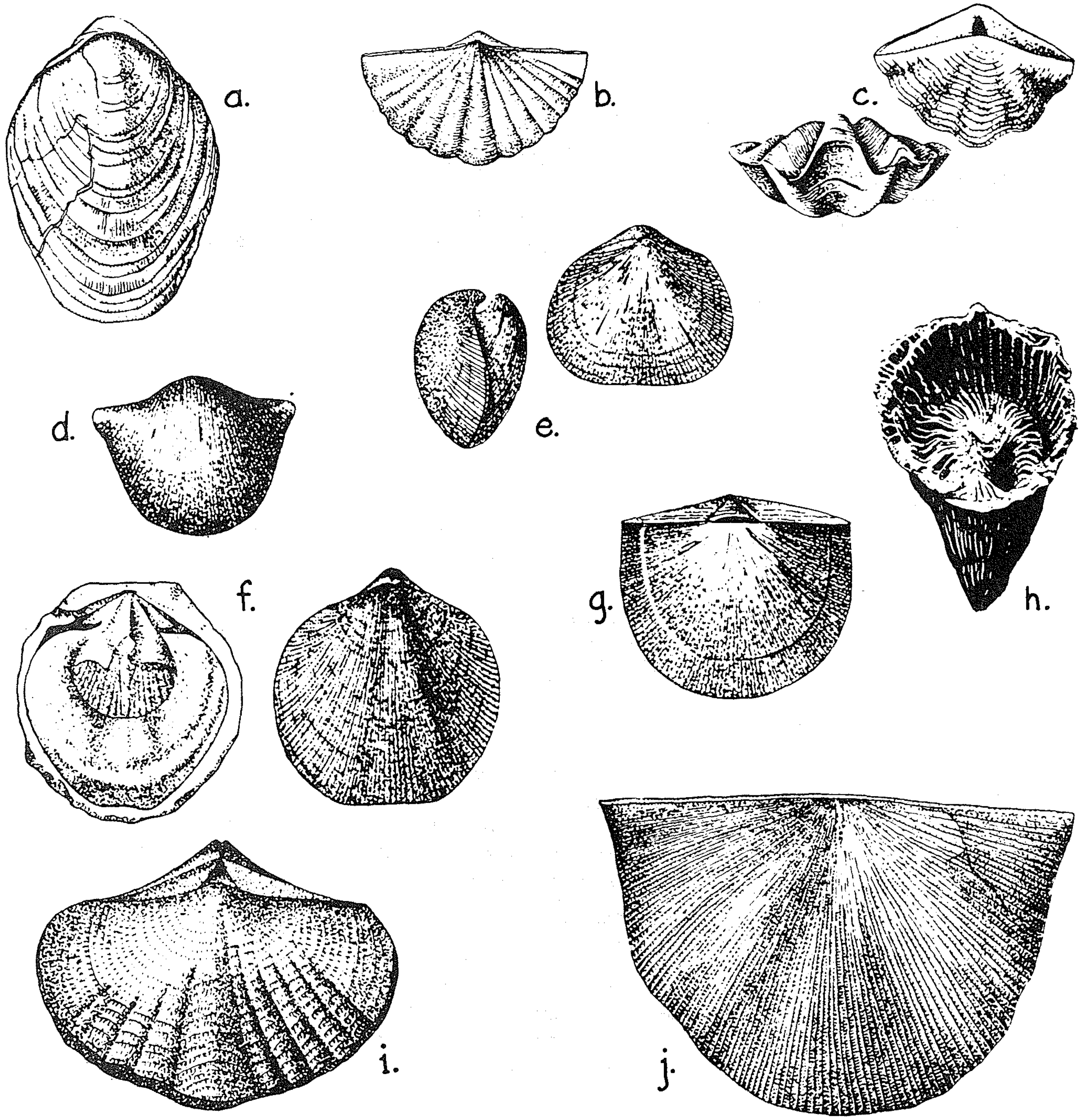
MIDDLE DEVONIAN

Onondaga Limestone and Albrights Reef

The Onondaga Limestone of the Hudson River Valley, approximately 100 feet thick, consists of gray, fossiliferous limestones, often cherty. At two localities in the Coxsackie quadrangle coral reefs have been recognized, one of which will be visited on this trip (Stop 5). Oliver (1954),(1956 a) has subdivided the Onondaga into four members: in ascending order, the Edgecliff, Nedrow, Morehouse and Seneca. Only the lower three are present in the Coxsackie area, the Seneca having been replaced by the overlying Bakoven Black Shale and Stony Hollow Sandstone.

The basal contact of the Onondaga (Edgecliff Member) with the underlying Schoharie is gradational. The Edgecliff (35-40 feet) is characterized by abundant white-weathering chert and a profusion of both rugose and tabulate corals in addition to brachiopods and other fossils. It consists of light gray coarse-grained crinoidal limestone in beds ½ to 3 feet thick. Lithologic separation of the Nedrow Member (20 feet) in the Hudson Valley is not so distinct as further west but its characteristic platyceratid gastropods persist. The remainder of the Onondaga is referred to the Morehouse Member, approximately 50 feet thick, which contains a middle cherty division between upper and lower non-cherty divisions. Morehouse beds consists of finer grained limestones than the Edgecliff and the chert usually is black. Fossils are abundant.

The Albrights reef (Stop 5) forms hills on both sides of the road one mile west-southwest of Albrights. It is approximately 1000 feet long, 250 feet wide and over 20 feet high (Oliver 1956 b). Tabulate and colonial rugose corals are abundant in the very coarse-grained pink or gray limestone which lacks distinct bedding. Fossils present are the corals: *Cyathophyllum sp.*, *Cystiphyllum sp.*, *Favosites sp.*, *Streptelasma sp.*, *Synaptophyllum sp.*, and *Zaphrentis sp.*; the brachiopods: *Amphigenia elongata* (Vanuxem), *Atrypa "reticularis"* (Linnaeus), *Coelospira camilla* (Hall), *Leptaena "rhomboidalis"* (Wilckens), *"Spirifer" divaricatus* (Hall), *"S." macrus* (Hall), *Stropheodonta concava* (Hall), and *Strophonella ampla* (Hall); and the trilobites: *Odontocephalus selenurus* (Eaton), *Phacops cristata* (Hall), and *Synphoria anchiops* (Hall).



SCHOHARIE AND ONONDAGA LIMESTONE FOSSILS:

a. *Amphigenia elongata*, ×¾. b. "*Spirifer*" *duodenarius*, ×1¼.
c. "*Spirifer*" *raricosta*, ×1¼. d. *Chonetes hemisphericus*, ×1¼.
e. *Schizophoria propinqua*, ×1¼. f. *Atrypa impressa*, ×1¼.
g. *Schuchertella pandora*, ×1¼. h. *Zaphrentis prolifica*, ×¾.
i. *Elytha fimbriata*, ×1½. j. *Strophonella ampla*, ×1¼.

Hamilton Group

The highest beds to be seen on this trip are those of the Hamilton shales and sandstones. In the Coxsackie quadrangle this group is divided into 5 members: in ascending order, the Bakoven, Stony Hollow, Mount Marion, Ashokan, and Kiskatom. Over 2000 feet of Hamilton beds are present. The top occurs in the adjacent Durham quadrangle to the west where an additional 1000 feet of Hamilton beds (entirely Kiskatom) are found. The Bakoven, Stony Hollow and Mount Marion members are chronological equivalents of the Marcellus Formation of the Hamilton in central and western New York. The Ashokan and Kiskatom are non-marine rocks representing the Skaneateles, Ludlowville and Moscow Formations.

Overlying the Onondaga Limestone with a sharp but apparently conformable contact are the black shales of the lower Hamilton, the Bakoven Member. These shales, 180-200 feet thick, contain a small fauna of brachiopods, pelecypods, cephalopods and "pteropods" typical of Devonian black shales elsewhere in New York. The Bakoven is a continuation of the Union Springs Black Shale of central New York. It is overlain by the Stony Hollow Sandstone Member, approximately 100 feet thick, which contains a few brachiopods, corals, and trilobites, but apparently none of the cephalopods so characteristic of its equivalent to the west, the Cherry Valley ("Agoniatite") Limestone. Both the Bakoven and Stony Hollow are chronological equivalents of the Seneca Member of the Onondaga Limestone in western New York. Inasmuch as no good exposures suitable for a large group have been located, the Bakoven and Stony Hollow will not be seen on this trip. The fauna consists of the brachiopods: Chonetes cf. mucronatus (Hall), Leiorhynchus limitare (Vanuxem), L. mysa (Hall), and Nucleospira concinna (Hall); the pelecypods: Lunulicardium marcellanse (Vanuxem)and Pterochaenia fragilis (Hall); and Styliolina fissurella (Hall), and Tornoceras (Parodoceras) discoideum (Conrad).

The remainder of the marine portion of the Hamilton Group in the Coxsackie area is known as the Mount Marion Member. These interbedded bluish-gray, sandy shales and argillaceous siltstones, 1200 feet thick, contain pebble beds, crossbedding and flow rolls in the upper portion near the transition into the overlying non-marine Ashokan flags. Fossils of brachiopods, pelecypods, and cephalopods, are abundant and usually occur as molds, both internal and external. Several good exposures are located in the vicinity of the Alcove Reservoir (Stops 4A and 4B).

Common Mt. Marion fossils are the following:

Brachiopods

Athyris cora (Hall)
Atrypa spinosa (Hall)
Camarotoechia congregata (Conrad)
C. prolifica (Hall)
C. sappho (Hall)
Chonetes coronatus (Conrad)
Leptostrophia perplana (Conrad)
Schizophoria cf. striatula (Schlotheim)
Paraspirifer acuminatus (Conrad)
Brachyspirifer audaculus (Conrad)
Mucrospirifer mucronatus (Conrad)
Tropidoleptus carinatus (Conrad)

Of Uncertain Affinity

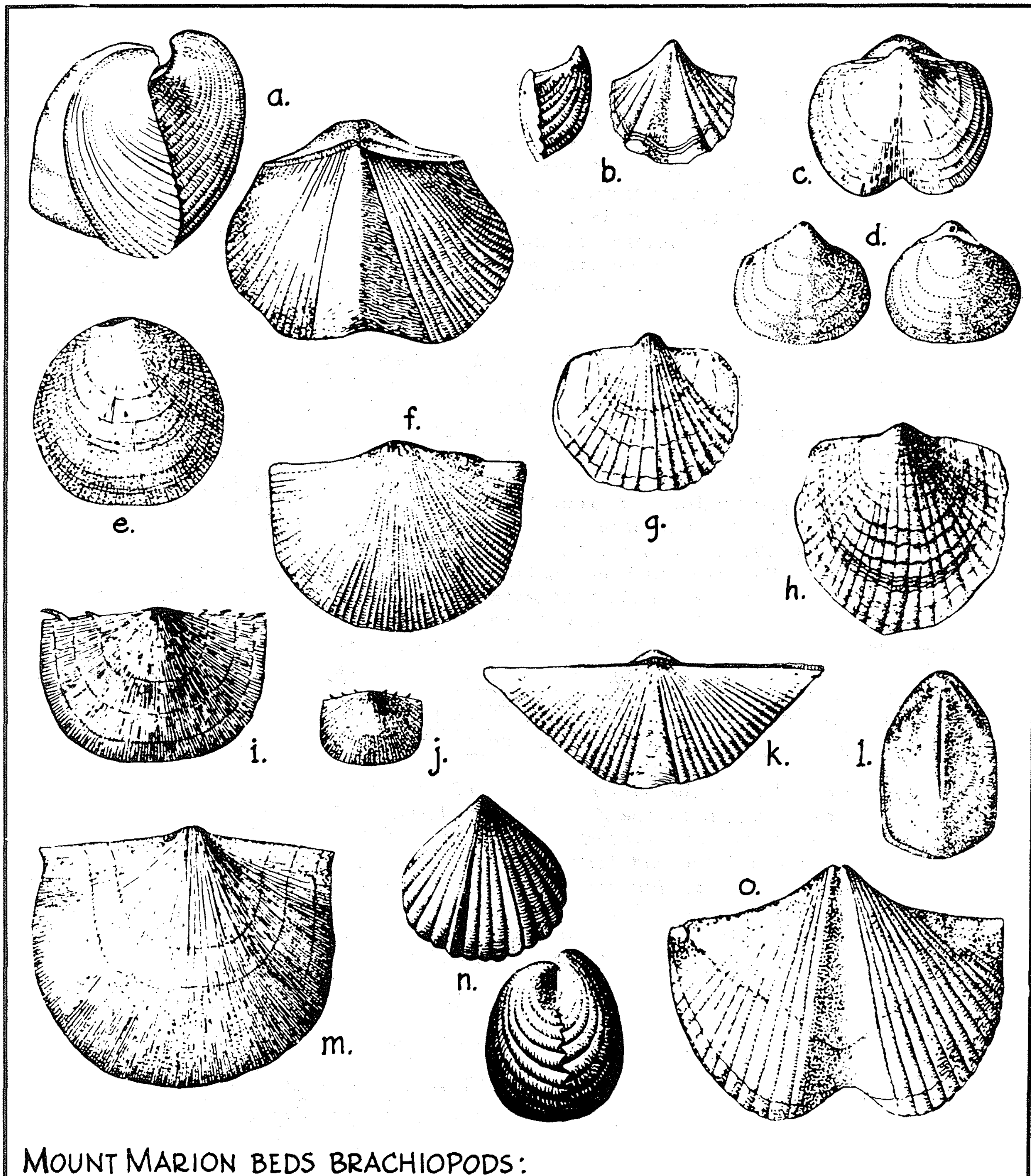
Tentaculites bellulus (Hall)

Pelecypods

Actinodesma erectum (Conrad)
Actinopteria boydi (Conrad)
Cypricardella complanata (Hall)
Goniophora hamiltonensis (Hall)
Grammysia bisulcata (Conrad)
Modiomorpha concentrica (Conrad)
Nucula bellistriata (Conrad)
Nyassa arguta (Hall)
Orthonata undulata (Conrad)
Paracyclus lirata (Conrad)

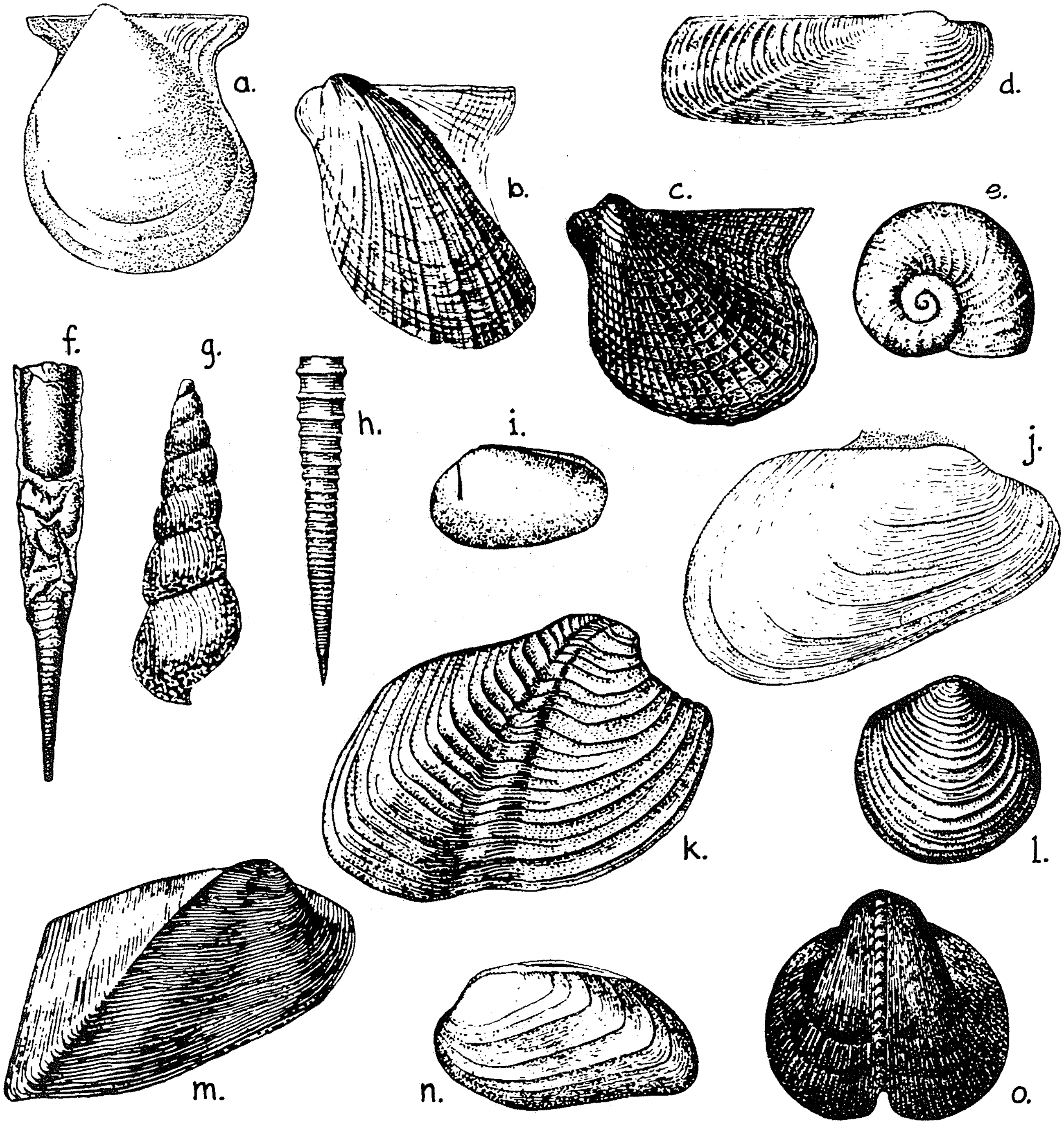
Trilobites

Greenops boothi (Green)
Homalonotus dekayi (Green)



MOUNT MARION BEDS BRACHIOPODS:

a. "Spirifer" (Paraspirifer) acuminatus, ×1½. b. Cyrtina hamiltonensis, ×1½. c. Schizophoria striatula, ×1¼. d. Athyris cora, ×1½. e. Rhipidomella vanuxemi, ×1½. f. Stropheodonta inaequiradiata, ×1¼. g. Tropidoleptus carinatus, ×1¼. H. Atrypa spinosa, ×1¼. i. Chonetes coronatus, ×1¼. j. Chonetes scitulus, ×1¼. k. "Spirifer" (Mucrospirifer) mucronatus, ×1¼. l. Dignomia alveata, ×1¼. m. Stropheodonta demissa, ×1¼. n. Camarotoechia congregata, ×1½. o. "Spirifer" (Spinocyrtia) granulosus, ×1¼.



MOUNT MARION BEDS FOSSILS:
a. Glyptodesma (Actinodesma) erectum, x 3/4. b. Cornellites ["Pterinea"] flabellum, x 3/4. c. Actinopteria boydi, x 1 1/4. d. Orthonota undulata, x 3/4. e. Diaphorostoma lineatum, x 1 1/4. f. Michelinoceras ? [Orthoceras] subulatum, x 3/4. g. Loxonema hamiltonensis, x 1 1/2. h. Tentaculites bellulus, x 1 1/2. i. Nuculites oblongatus, x 1 1/4. j. Modiomorpha mytiloides, x 3/4. k. Grammysia bisulcata, x 1 1/4. l. Paracyclas lirata, x 1 1/4. m. Goniophora hamiltonensis, x 1 1/4. n. Nyassa arguta, x 1 1/4. o. Bucanopsis lyra, x 1 1/2.

The greater portion of the Hamilton beds of this area consists of non-marine strata. These beds are unfossiliferous, except for small crustaceans and plant remains. The lower 300 feet, the Ashokan, contains laminated "bluestones" (sandstones) formerly extensively quarried for flagstones used in sidewalks and building construction. The interbedded shales are olive, weathering reddish or brown. The upper portion is known as the Kiskatom Member. This member consists of about 1500 feet of alternating red and green, green or gray sandstones. Cross-bedding, pebble layers and flow rolls occur. Fossils are rare - plant fragments are most common. Neither Ashokan nor Kiskatom beds will be seen on this trip.

STRUCTURE

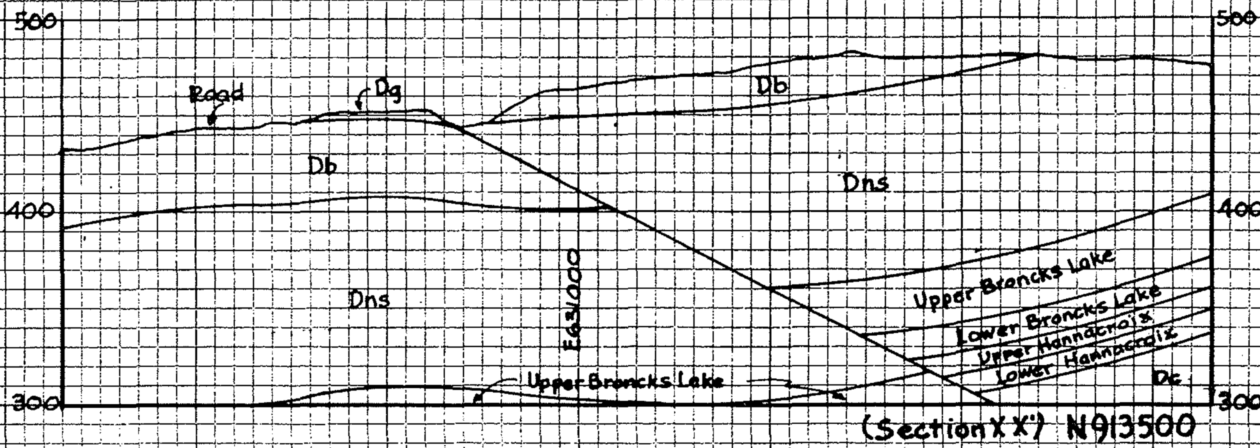
STRUCTURES IN THE WESTERN CENTRAL HUDSON VALLEY

The Silurian and Devonian formations lie unconformably on Ordovician graywackes, siltstones and shales which have undergone deformation varying from gentle warps to isoclinal folding. West of the Hudson River, these younger formations are strongly folded and thrust faulted. The faults and folds trend approximately north-south and the thrust faults usually dip from 20° to 35° eastward. Normal faulting is rare although the outcrop pattern caused by thrust faulting may locally seem to be caused by normal faults. Folding is most intense in the Kingston area. Northward the structures are similar but have a less violent aspect. Westward from the Hudson Valley the amplitude of the folding decreases and the faulting becomes less common.

Typical Hudson Valley fold-fault structures in the Silurian-Devonian strata consist of an anticline thrust over a syncline so that in plan two anticlines are adjacent to each other. In some cases the hidden synclinal structure may be very large, but the size of the hidden structure is rarely decipherable from the surface evidence. Plate II shows two typical structures in the Ravena area. Note that the lower and more southern structure gave little surface evidence of the syncline which was detected by core drilling.

ECONOMIC GEOLOGY

For the past two to three years the economics of industrial rock materials has been undergoing revolutionary changes in the central Hudson Valley. The changes are of major significance to producers of portland cement and lightweight aggregate in the whole eastern United States. In addition, new concepts of the quality of some limestones are of considerable importance in the quarrying and use of coarse aggregate. An indication of the scale of these changes in the raw material situation in the Hudson Valley may be seen in the increase of crushed stone reserves by a factor of about 3 to 5, the cement reserves by a factor of about 5 to 10 and the lightweight aggregate reserves from negligible to over a billion tons. Translated into monetary value this is the equivalent of finding a mining camp of the scale of Butte, Montana. All of these changes are based to a large extent upon systematic geologic studies of the nature and uses of rock raw materials and demonstrate clearly the value of geologists in this field.



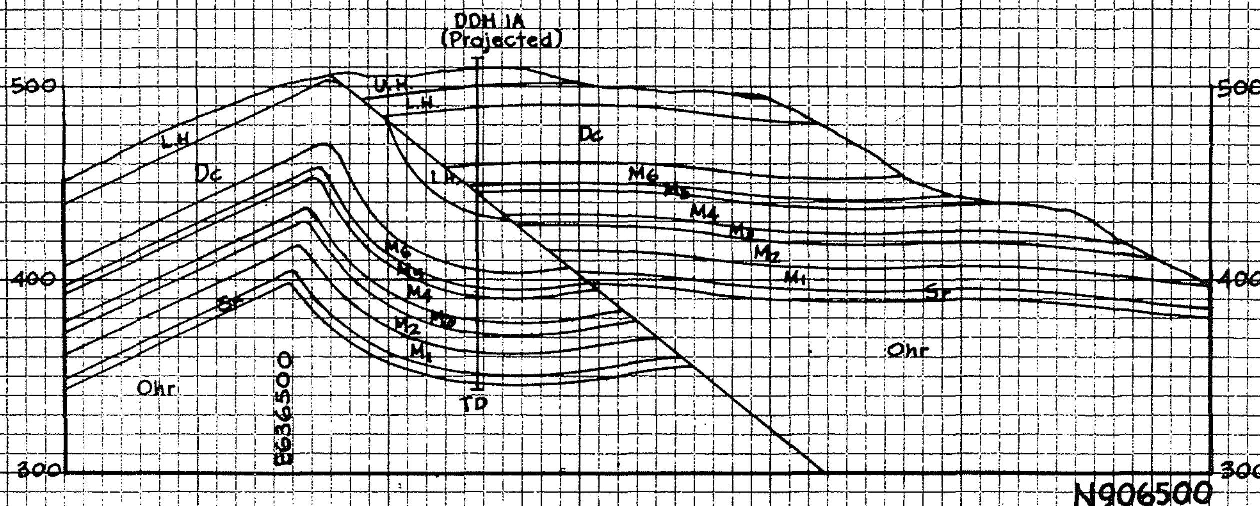


Plate II C

Typical Hudson Valley-Type Fold-Thrust Fault Structures in the Ravena Area

SECTION N913500 (XX') is across the center on the right sheet of Plate III. The estimate of the amount of Becraft Limestone caught under the thrust fault is a minimum.

SECTION N906500 is a core-drilled structure southeast of Section N913500. Note that the size of the syncline under the thrust fault is not decipherable from surface outcrops. The stratigraphic relationships at the surface actually suggest normal faulting.

Scale 1" = 100'

The most significant new discoveries are that at least locally the New Scotland, Port Ewen, and Glenerie formations are suitable for coarse aggregate in concrete, and that the Esopus formation, at least locally, is suitable for expanded lightweight aggregate. In addition, careful analytical work, stratigraphically controlled, has resulted in methods of blending rock strata which are new in the Hudson Valley.

The Hudson Valley is uniquely situated for the economic production of raw materials in that it combines excellent transportation facilities (water, air, rail, highway) with one of the world's largest metropolitan markets. The value of any raw material produced in the Hudson Valley is likely to be considerably enhanced over less favorably situated occurrences of the same material.

Portland cement plants have long been established just south of Catskill and at Becraft Mountain southeast of Hudson, and natural cement has been produced in the Rosendale-Kingston area for many years. Coarse aggregate producers have operated at Kingston, at Hudson, west of Catskill, and at South Bethlehem for a considerable time.

Within the past few years the following companies have either announced the construction of new plants or have already begun operation: Hudson Cement Company at East Kingston, in operation; Southern Lightweight Aggregate Company just south of Saugerties, plant to be constructed: Atlantic Cement Company, Ravena (jointly owned by Newmont Mining Company and the Cerro Corporation), plant to be constructed. Extensive optioning and current drilling immediately southwest of Kingston indicate still more activity within the Hudson Valley.

The operation of the Hudson Cement Company at East Kingston is based on new concepts of utilization of rock strata in the Hudson Valley. Quarrying procedures involve the blending of various rock types to produce portland cement, and the selective quarrying of other rock types to produce coarse aggregate. The structures in the area are complex. The normal Hudson Valley folding and thrust faulting is abnormally severe and large areas of overturned and steeply dipping beds occur. The planning and execution of the drilling, the determination of reserves of various categories of rock, the chemical and physical testing of the rock, and the day-to-day development of the quarrying operation all require geologic control. The basis for all phases of operation is a detailed geologic outcrop map and vertical cross-sections which are at a scale of 100 feet to the inch, with 5 foot contour interval.

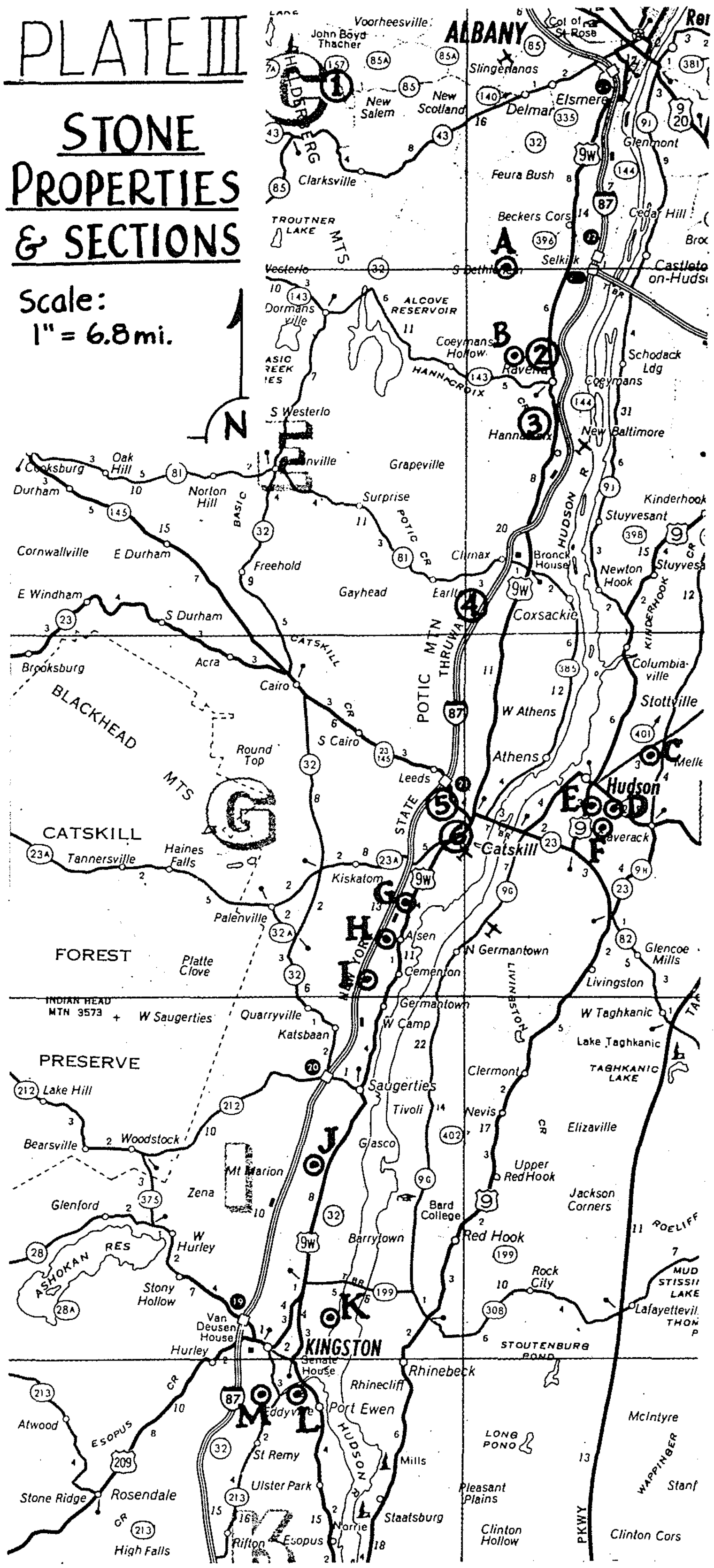
The operation of the Callanan Road Improvement Company at Kingston and South Bethlehem and the projected operation of the Atlantic Cement Company are, so far as the quarrying is concerned, based on similar detailed geologic data.

The Southern Lightweight Aggregate Company at Mt. Marion, just south of Saugerties, will quarry shales of the Esopus formation. This rock, when heated to the proper temperature, expands to a scoriaceous material which makes excellent aggregate for lightweight cement blocks. Considerably more activity in lightweight aggregate exploration is occurring throughout the valley.

PLATE III

STONE PROPERTIES & SECTIONS

Scale:
1" = 6.8 mi.



QUARRIES AND CURRENT PROSPECTS

A. Callanan Road Improvement Co.
B. Atlantic Cement Co. - to be constructed.
C. Catskill Mountain Stone Co. - crushed stone.
D. Lone Star Cement Co.
E. Universal Atlas Cement Co.
F. Colarusso and Sons - crushed stone.
G. North American Cement Corp.
H. Lehigh Portland Cement Co.
I. Alpha Portland Cement Co.
J. Southern Lightweight Aggregate Co. - to be constructed.
K. Hudson Cement Co.
L. Callanan Road Improvement Co.
M. New York Trap Rock Co. - prospect. Product uncertain.

STRATIGRAPHIC SECTIONS

① John Boyd Thacher Park
Db - Dns - Dk - Dg - Dm - Sr

② Blenis hair pin curve quarry
Dc - Dm

③ Hannacroix Creek (Deans Mills area) Dk - Dc - Dm - Sr

④ Broncks Lake
Da - Db - Dns - Dk - Dc

⑤ Austin's Glen
Db - Dns - Dk - Dc - Dm

⑥ Quarry Hill
Dk - Dc - Dm

USES OF ROCK FORMATIONS IN THE CENTRAL HUDSON VALLEY

Principal Formations and Lithologies	Potential Uses
Onondaga limestone	Coarse aggregate, portland cement, locally agricultural lime and blast furnace flux.
Schoharie sandy limestone	None known
Esopus silty shale	Lightweight aggregate
Glenerie impure limestone	Coarse aggregate, portland cement*
Port Ewen impure limestone	Coarse aggregate, portland cement*
Alsen impure limestone	Coarse aggregate, portland cement*
Becraft limestone	Coarse aggregate, portland cement* agricultural lime
New Scotland silty limestone and limey siltstone	Coarse aggregate, portland cement*
Kalkberg impure limestone	Coarse aggregate, portland cement*
Coeymans limestone	Portland cement, coarse aggregate
Manlius limestone	Portland cement, agricultural lime, blast furnace flux, coarse aggregate.
Rondout magnesium limestone	Natural cement.

*Mixed with purer limestones such as Becraft, Coeymans, or Manlius

It is interesting to note that in the Kingston area the total potentially economic rock section is about 800 feet thick.

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TRIP STOPS

Stop 1A. Callanan Road Improvement Company Quarry, northeastern part.

Outcrop has Normanskill shales, siltstones, and graywackes at the base, overlain by the full thickness of the Rondout Formation and 12 feet of the Manlius Formation. All units are essentially conformable even though they are of Ordovician, Silurian (?) and Devonian ages. Of particular interest are the abundant *Tentaculites* in the lower unit of the Manlius Formation and the transparent obtuse rhombohedrons of calcite associated with quartz crystals in the Rondout Formation.

Stop 1B. Callanan Road Improvement Company Quarry, center.

The walls of the quarry have typical Hudson Valley thrust fault structures. The Rondout, Manlius, Coeymans and part of the Kalkberg formations are exposed in the walls of the quarry. Plate VI is a picture of the quarry, looking south, in which the faults and formations are indicated.

Stop 2. Synclinal structure 4500 feet south-southeast of the Callanan Road Improvement Company quarry.

New Scotland Limestone, Becraft Limestone, Glenerie Sandstone and Chert (Oriskany) and Esopus Shale are exposed. The Becraft Formation is thrust over the Glenerie Formation at the east side of the structure, and a zone of cleavage and shear in the Becraft branches north-northwestward from the thrust fault. Plate V is a map of the area and Plate II shows a cross-section through the structure which was core drilled about 10,000 feet southeast of Stop 2.

Stop 3. An exposure of the Esopus Formation in a cliff.

The Glenerie Formation and the Becraft Formation are exposed at the base.

Stop 4A. Mt. Marion beds, lower part.

The exposure is in an old quarry from which flagstone was produced. Brachiopods and *Tentaculites* are abundant.

Stop 4B. Mt. Marion Sandstone, upper part.

The exposures are in a quarry from which flagstone was produced. Lack of marine fossils and the fairly common plant remains suggest non-marine origin.

Stop 5. Onondaga Reef.

This is one of the reefs which is typical of the Onondaga Formation in New York. Fossil collecting is excellent.

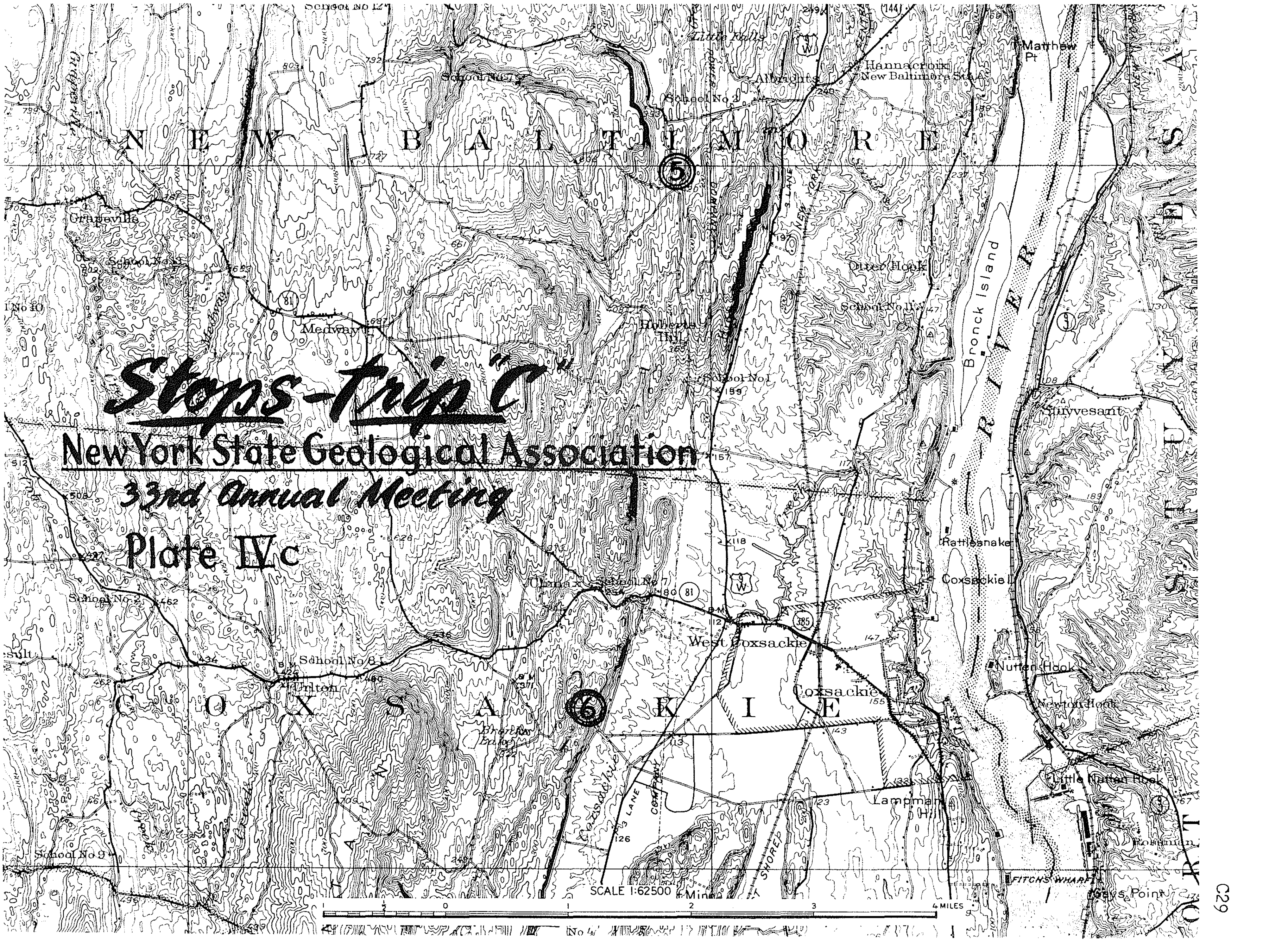
Stop 6. Broncks Lake stratigraphic section.

All units of the Kalkberg Formation are exposed but not fully. All of the New Scotland and Becraft Formations can be seen, and 24 feet of the Alsen Formation is visible. The strata dip steeply westward and are cut by a fault which repeats part of the Kalkberg Formation.

NOTES ON TRIP C

C28


Lower
Schodack Island
Houghtaling Island
Upper Schodack I
Mull I
Barren Island
RENSSELAER CO
ALBANY CO
Castleton-on-Hudson
Beaver Dam
Selkirk
Bethlehem Heights
South Bethlehem
Callanans Corners
Ravena
3 LANE
ADIRONDACK
LUNCH
Coeymans Hollow
Badger Hill
Indian Fields
School No.16
Creek


Stops-trip "C"
New York State Geological Association
33rd Annual Meeting
Plate IVc
NEW BALTIMORE
COXSACKIE
STUYVESANT
RIVER
Bronck Island
Hannacroix
New Baltimore Sta.
Matthew Pt
Grapeville
Medway
Roberts Hill
Otter Hook
Stuyvesant
Rattlesnake
Coxsackie I.
West Coxsackie
Coxsackie
Climax
Urlton
Nutten Hook
Newton Hook
Little Nutten Hook
Lampman H.
FITCHS WHARF
Gays Point
SCALE 1:62500
0
1
2
3
4 MILES

C30

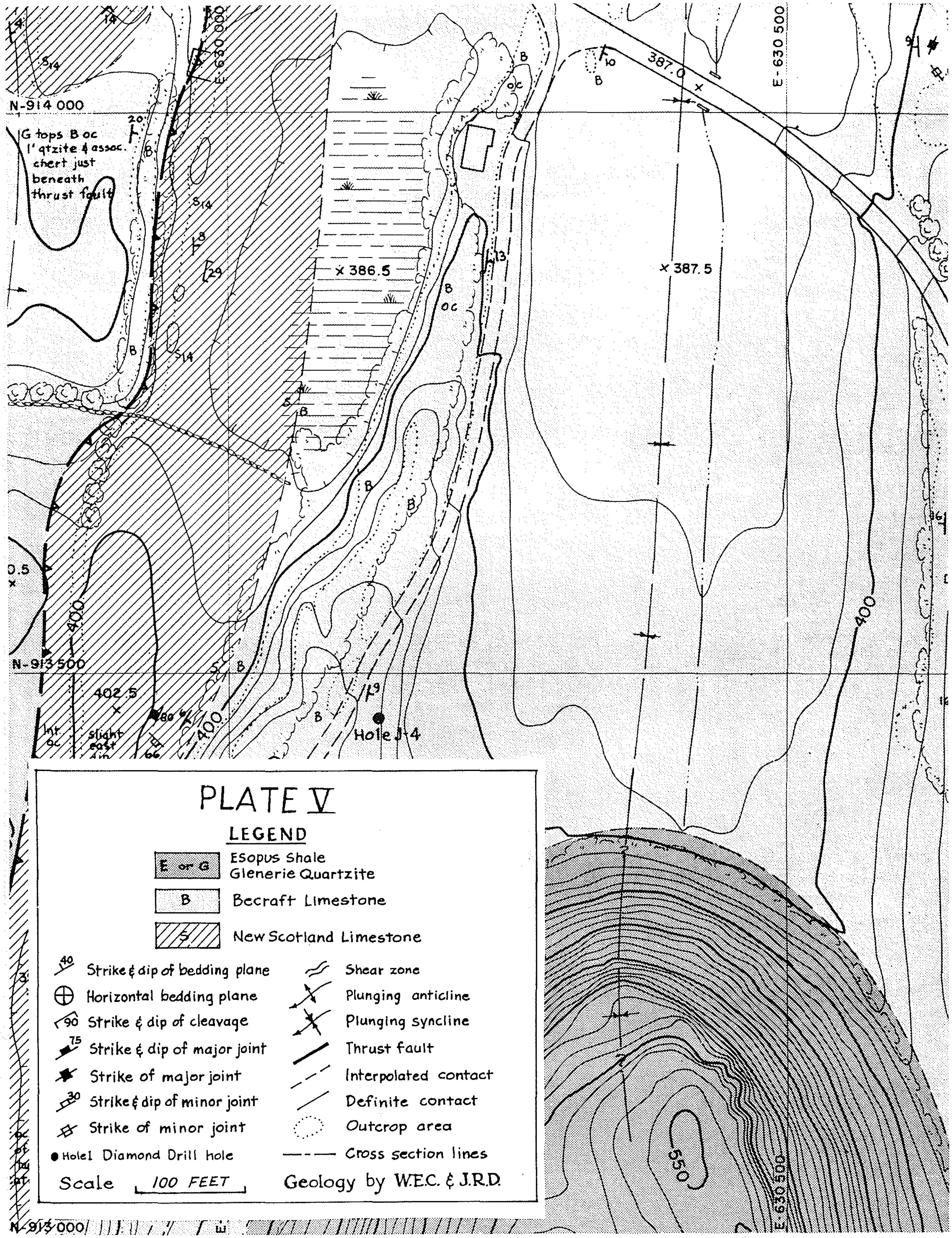
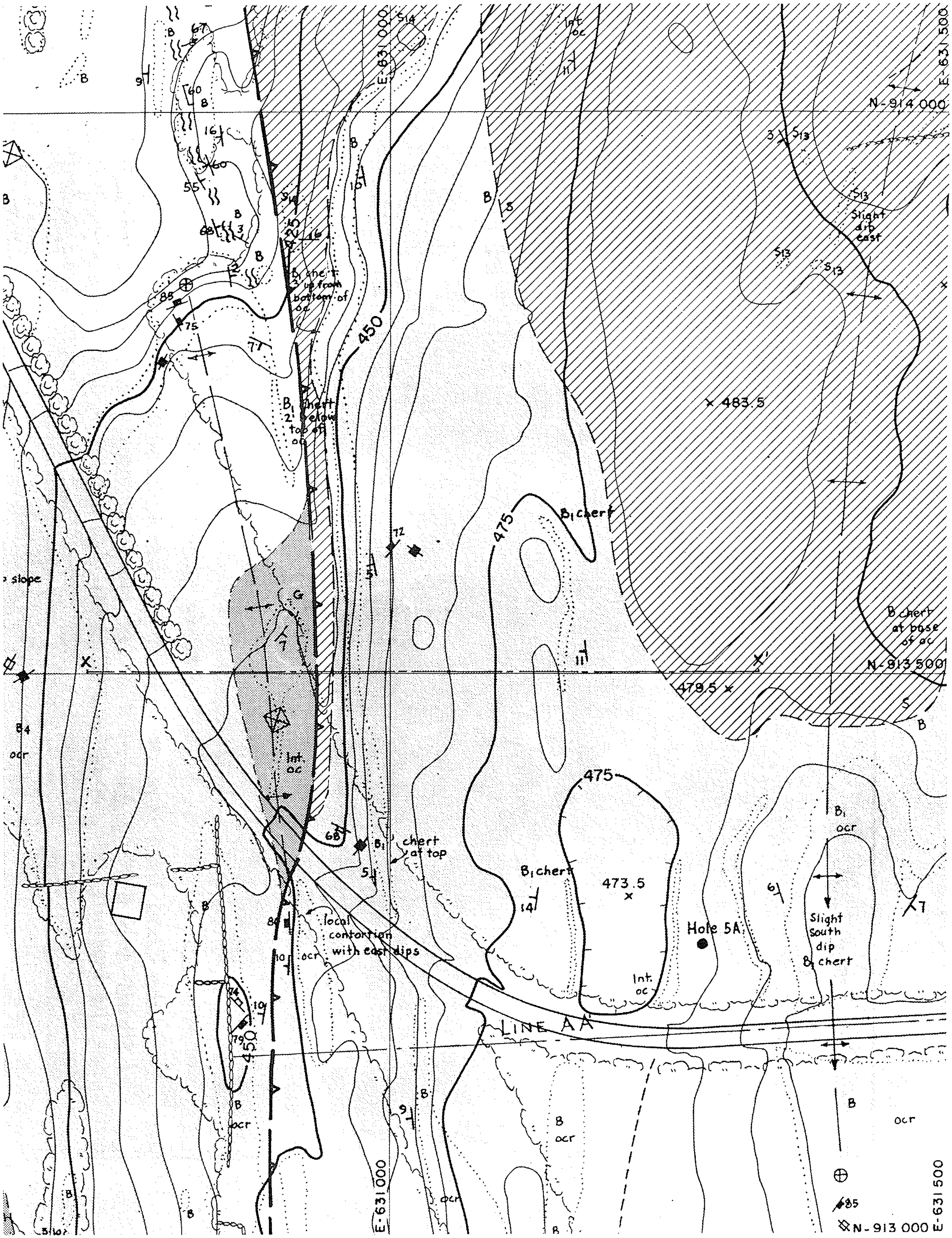


PLATE V
LEGEND
E or G Esopus Shale
Glenerie Quartzite
B Becraft Limestone
S New Scotland Limestone
Strike & dip of bedding plane
Horizontal bedding plane
Strike & dip of cleavage
Strike & dip of major joint
Strike of major joint
Strike & dip of minor joint
Strike of minor joint
Hole1 Diamond Drill hole
Shear zone
Plunging anticline
Plunging syncline
Thrust fault
Interpolated contact
Definite contact
Outcrop area
Cross section lines
Scale 100 FEET
Geology by W.E.C. & J.R.D.
N-914 000
N-913 500
N-913 000
E-630 500
G tops B oc
1' qtzite & assoc. chert just beneath thrust fault
x 386.5
x 387.5
387.0
402.5
400
550
Hole J-4
Slight east dip


E-631 000
E-631 500
N-914 000
N-913 500
N-913 000
B, chert 3' up from bottom of oc
B, chert 2' below top of oc
B, chert
B chert at base of oc
Slight dip east
Int. oc
B4 ocr
B, chert at top
local contortion with east dips
Hole 5A
Slight South dip B, chert
LINE AA
483.5
479.5
473.5
450
475
slope

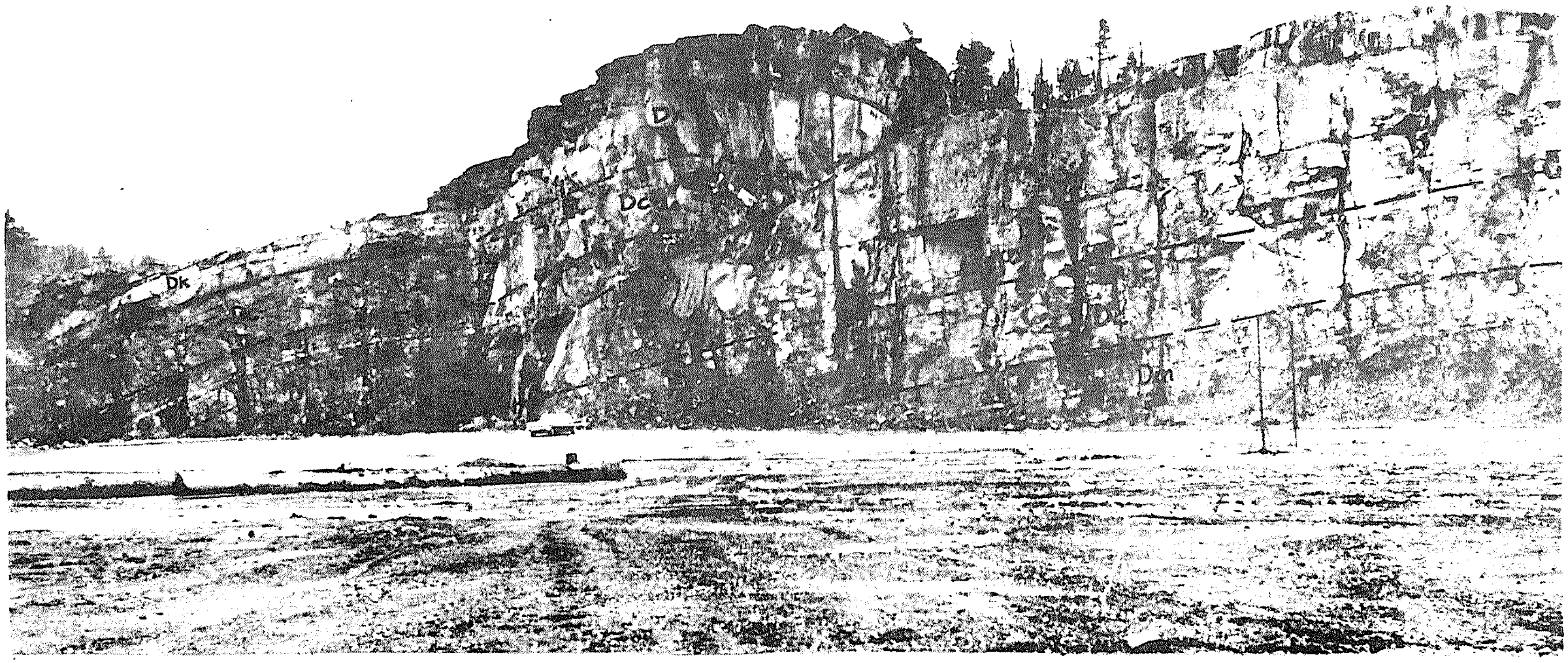


PLATE VIc

Callanan Road Improvement Company, South Bethlehem quarry, looking south. A thrust fault dipping eastward is overlain by an anticline. Exposed formations are the Manlius (Dm), Coeymans (Dc), and Kalkberg (DK) (upper & lower Hannacroix).

TRIP D

STRATIGRAPHY AND STRUCTURE IN THE SOUTHERN TACONICS (RENSSELAER AND COLUMBIA COUNTIES, NEW YORK)*

By Donald W. Fisher
Geological Survey, N.Y. State Museum and Science Service, Albany, N. Y.

"The structural [and stratigraphic] investigation of the Taconic region is only in its beginning stages, and....the interpretation of one particular area, to be satisfying, should allow correlations with adjoining areas. In this region of dense underbrush, extensive forests, widespread till cover, low relief, and few fossil localities, facts and observations are hard to accumulate, and their interpretation is beset with difficulties." ---R. Balk (1953)

THE TACONIC SYSTEM

During the early days of the Geological Survey, there was born a controversy which, in modified form, continues today. In the mid-19th century, the argument was primarily stratigraphical and dealt with the age of the rocks east of the Hudson River;in the mid-20th century the argument is primarily structural, dealing with the manner of deformation to account for the present position of these same rocks.

The "Taconic System" was born when E. Emmons (1842) named the deformed shales, quartzites and limestones east of the Hudson River, announcing that they lay unconformably beneath the base of the "New York System" (Upper Cambrian Potsdam Sandstone of present terminology). Later, Emmons (1844) discovered the trilobites Elliptocephala asaphoides and Atops trilineatus (See Plate 2) in deformed strata in western Rensselaer County, and believed that he had found the "Primordial fauna"---the opening chapter of life history of the Earth. Emmons soon became aware of the hostility to his "Taconic System". He said (1855), "In regard to the Taconic System, I do not know that I am indebted to any one for favors, or for suggestions. Indeed, nothing very flattering has ever been said, or published, respecting the views I have maintained on this subject." Although confronted by such formidable opposition as Hall, Dana and Sir Charles Lyell among others, who were unwilling to accept the then novel concept of thrusting or the antiquity of the fossils, Emmons steadfastly maintained that his "Taconic System" was older than Potsdam and correlated it with the Lower Cambrian of Professor Sedgwick of Great Britain. Although Emmons was correct in this thesis, he was incorrect in his resolute view that the entire Taconics were pre-Potsdam, for Bishop, Dana, and Walcott found Trenton fossils at several sites. Meanwhile, S. W. Ford, a Troy jeweler and Prof. W. B. Dwight of Vassar had located several localities where the "Primordial fauna" could be obtained. The bitter controversy lingered long after Emmons' death in 1863. Today, the name Taconian is used as a series name for the Lower Cambrian in acknowledgment of Emmons' recognition of the low stratigraphic position of these rocks.

*Published by permission of the Assistant Commissioner, New York State Museum and Science Service.

GEOLOGIC MAP OF THE SOUTHERN TACONICS

by Donald W. Fisher
(from Geologic Map of New York State, in press)

- ▱ Selected outcrops
- Q - Glacial and alluvial deposits; underlying bedrock geology unknown.

DEVONIAN
- Dha - Kiskatom and Ashokan fms.
- Dou - Onondaga ls. through Esopus sh.
- Dhg - Helderberg lss.
- DS - Helderberg lss. and Rondout fm.

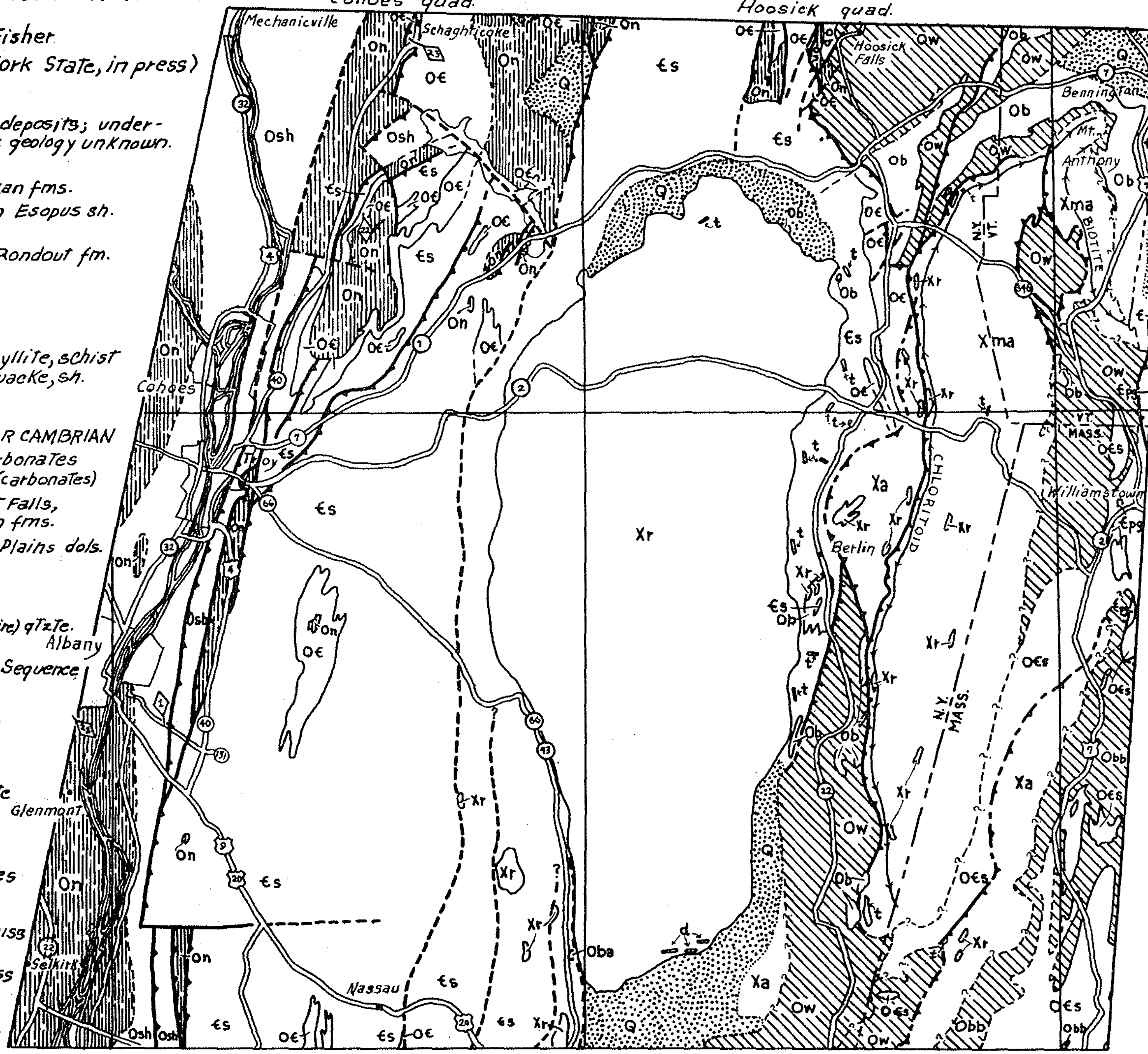
MIDDLE ORDOVICIAN
- Osh - Snake Hill sh.
- Ow - Walloomsac sl.
- Obb - "Berkshire" black phyllite, schist
- On - Normanskill graywacke, sh.
- Oba - Balmville ls.

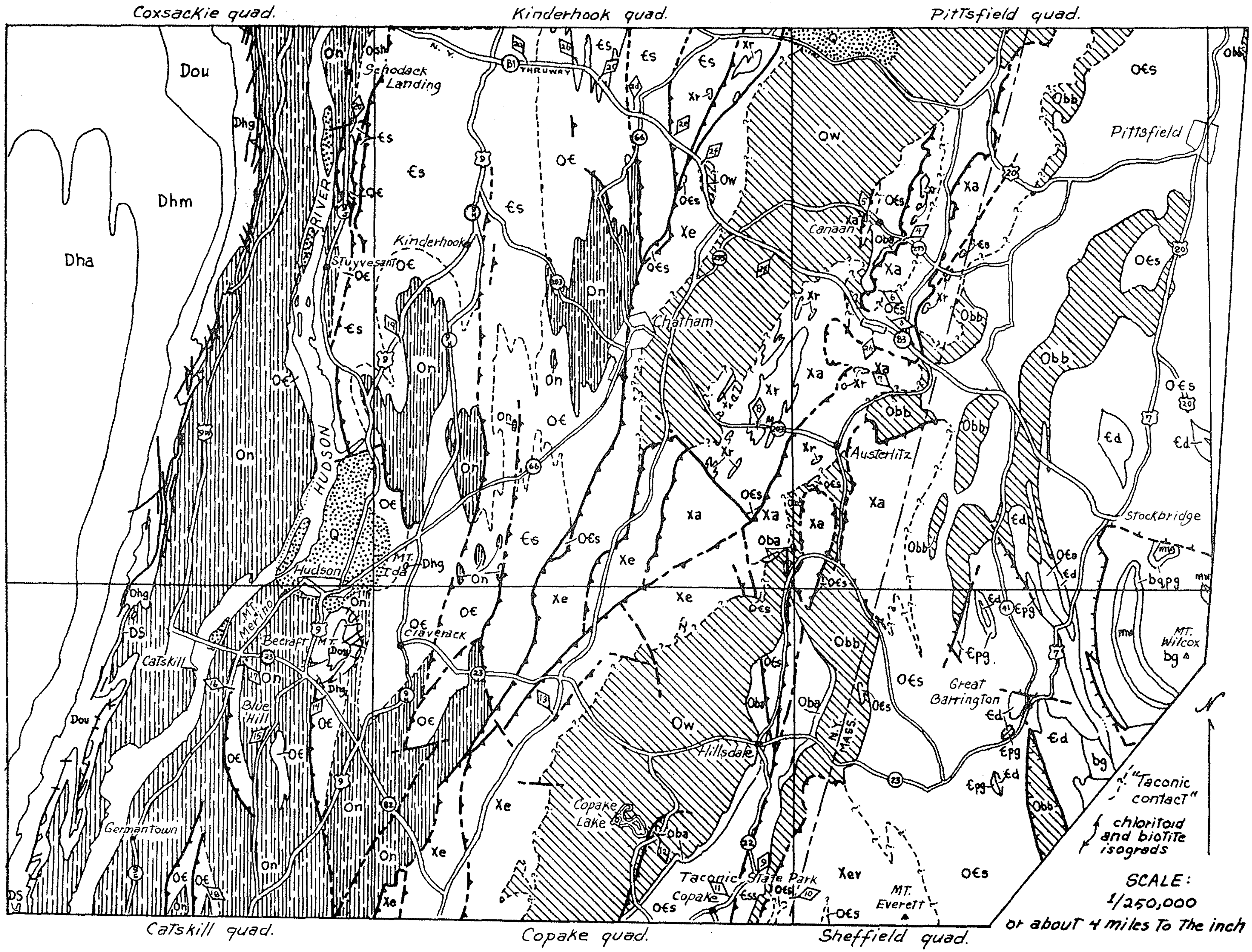
LOWER ORDOVICIAN AND UPPER CAMBRIAN
- Ob - Lower Ordovician carbonates
- O€s - Stockbridge group (carbonates)
- O€ - Deep Kill, Stuyvesant Falls, Germantown fms.
- €ss - Briarcliff and Pine Plains dols.

LOWER CAMBRIAN
- €l - Carbonates
- €pg - Poughquag (=Cheshire) qtzte.
- €d - Dalton fm.
- €s - Clastics of Taconic Sequence

AGE UNKNOWN
- Xa - Austerlitz phyllite
- Xe - Elizaville sh.
- Xev - Everett schist
- Xma - Mt. Anthony phyllite
- Xr - Rensselaer graywacke
- t - Tuff
- d - Albite-basalt dikes

PRECAMBRIAN
- bg - Biotite granitic gneiss
- bqpg - Biotite quartz plagioclase gneiss
- mu - Metasedimentary rocks, undifferentiated




Coxsackie quad.
Kinderhook quad.
Pittsfield quad.
Catskill quad.
Copake quad.
Sheffield quad.
Schodack Landing
Kinderhook
Stuyvesant
Chatham
Canaan
Pittsfield
Austerlitz
Stockbridge
Hudson
MT. Ida
MT. Merino
Becraft MT.
Catskill
Blue Hill
Claverack
Germantown
Hillsdale
Copake Lake
Taconic State Park
Copake
MT. Everett
Great Barrington
MT. Wilcox
HUDSON RIVER
THRUWAY
N. Y.
MASS.
Dou
Dhm
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Xe
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Obb
Oba
Єd
Єpg
bg
bgpg
Xev
Q
"Taconic contact"
chloritoid and biotite isograds
SCALE: 1/250,000 or about 4 miles to the inch

PLATE 1

THE TACONIC PROBLEM

The Taconic Problem is twofold, dependent upon:

(1) establishment of the correct stratigraphic succession, and
(2) formulation of a workable structural device to explain the present attitudes of the rock units.

Excluding a few minor discrepancies, the stratigraphy has been fairly well worked out in all areas despite the meager paleontological control. To be sure, if fossils were numerous in the Taconics, geologic relations would have been clarified long ago. Unfortunately, fossils are exceedingly scarce because of original inhospitable environments, lack of or poor preservation, and eastwardly progressive metamorphism. When found, Taconic fossils can be categorized broadly as (1) Early Cambrian and (2) graptolites. Included in the former are inarticulate brachiopods, trilobite fragments, and fossils of uncertain biologic affinities (see Plate 2)—all difficult to identify. The latter category, the graptolites, (See Plate 3) are also relatively difficult to identify on the species level and the number of paleontologists who are competent to do so are woefully few. Nonetheless, careful scrutiny and ultimate discovery of fossils in Taconic rocks reveals not only relative age but much regarding paleoecology, morphology, and evolution of these Early Paleozoic animals, for "To eyes that have learned to see, fossils are very much alive"....G. G. Simpson.

The Taconic controversy is alive a century after its inception because of the lack of a single structural explanation, satisfactory to all, to account for the present position of the rocks. The failure of some engaged in detailed mapping to venture beyond the borders of their own mapped area, and of others who expound on Taconic geology while possessing only a cursory knowledge of the field relations, has further added to the confusion. Often, workers mapping concurrently in adjacent areas disagree on presence of faults, unconformities, and physical makeup of rock, let alone age of the rocks. The task of the regional compiler is indeed a challenging and frustrating one.

STRATIGRAPHY

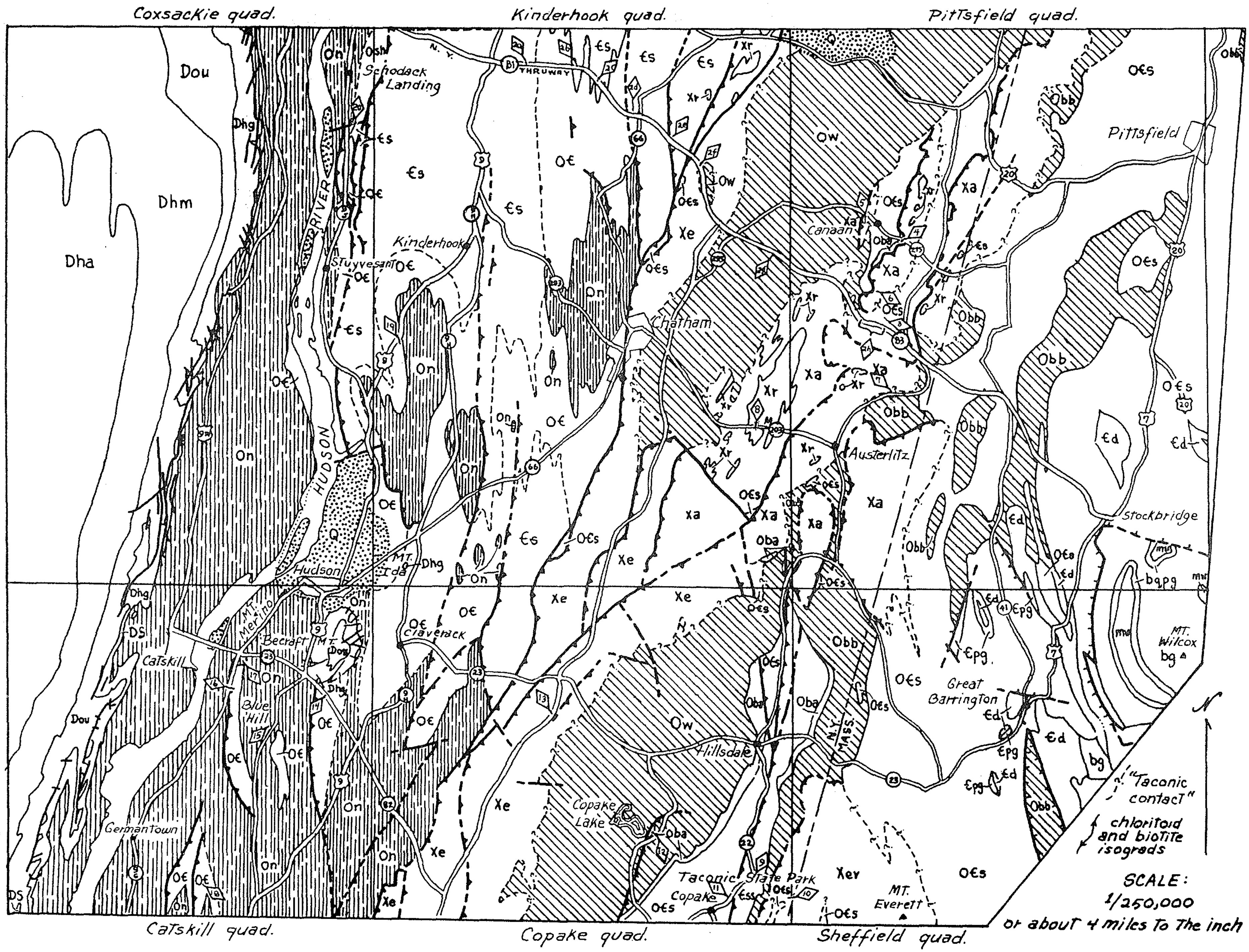
The stratigraphic succession in the southern Taconics has resulted from the work of Dale (1893, 1904), Ruedemann (1914, 1930), Craddock (1957), Weaver (1957) and the unpublished works of Elam, Cutcliffe, Potter, Talmadge, Warthin, and Fisher; that of the northern Taconics by Dale (1899), Keith (1932), Kaiser (1945), Fowler (1950), Zen (1959, 1961), and the unpublished works of Platt, Theokritoff, Shumaker, and Hewitt. For a comprehensive treatment of the stratigraphy of the northern Taconics the reader is referred to Zen (1961).

Following are brief remarks on the recognized units in the southern Taconics. Symbols in parentheses refer to the accompanying geologic map (See Plate 1).

THE EUGEOSYNCLINAL (TACONIC) SEQUENCE

Age Unknown, Probably Lower Cambrian

Rensselaer Graywacke (Xr) - Named by Dale (1893, p. 291), this unit has received more attention than any other in the Taconics primarily because it forms the prominent topographic upland in Rensselaer County and because of


Coxsackie quad.
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As eastern New York and adjacent states were blanketed by limestones, dolomites, and orthoquartzites (miogeosynclinal deposits) from the Late Cambrian through the Late Devonian, a pre-Late Cambrian age is mandatory--unless one assumes that the Precambrian Green Mts. were exposed and supplying detritus to the west during the Late Middle or Upper Ordovician. On the west flank of the Precambrian Green Mountain anticlinorium are Early Cambrian carbonates and orthoquartzites having the Elliptocephala asaphoides fauna. Either the Rensselaer is older than these shelf deposits or a western correlative of them. The writer favors the former view.

Whether the Rensselaer is lower Early Cambrian or Precambrian is an academic question dependent upon the placement of the base of the Cambrian System---an unresolved problem at this writing. Some advocate that the base of the oldest widespread olenellid trilobite zone be selected; others that the physical discontinuity between the gneisses of the "basement" and unmetamorphosed sedimentary rocks be selected. The latter course creates special problems in that the physical break is not a time plane. No indisputable fossils have thus far been found in the Rensselaer. Previous workers have variously classed it as Upper Devonian, Middle Devonian, Silurian, Upper and Middle Ordovician, and Lower Cambrian.

Austerlitz Phyllite (Xa) - (new name, Fisher, in press) In the eastern parts of Columbia and Rensselaer Counties is a widespread purple and green to greenish-gray phyllite that constitutes the high north-south ridges. This unit has been named from Austerlitz Township in eastern Columbia County. Chlorite and muscovite are ubiquitous minerals. Along or near the State Line, the Austerlitz assumes a "sandpaper" texture because of abundant coarse dark green chloritoid. Where quartz is abundant, a "salt and pepper" appearance is prominent. Although no fossils have been found, interbedded green chloritic quartzites and subgraywackes coupled with the purple and green color intimates that the unit is a metamorphic phase of the Nassau Formation and transitional with the Rensselaer and Curtiss Mountain units. In the past, the Austerlitz Phyllite has been included in the encompassing term "Berkshire Schist". The black portion of the "Berkshire" is now considered to be Middle Ordovician and it is therefore undesirable to continue using that name. In some, as yet unmapped, areas there appears to be both a vertical and lateral transition of black into green phyllite, so that some of the green, too may be Ordovician.

Elizaville Shale (Xe)- Named by Weaver (1957, p. 739), this unit is a silty, greenish-gray shale or argillite, often laminated and resembling much of the Lower Cambrian Mettawee Formation to the north. In places the cleavage is so pronounced that the formation may be termed a slate. Thin brownish quartzites are common as are black carbonaceous patches along the bedding. The thickness has been estimated at 2000'. The unit is unknown west of the

Chatham Fault. Within the upper Elizaville (and upper Nassau) is a conspicuous ridge-making green chloritic quartzite varying from 10-70' thick which has been named the Curtiss Mountain Quartzite (Fisher, in press). The type locality is on Curtiss Mountain, a conspicuous north-south ridge west of Tackawasick Lake in the Troy quadrangle. This unit is most useful in working out the structure in the southern Taconics. It appears to be a facies between the Nassau, Elizaville and Rensselaer and thus holds a position akin to that of the Zion Hill Quartzite in the northern Taconics.

Everett Schist (Xev) - Named by Hobbs (1897), this is a green quartz-chlorite schist comprising the bulk of the Mt. Washington massif along the New York-Massachusetts line. Foliation is well developed and magnetite octahedra and pyrite cubes are fairly common. This is the highest rank metamorphic rock that we shall see on this trip. Fossils have been completely obliterated if, in fact, they were originally present. Weaver mapped this unit as the Berkshire schist and correlated it with his Middle Ordovician Trentonian black slate to the west. Evidence is conflicting as to whether the Everett green schist is transitional with the black beneath or whether it lies in fault contact or unconformity with it. In the northern Taconics, MacFadyen (1956) called a similar green schist the Mt. Anthony Formation (Upper Ordovician).

Lower Cambrian (Clt)

Bomoseen Subgraywacke - The Bomoseen (type locality at Lake Bomoseen, Vermont) is extensive in the northern Taconics, especially in the west, but poorly developed in the south. It occurs in the Troy quadrangle but is not definitely known further south. It is an olive-green, massive, chlorite-muscovite-albite-microcline quartzite (subgraywacke) with disseminated hematite and graphite and clearly a facies of the Mettawee. Except for the single report of the brachiopod Obolella, fossils are unknown. The Bomoseen will not be visited on this trip.

Mettawee Slate - This unit, named from the Mettawee River in Washington County (Ruedemann, in Cushing and Ruedemann, 1914, p. 69), is a green, purple, variegated green and purple or gray slate or shale. Chlorite and sericite are present in comparatively large amounts. Cleavage is usually well developed and it is the perfection of this feature, together with the uniform physical makeup, which makes the Washington County Mettawee so economically usable as slate flagging. In Columbia County, the Mettawee is predominantly a quartz-silt, greenish-gray argillite with lenticular nodular limestone and limestone conglomerates or breccias having a slump origin (brecciolas) in its upper part. As persistent limestone brecciola, 5-20' thick, in northern Columbia and western Rensselaer Counties is the Stuyvesant Conglomerate (Ford, 1885) an ill-sorted heterogeneous mixture of slabby coarse to fine textured limestone in an argillaceous or quartz-sand matrix--the quartz grains usually well-rounded. The Stuyvesant Conglomerate has afforded most of the Early Cambrian fossils in New York. These include (see Plate 2): the agnostid trilobites, Calodiscus lobatus, C. meeki, Serrodiscus speciosus, Pagetia prindlei, P. connexa, and Pagetides elegans; the olenellid trilobite Elliptocephala asaphoides; the ptychoparid trilobite Atops trilineatus; and the trilobites Fordaspis nana, Kootenia troyensis, Bonnaria salemensis, and Kochiella fitchi. Botsfordia caelata, Obolella crassa and Acrotreta taconica are the most common brachiopods; Helcionella subrugosa is the most frequent gastropod; fragments

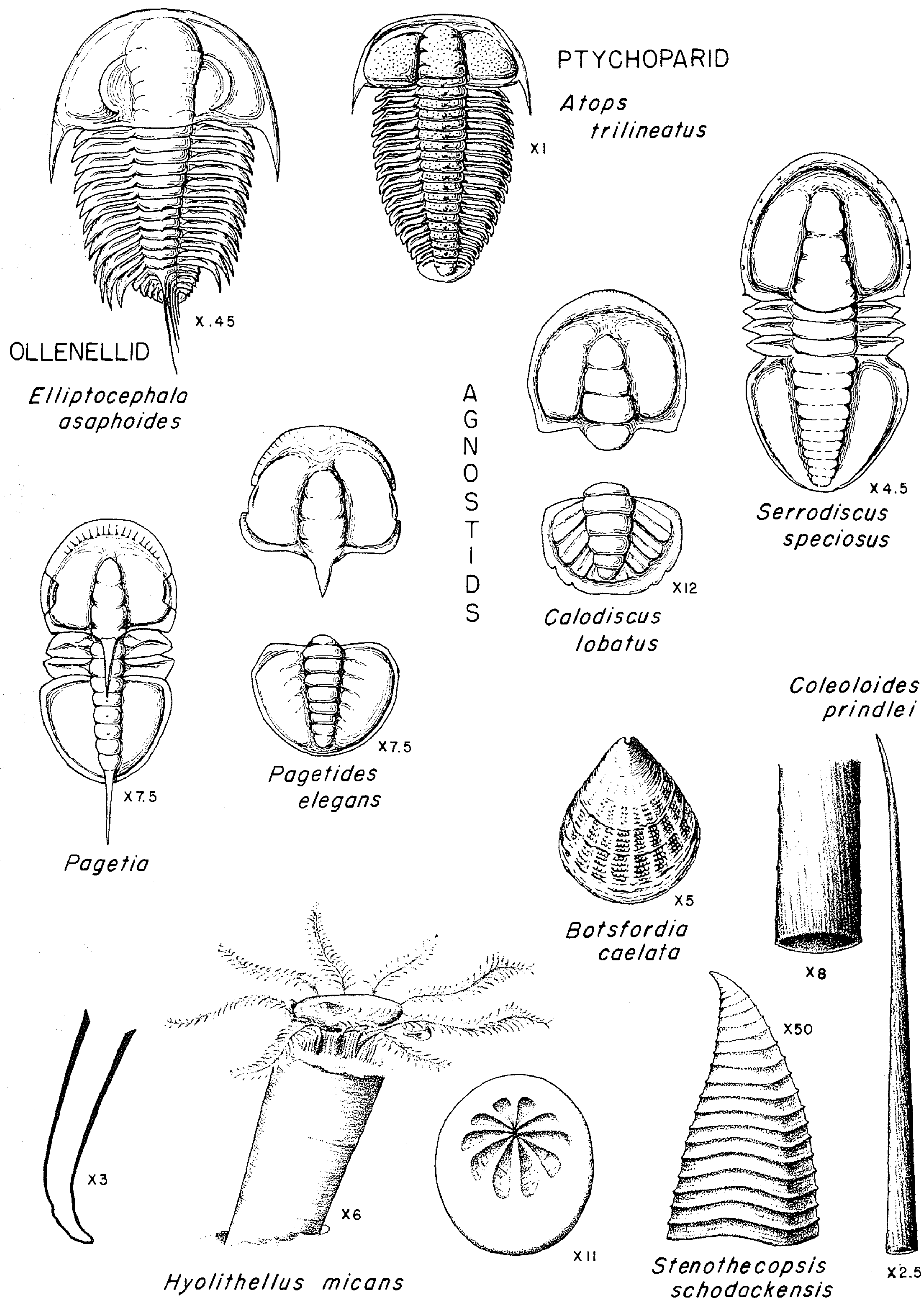


PLATE 2 LOWER CAMBRIAN FOSSILS

of archaeocyathids are locally common. Most Early Cambrian faunas, and this is no exception, are characterized by strange fossils whose systematic position is in doubt as they bear no close resemblance to living animals. In the Stuyvesant Conglomerate these include Hyolithellus micans (a possible tube worm), Coleoloides prindlei (worm? or mollusk?), the hyolithids Hyolithes americanus and H. communis (a probable extinct class of mollusks), Stenothecopsis schodackensis (a possible conularid or phoronid), and Salterella pulchella, Stenothecoides labradorica, and Fordilla troyensis. After lengthy search, most of the above may be collected behind the Troy High School.

Nassau Formation - The name Nassau was given (Ruedemann, in Cushing and Ruedemann, 1914, p. 70) to the intermixed greenish and reddish quartzose shales and interbedded green quartzites so prevalent in southern Rensselaer and northern Columbia Counties. Accessory minerals in the shales include muscovite, chlorite, plagioclase and hematite; those in the quartzites are zircon, tourmaline, and apatite with silica, calcite, dolomite and sericite as cement. The thickness has been estimated as upwards of 800'. The Ashley Hill Limestone (Dale, 1893) with a fauna almost identical to the Stuyvesant Conglomerate, lies within the upper Nassau and therefore fixes its age as Early Cambrian. The Nassau is clearly a quartz-rich facies of the Mettawee.

Schodack?, Hooker?, or West Castleton? Formation - This unit has fallen victim to a nomenclatorial "snafu"---a situation not at all uncommon in stratigraphy. Briefly, the problem is this. Stratigraphically above the Mettawee, or Bomoseen where the Mettawee is missing, are interbedded black shales, usually silty and micaceous, and thin bedded fine textured limestones, locally with thin siltstones, and limestone brecciolas with black chert and buff dolomites. Dale (1899), in Washington County, called this Unit D (Cambrian black slate). Regrettably, Ruedemann (Cushing and Ruedemann, 1914, p. 69) selected the unsuitable geographic name Schodack for this unit, taking the name from known Early Cambrian exposures 2 miles south of Schodack some 75 miles to the south. But these fossiliferous strata are not interbedded black shales and limestones----they are the Stuyvesant limestone conglomerate within the Mettawee green argillite! The name Schodack continued to be applied to the Lower Cambrian black shales and limestones throughout eastern New York until recently, when Theokritoff (1959) advised against its continued use in the northern Taconics. Keith (1923) had called a similar but doubtfully identical unit in Vermont, the Hooker, and Zen (1959, 1961) has lately substituted the name West Castleton for the Early Cambrian black shales and limestones in Washington County and adjacent Vermont. Now, Atops trilineatus and Elliptocephala asaphoides (identified by A. R. Palmer, U.S. National Museum) have been discovered by the writer in black shales and interbedded limestones and siltstones at Judson Point, 9 miles south of the "type" Schodack at Schodack Landing. This, disconcertingly, is the same unit that overlies the fossiliferous Mettawee at Schodack Landing and therefore, ironically, Ruedemann was indeed correct!

North of Oakwood Cemetery, North Troy, there is about 30' of rather massive tan to pink ferruginous calcareous sandstone or quartzite which Ruedemann (Cushing and Ruedemann, 1914, p. 70) named the Diamond Rock Quartzite; its meager poorly preserved fauna indicates an Early Cambrian age. It has not been positively identified outside of the type locality. The Diamond Rock overlies the Mettawee and underlies the inadequately defined "Troy" shales, which probably are, in part, the "Schodack" black shales and limestones and Mettawee shales.

Upper Cambrian and Lower Ordovician (O€)

In the Taconic Sequence are Upper Cambrian (Croixian) and Lower Ordovician (Canadian) clastics, which, in the northern Taconics, are separable into the Hatch Hill and Poultney Formations, respectively. These lithologies change southward so that extension of these names is impractical. In northern Rensselaer County, the Lower Ordovician Schaghticoke (pronounced skat-i-coke) and Deepkill formations with their diagnostic graptolite faunas of Dictyonema flabelliforme and Staurograptus dichotomus on the one hand and Tetragraptus, Phyllograptus and Didymograptus bifidus on the other, are classic (see Plate 3). However the names Schaghticoke and Deepkill have assumed a time connotation and although their lithologies extend into Columbia County, it is felt unwise to use these names for lithic units in the southern Taconics owing to the time-transgressive nature of the units, for example the Schaghticoke lithology (Early Ordovician at its type locality) is apparently Late Cambrian in Columbia County. Accordingly, the new names Germantown and Stuyvesant Falls have been proposed (Fisher, in press) for Late Cambrian and Early Ordovician rocks in the southern Taconics. The Germantown consists of ribbon limestones, thin siltstones, brecciolas, and interbedded black shales bearing Callograptus and Dendrograptus, which, to W. B. N. Berry suggest a Late Cambrian age. Overlying the Germantown with a sharp lithologic change is a sequence of interbedded green fine textured argillite which has produced the graptolites Tetragraptus, and Didymograptus south of Becraft Mountain. The Stuyvesant Falls Formation is at least 400' thick at its type locality in Kinderhook Creek at Stuyvesant Falls where it underlies the Mt. Merino shale of the Normanskill. Complete sections of the Germantown Formation are unknown and its base is obscured within the black shale-limestone terrane. It is probably no less than 400' thick.

Middle Ordovician

Normanskill Group (On) - Within the Taconic Sequence resting unconformably upon clastics of varying ages is a succession of shales and graywackes about 2000' thick. The basal unit (called the Indian River Slate in the northern Taconics) is a green or red shale or slate locally with green chert or siliceous argillite. The medial unit (Mt. Merino black shale and chert) is the most graptoliferous with many genera represented, while the upper unit (Austin Glen Graywacke) is composed of tan weathering graywacke interbedded with gray and black shales. The graywacke is composed principally of angular quartz and shale fragments in a calcareous argillaceous matrix. Plagioclase feldspar is subsidiary. Nemagraptus gracilis is characteristic of the Mt. Merino and Climacograptus bicornis is characteristic of the Austin Glen (see Plate 3). No younger rocks are known within the Taconic Sequence. Prof. W. B. N. Berry, University of California, has recently restudied the graptolite faunas of the Normanskill and older shales, and in so doing, has discovered many new fossil localities. Some of his revisions have appeared in print (Berry, 1960).

THE MIOGEOSYNCLINAL SEQUENCE

Poughquag (=Cheshire) Quartzite (€p) - The name Poughquag was given by Dana (1872) to the basal quartzite holding the Elliptocephala fauna and resting on the Precambrian gneisses. Later, Emerson (1892) applied the name

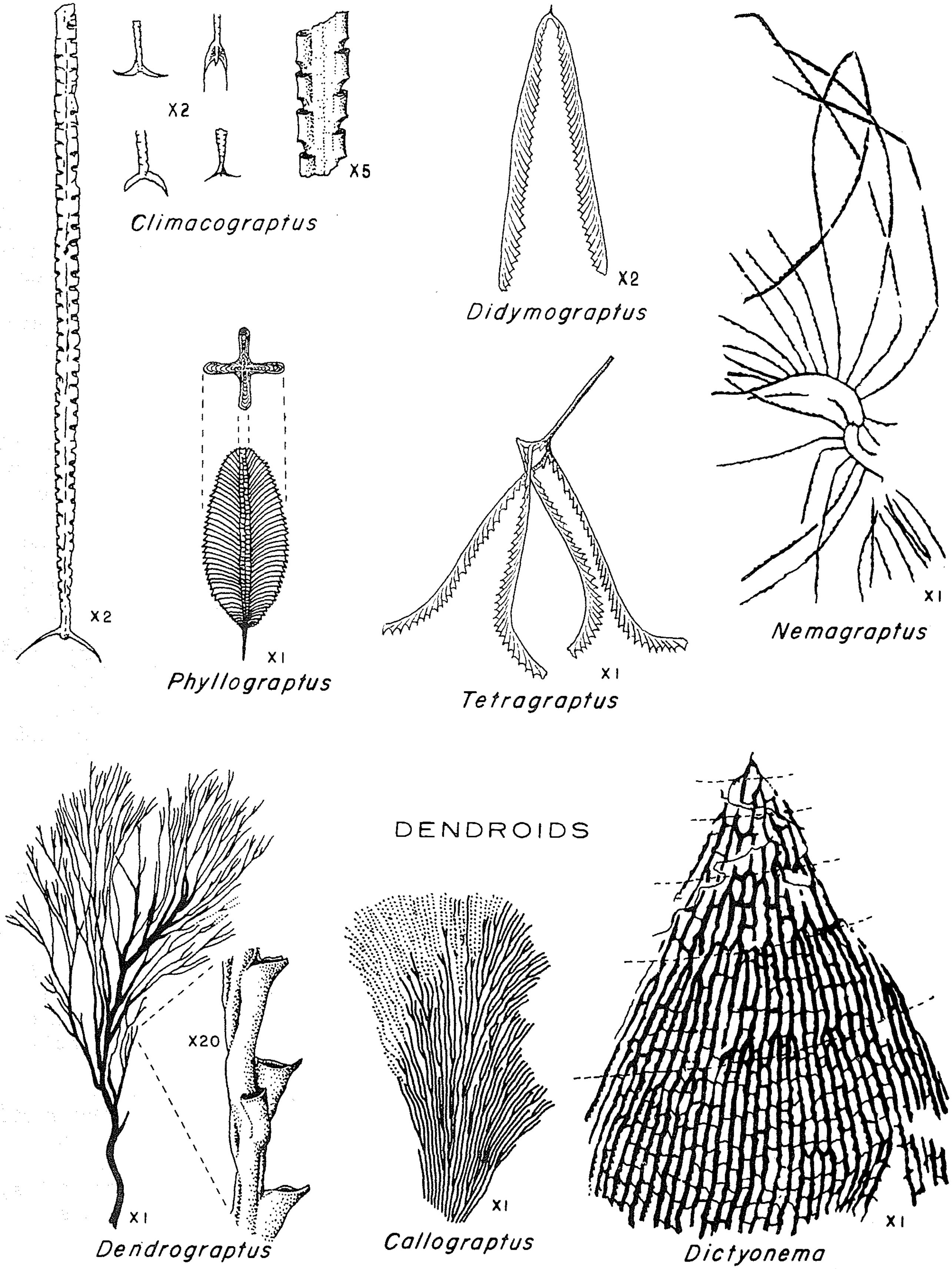


PLATE 3 GRAPTOLITES

Cheshire to the same unit in western Massachusetts and Vermont. The Poughquag is a fine to medium textured virtreous to conglomeratic quartzite, feldspathic at its base and usually brownish to white in color. In New York State it is not known to outcrop north of Stissing Mountain, Duchess County.

Stockbridge Group (O€s) - The name Stockbridge was given (Emmons, 1842, p. 154) to the carbonates above the basal quartzite (Poughquag) and beneath the Berkshire schist (black portion only), thus ranging from Early Cambrian through lower Middle Ordovician. Stockbridge is synonymous with the later term, Wappinger (Dana, 1879). In places, the Stockbridge has yielded fossils. This has led to a critical examination of the subtle lithologic differences within the carbonate terrane and has permitted the following subdivision, in ascending order:

Stissing Formation (€l) - In discovering Hyolithes billingsi, Paterina stissingensis and Prozacanthoides stissingensis at Stissing Mountain, Dwight (1890) announced what he thought were Middle Cambrian fossils. The last to work in that area (Knopf, 1946) regarded this unit as wholly Lower Cambrian. The Stissing Formation consists of a lower dolomite with Hyolithellus micans, an intermediate red dolomitic shale and argillaceous dolomite and an upper bluish-gray cherty dolomite and limestone with the fossils which Dwight reported. The Stissing may be present in southern Columbia County.

Pine Plains Formation (€ss) - Sandy dolomites, shales, sandstones, oolites; no fossils except the algae Cryptozoon; Upper Cambrian but may be older; Knopf (1946) reports at least 1300' thick.

Briarcliff Dolomite (€ss) - Vuggy, light colored dolomite, slightly sandy. The occurrence of the trilobites Plethometopus, Plethopeltis and Prosaukia confirm a Late Cambrian (Trempealeau) age; Knopf (1946) reports at least 1000' thick.

Halcyon Lake Calc-dolomite (Ob) - Fine to medium textured calcareous dolomite and dolomitic limestone with the nautiloids, Ectenoceras and Ellsmereoceras, and the gastropods, Ozarkispira and Sinuopea, all indicative of an Early Ordovician (Lower Canadian) age; about 300' thick.

Rochdale Limestone (Ob) - Limestones, dolomites, rarely sandy; the gastropod Lecanospira compacta is most abundant, also has nautiloids Dwightoceras, Eothinoceras and Vassaroceras and the trilobite Hystricurus conicus, all guides to the Early Ordovician (Middle Canadian); about 400' thick.

Copake Limestone (Ob) - Dolomitic limestones, calcareous dolomites with 80-90' of cross-bedded sandy dolomite in the basal portion; 212' at type locality at Tom Hill at Copake, Columbia County; has with brachiopod Syntrophia lateralis, the gastropod Ecculiomphalus volutatus and the trilobite Isoteloides cf. whitfieldi, all denoting a correlation with the Upper Canadian Fort Cassin Formation of the Champlain Valley.

Balmville Limestone (Oba) - Named by Holzwasser (1926, p. 40) from the very fossiliferous outcrop at Balmville, two miles north of Newburgh, N. Y., where it is 70' thick, it unconformably rests on various divisions of the Stockbridge. The Balmville is a detrital limestone, commonly conglomeratic (calcirudite) or coarse textured (calcarenite) but usually medium (calcisiltite) to fine textured (calcilutite); sometimes it is an argilli-calcilutite. Fossil fragments are relatively common (as rocks east of the Hudson River go) with pelmatozoan ossicles and columnals most obvious. Less frequently, sections of brachiopods, gastropods, horn corals and bryozoa can be seen. Faunal lists have not been published for Columbia County, but in Duchess and Ulster County the Balmville has yielded the following: the algae Solenopora compacta; the corals Lambeophyllum and Tetradium; Receptaculites; the bryozoans Arthropora armatum, Batostoma winchelli, Eridotrypa aedilis, Helopora divaricata, Phyllodictya varia and Rhinidictya mutabilis; the brachiopods Dinorthis pectinella, Nicollella, Paucicrura, Rafinesquina alternata and Sowerbyella; unidentified endoceroids; and the trilobites Flexicalymene senaria and Illaenus crassicauda. The abundance of echinoderm debris requires a post-Canadian age. This fauna seems to agree most closely with the Rockland and Black River limestones (Amsterdam, Chaumont) of the Mohawk and Black River Valleys. In Columbia County, the Balmville occurs in fault blocks (horses) and in normal stratigraphic position.

Walloomsac Slate (Ow) - Named by Prindle and Knopf (1932, p. 269), this is a black slate or black phyllite which occupies large areas in eastern Rensselaer and eastern Columbia Counties. It is conformable with the Balmville and disconformable on older portions of the Stockbridge Group. It likewise rests on the Elizaville Shale but the nature of this juncture is disputable. Similarly, the Walloomsac's upper contact is in dispute. Previously mapped by Craddock and Weaver (1957) as Trentonian black slate, the Walloomsac can be traced southward into the Rhinebeck quadrangle into the graptolite-bearing Mt. Merino portion of the Normanskill. Potter (unpubl.) has demonstrated that the Walloomsac of the Hoosick quadrangle grades laterally into the Mt. Merino and Austin Glen units. Occasional thin beds of limestone may be found within the lower portion of the Walloomsac. Fossils have not been found in the Walloomsac of Rensselaer and Columbia Counties. Striated cleavage planes are common as are pyrite crystals and white quartz veins. An estimated thickness of upwards of 1000' has been reported for Columbia County.

Snake Hill Formation(Osh) - The type locality is at Snake Hill on Saratoga Lake where the characteristic quartz-silt gray-black shales and thin calcareous siltstone beds occur. The Snake Hill is a facies of the Normanskill of the Hudson Valley and the Canajoharie black shale of the Mohawk Valley. The fauna consists primarily of graptolites in the shales and brachiopods and pelecypods in the siltstones.

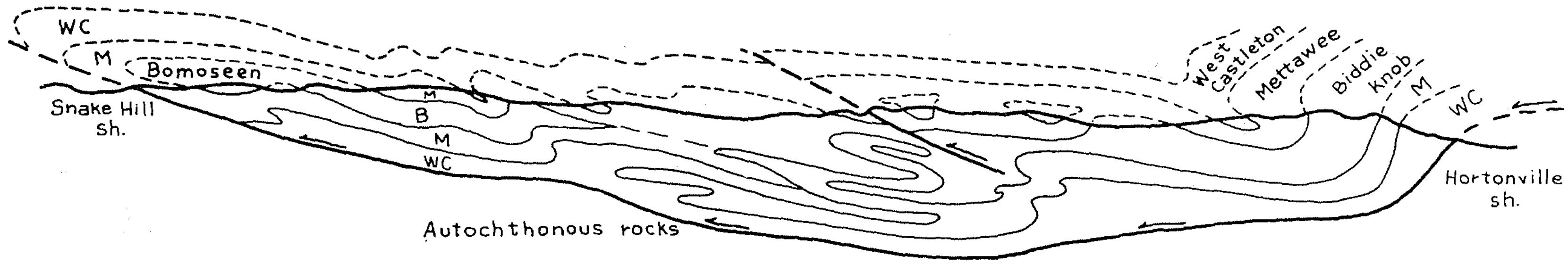
East of the Hudson River and within the Snake Hill Formation is a north-south linear agglomeration of a slump blocks of fossiliferous limestone, dolomite, shale and graywacke termed the Rysedorph Conglomerate. Its fauna was fully described by Ruedemann (1901) and has been much quoted because of its uniqueness. The Rysedorph seems to represent the spalling off of a thrust plate (gravity slide) during its westward travel into the then unconsolidated Snake Hill sediments.

To the north, in the Schuylerville, Cambridge and Fort Ann quadrangles, are larger exotic blocks of Trenton and Canadian carbonates collectively known as the Bald Mountain Limestone (Ruedemann, in Cushing and Ruedemann, 1914). Various interpretations have been offered to account for their presence. One of the more logical appears to be that the carbonate represents a block caught between two proximal eastward dipping reverse faults. Slump blocks exist to the west of the carbonate sliver within the Snake Hill formation. Numerous other Trenton and Canadian carbonate blocks (horses) occur along reverse faults elsewhere in the Taconics, for example the carbonates at Rock City School on the Kinderhook quadrangle, and the Tackawasick Limestone at the west edge of the Rensselaer Plateau in the southeast corner of the Troy quadrangle.

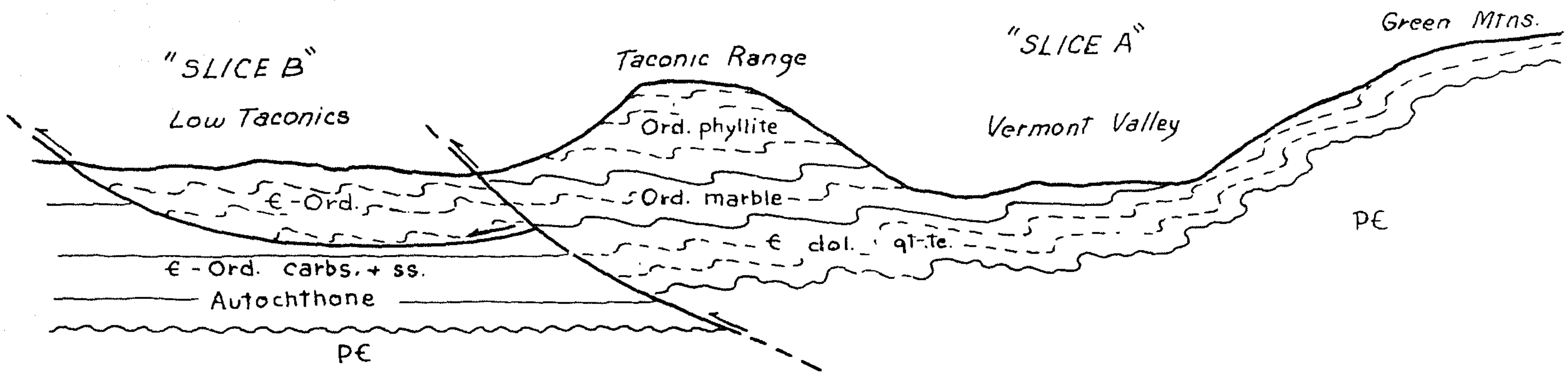
STRUCTURE

The major structures in the Taconics are lengthy essentially N-S reverse faults and paralleling pene-isoclinal folds overturned to the west with much of the folding doubly plunging both to north and south. The N 10° - 15° E trend of some of the major faults (notably the Chatham Fault) truncate the N-S post-Normanskill folds. Transverse east-west tear faults are less common as are symmetrical folds. Of the minor structures, cleavage is the most prominent. Naturally, it is conspicuous in the shales but it is also obvious in the Balmville Limestone and an irregular cleavage can be detected in many dolomites accounting for the rugged appearance of weathered surfaces. East of the Chatham Fault, cleavage sharply increases and masks bedding so effectively that the amount and direction of folding is exceedingly difficult to determine.

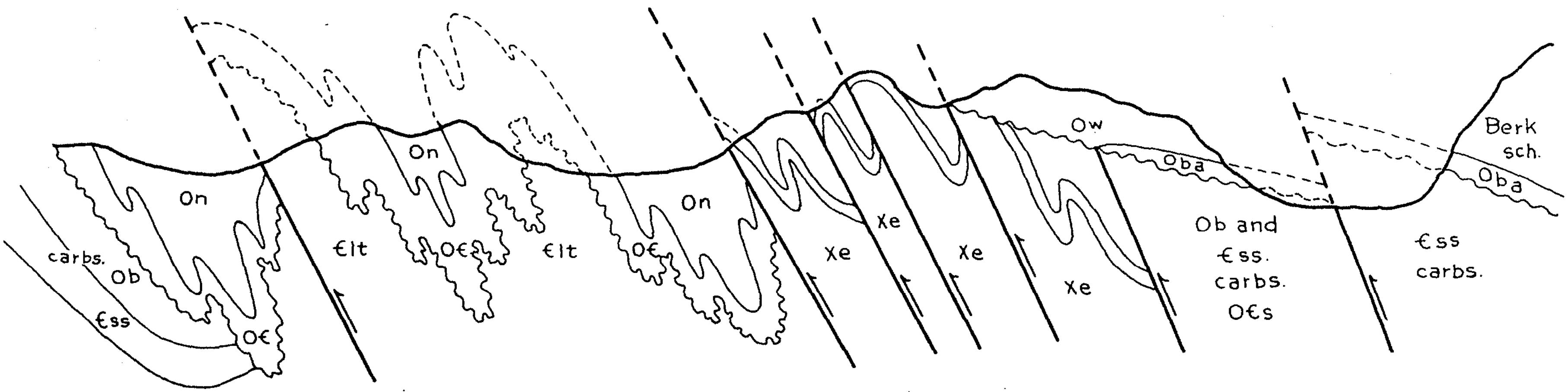
As with fossils, metamorphism (even low rank) is disastrous to primary features. Nonetheless, there are three types of sedimentary structures which can be utilized with some confidence in distinguishing between top and bottom of bedding. Small-scale cross-bedding is most reliable and occurs in the thin siltstones, calcareous sandstones and sandy dolomites. This criterion has proved serviceable in the Nassau, "Schodack", Germantown, Stuyvesant Falls, Austin Glen and parts of the Stockbridge units. Flow casts on the bottoms of beds are reliable but less frequent. They are exceedingly abundant in the Stuyvesant Falls Formation and less abundant in the Rensselaer, Nassau, Curtiss Mountain, "Schodack", Germantown, Austin Glen and Pine Plains units. Graded bedding in the Rensselaer, Stuyvesant, Germantown, Austin Glen and Stockbridge units must be used with caution. Micro-graded bedding is trustworthy but large-scale graded bedding occasionally gives contradictory results. Ripple marks are too rare to be of much help.



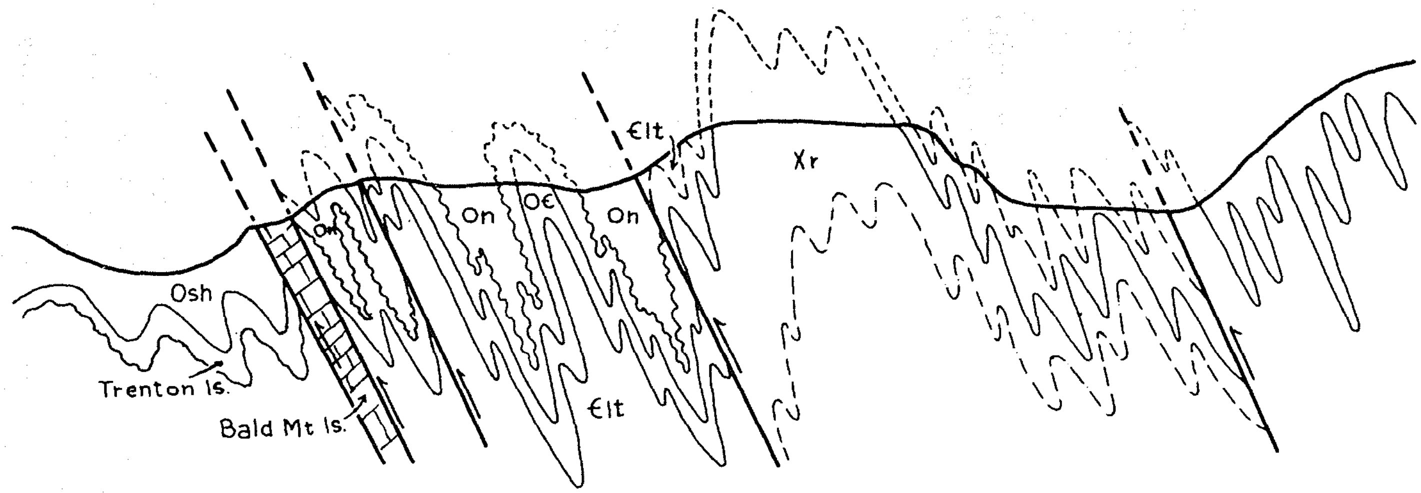
(A) ALLOCHTHONE OR KLIPPE HYPOTHESIS



(AA) P. C. HEWITT HYPOTHESIS



(B) BUCHER HYPOTHESIS



(C) C. LOCHMAN *IN SITU* HYPOTHESIS

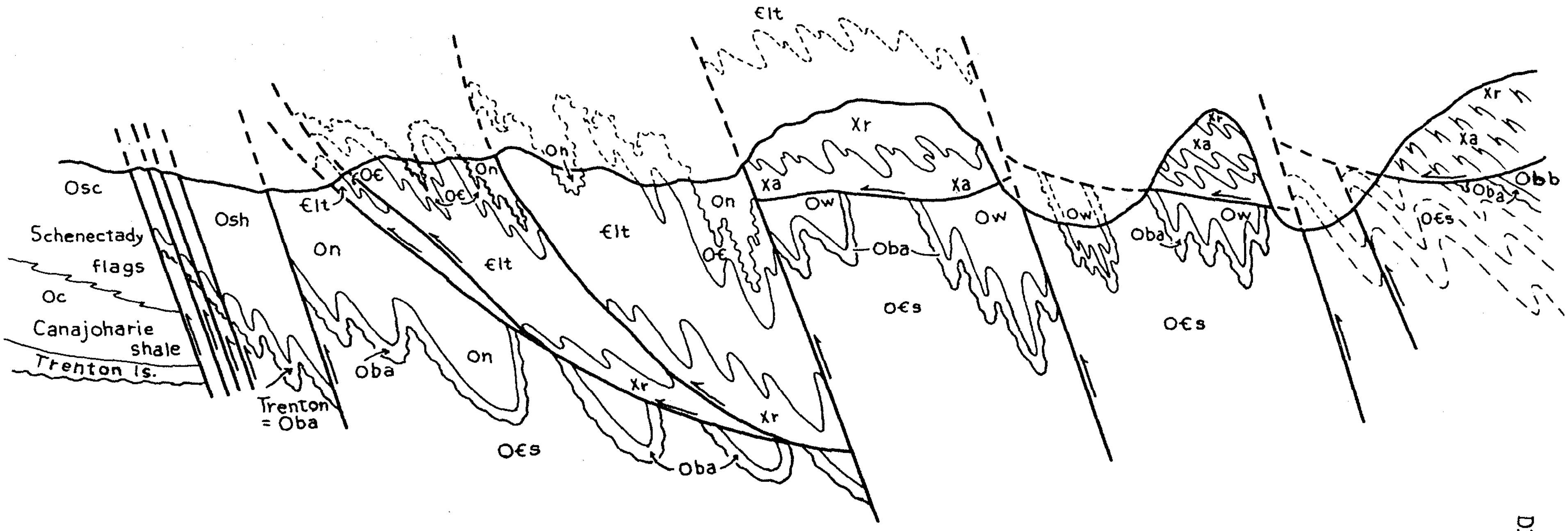


PLATE 4 (D) D. FISHER INTERPRETATION OF COLUMBIA COUNTY

THE TACONIC PROBLEM CONTINUED:

HYPOTHESES PROPOSED TO EXPLAIN THE FIELD RELATIONS

The Taconic Sequence is a succession of clastics, primarily micaceous and quartz-silt shales, purple and green shales and slates, red slates, quartzites, graywackes, and interbedded black shales and ribbon limestones, having relatively great north-south extent (ca. 150 miles) and relatively small east-west extent (ca. 25 miles). Lamprophyres, dikes of diabase and albite-basalt, and tuffs occur within it. Clearly, this is a eugeosynclinal suite. Peripheral to the Taconic Sequence are contemporaneous miogeosynclinal carbonates and orthoquartzites. In order to explain the apparent anomalous position of the Taconic Sequence, differing structural hypotheses have been proposed and it is these that are the source of current controversy.

All workers recognize a western bounding fault or zone of faults, usually termed "Logan's Line" although it properly should be called Emmons' Line for it was he who first recognized it! However, the nature of the eastern boundary is cause for dispute. This "Taconic Contact" holds the key to the Taconic Problem. When exposed, which is seldom, the field relations are inconclusive for the increased metamorphic rank of initially similar lithologies only obscures the character of the eastern contact. In addition, fossils are absent in these metamorphic rocks. Different workers see this eastern boundary as a fault, unconformity, conformable contact or transitional contact.....some workers are noncommital.

Fundamentally, three hypotheses exist which attempt to explain the structure of the Taconics. Some favor one over the other two or have adaptations or combinations of these for their own mapped areas. The three hypotheses are briefly described, to which the writer adds his own modified combination of the three which is particularly adaptable in northern Columbia County. All are illustrated with schematic structure sections (see Plate 4). Without benefit of a stereogram it is exceedingly difficult to illustrate the complex structure of the Taconics.

A. The Allochthone or Klippe Hypothesis is perhaps the most publicized. This presupposes that the Taconic Sequence was initially deposited far to the east and that emplacement of an allochthone of eugeosynclinal rocks was accomplished by westward low angle thrusting due to crustal shortening or gravity sliding. Subsequent erosion isolated the Taconic Sequence exposing contemporaneous miogeosynclinal (autochthonous) rocks on the east. Conceived by Ruedemann (1909) and elaborated by Keith (1912), this hypothesis has received the support of Marshall Kay, John Rodgers, Wallace Cady, J. Thompson,

R. Shumaker, L. Platt, D. Potter and G. Theokritoff. E-an Zen (1959, 1961) has altered this concept to say that the allochthone is a large flat-lying westward overturned anticline (nappe). Whereas Zen's theme is ingeniously suitable for the northern Taconics, no evidence for such a structure has been forthcoming by any worker in the southern Taconics.

B. The Bucher Hypothesis regards folding as the major means of deformation with the Taconic Sequence forming a tight anticlinorium and the migeosynclinal sequence forming adjacent tight synclinoria. Some faulting is admitted but large scale thrusting is denied. Shale to carbonate facies changes are viewed as more apparent than real but great weight is assigned important unconformities in explaining contrasting rock units. These unconformities are acknowledged as difficult to locate in deformed strata. Walter Bucher formulated this hypothesis based on the field work of his students, J. C. Craddock and J. Weaver, in the Kinderhook and Copake quadrangles respectively.

Misuse of certain paleontological data is obvious, especially in carbonate slices along faults and relative ages of certain rock units.

C. In situ Hypothesis - Adherents of the existence of rapid shale to carbonate facies changes (Christina Lockman, R. Balk, J. Elam) believe that the Taconic Sequence was deposited in place but that severe deformation compressed the rocks to such a degree that the original situation is greatly foreshortened. High angle reverse faulting is preferred over low angle thrusting and westward travel of an allochthone is rejected. This hypothesis fails to satisfactorily explain the mechanics of producing contemporaneous carbonate blocks along the major faults.

D. Field relations in Columbia County are satisfied by supposing peneisoclinal folding following Normanskill deposition with subsequent westward submarine gravity sliding of an allochthone into the Snake Hill sediments accompanied by spalling-off of heterogeneous rocks into the host sea. Uplift and erosion during the ensuing Silurian was succeeded, in the Middle and Late Devonian, by high angle reverse faulting thereby imbricating the Ordovician allochthone. Pre-Normanskill and post-Canadian folding and minor faulting is demonstrable. It is dubious whether there was any post-Early Cambrian and pre-Late Cambrian folding. The differing Lower Cambrian units beneath younger strata can be explained by admitting differential uplift and erosion or contemporaneity of differing Early Cambrian facies. Intricate inter-tonguing and time-transgressiveness of principal mapping units is evident but, as yet, inadequately worked out.

Lack of agreement on the manner of Taconic deformation remains as much a puzzle today as was the "Taconic System" over a century ago. Much tedious work remains for young energetic geologists with a keen mind and an observing eye.

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APPENDIX: SELECTED OUTCROPS, MARKED ON GEOLOGIC MAP

1. Troy quadrangle, along both sides of Red Mill Rd. (N. Y. 151), 1 mile west of N. Y. 40; slump blocks of Austin Glen Graywacke and Trenton Limestone in badly deformed Snake Hill Shale; Rysedorph Hill 0.2 mile to the northeast.

2. Berkshire Spur of Thruway (travelling east); no stopping permitted.

   (a) Kinderhook quadrangle, 0.5 mile east of U. S. 9; greenish-gray slaty argillite of Mettawee Formation.

   (b) Kinderhook quadrangle, few hundred feet west of crossing of N.Y. 203 at North Chatham and 0.3 mile further east; interbedded black shale, limestone and calcareous sandstone, beds nearly vertical, Lower Cambrian.

(c) Kinderhook quadrangle, 0.4 mile further east where Columbia County 32 passes beneath Thruway; grayish-green slaty argillite of Mettawee Formation.

(d) Kinderhook quadrangle, 1 mile further east, principally on west-bound lane; essentially vertical beds of interbedded black shale, limestone and calcareous sandstone, probably Lower Cambrian.

(e) Kinderhook quadrangle, 1.6 miles further east, principally on westbound lane; purple and green shales with interbedded thin red and green siltstones, Nassau Formation.

(f) Kinderhook quadrangle, 1.5 miles further east and 0.3 mile east of Old Chatham, also along town road paralleling Thruway; black slate, presumably Walloomsac, no fossils yet found, purple and green Nassau beneath, along town road. Nature of contact disputable.

(g) Kinderhook quadrangle, 3 miles further east and 1 mile east of East Chatham where N. Y. 295 passes over Thruway; Anticline in black slate (Walloomsac ?) on east-bound lane. Amos Eaton born at New Concord (Historic marker), 1.1 miles south of East Chatham.

(h) Pittsfield quadrangle, 3.8 miles further east, along both lanes; 1 mile of exposures of eastward dipping Stockbridge dolomites and dolomitic limestones, locally much deformed.

3. Pittsfield quadrangle, town road paralleling Thruway on the north, 1 mile west of B3 interchange; eastward dipping Stockbridge carbonates.

4. Pittsfield quadrangle, 1.2 miles east of Canaan at west end of Queechy Lake along N. Y. 295; fossiliferous Balmville Limestone on dolomite and underneath Austerlitz purple and green phyllite.

5. Pittsfield quadrangle, 0.2 mile southwest of Canaan along south side of B. & A. R.R. at junction with Columbia County 5; eastward dipping Austerlitz purple and green phyllite with interbedded thin green chloritic quartzite; black slate outcrops 500' to the west along the R. R.

6. Pittsfield quadrangle, 2.3 miles south of Canaan in tunnels of the B. & A. R.R.; Austerlitz purple and green phyllite thrust on Stockbridge carbonates, fossiliferous Balmville Limestone locally present.

7. Pittsfield quadrangle, 4 miles northeast of Austerlitz on west side of N. Y. 22; "Berkshire" black phyllite.

8. Kinderhook quadrangle, 2.4 miles west of Austerlitz and 5.3 miles east of Chatham along both sides of N. Y. 203; Rensselaer Graywacke with many quartz veins, some of which are feldspar-bearing.

9. Copake quadrangle, road-cut on west side of N.Y. 22 at Copake Falls; interbedded dolomite and shale with ripple marks (?) or flow structure (?) on dolomite, Pine Plains Formation.

10. Copake quadrangle, Taconic State Park, green Everett Schist on north side of N. Y. 344 at eastern edge of Park.

11. Copake quadrangle, 0.7 mile northeast of Copake at Tom Hill on west side of N. Y. 22; Copake Limestone and Balmville Limestone with distorted fossils due to flowage.

12. Copake quadrangle, along west side of Columbia County 7 at east end of Copake Lake; Balmville Limestone thrust on Walloomsac Slate.

13. Copake quadrangle, 5 miles east of Claverack and 1.5 miles south of present termination of Taconic Parkway at N. Y. 23; green argillite (Elizaville) and chloritic quartzite (Curtiss Mountain) along both sides of Parkway.

14. Catskill quadrangle, exposures on both sides of U. S. 9, 0.5 mile south of southern edge of Becraft Mountain; interbedded graptoliferous black shale and limestone (Germantown Fm.) and greenish-gray silty shale with Deepkill graptolites.

15. Catskill quadrangle, along west side of Columbia County 31 at Blue Hill, 1.5 miles southwest of southern edge of Becraft Mountain; red and green shale and much green chert, lower member of Normanskill Group.

16. Catskill quadrangle, 2.5 miles southwest of southern edge of Becraft Mountain along both sides of Columbia County 14; ferruginous quartzite overlying quartzose greenish-gray shale (Germantown Fm.)

17. Catskill quadrangle, 0.5 mile east of eastern terminus of Rip Van Winkle Bridge along south side of N. Y. 23; deformed Mt. Merino Shale of Normanskill Group.

18. Catskill quadrangle, 2.5 miles ESE of Germantown along Columbia County 8 and in Fisher's Quarry 500' to the northeast: interbedded black shale, limestone and limestone brecciola of Germantown Fm. overlying Mettawee green argillite.

19. Kinderhook quadrangle, in and along Kinderhook Creek at Stuyvesant Falls where Columbia County 25A passes over creek (type locality of Stuyvesant Falls Fm.); interbedded green silty shale and flow-cast green siltstones and chertified argillite underlying Mt. Merino shale of Normanskill Group.

20. Coxsackie quadrangle, roadcut along N. Y. 9J and cuts along railroad 1.9 miles south of Schodack Landing; grayish-green argillite (Mettawee) with fossiliferous limestone brecciola (Stuyvesant Conglomerate) near top, Mettawee overlain by laminated siltstones and interbedded black shales. Type locality of Schodack Formation.

21. Albany quadrangle, along the Normanskill at Kenwood between the Thruway and N. Y. 32, type locality of the Normanskill; gray and black shale with interbedded graywacke.

22. Cohoes quadrangle, along the Deep Kill 0.6 mile east of N. Y. 40 and 1 mile SSE of Melrose, type locality of the Deep Kill Formation; interbedded limestone and black shale in lower portion and greenish-gray shale in upper portion overlain by red shale of basal Normanskill. A reverse fault here repeats a portion of the section.

23. Cohoes quadrangle, in and along the Hoosic River where N. Y. 40 crosses it at Schaghticoke type locality of Schaghticoke Formation; interbedded green and black shale and thin limestones and siltstones, all badly deformed.

NOTES ON TRIP D. (TACONIC TRIP)

NOTES ON TRIP D

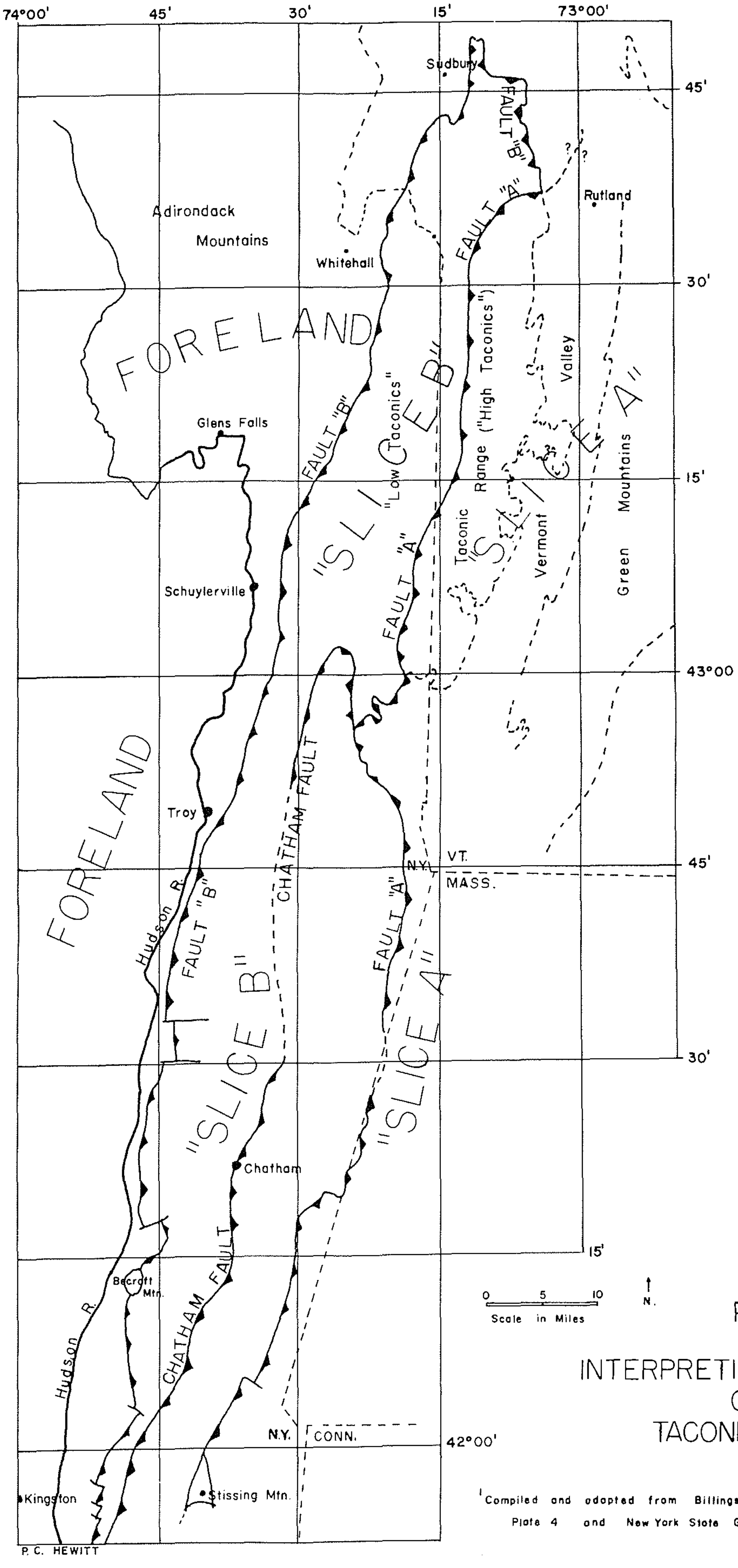

PLATE 5

INTERPRETIVE DIAGRAM OF TACONIC AREA[1]

[1]Compiled and adapted from Billings, Thompson and Rodgers, 1952; Plate 4 and New York State Geological Map (In press).

A NEW INTERPRETATION OF THE TACONIC PROBLEM

By Philip C. Hewitt

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AA. HEWITT'S HYPOTHESIS

A possible interpretation of the evidence accumulated during the recent numerous studies of the Taconics has been suggested by Hewitt (Vermont Geol. Surv. Bull., in press). Reference to Plates 4 and 5 will assist the reader in the following discussion.

Probably the most vexing difficulty lies in the great disparity of opinion regarding the nature of the eastern front of the "High Taconics" section, that is, the Taconic Range proper. West of this area is the "Low Taconics" section. Workers north of the boundary between the Equinox and Pawlet quadrangles in Vermont believe that a fault exists along the eastern front of the Taconic Range. From the northern boundary of the Equinox quadrangle southward into New York, there has been no evidence reported of a fault along this eastern zone. MacFadyen (1956) believed the contact to be such that the sequence is a normal one and Hewitt (Vermont Geol. Surv. Bull., in press) believes that there is evidence indicating a gradational and interbedded contact between the Ordovician marbles and the overlying phyllites in several localities. These two interpretations of a fault in the one case as against the normal contact in the other appear to be diametrically opposed.

Although there is no general agreement regarding the supposed fault along the eastern front of the "High Taconics", virtually all students of the problem agree that a fault does exist along the western edge of this area. The same fault seems to be traceable from the west side of Stissing Mountain (Millbrook quadrangle, N.Y.) northeastward through New York State and into Vermont. Zen (1961) shows that the fault eventually bends eastward in the Castleton area. Adherents of the klippe hypothesis require that the fault turn southward and trend to the southwest roughly parallel to and eventually joining the westerly and generally accepted fault discussed above. Adherents of the normal sequential deposition theory do not accept the eastern fault since it is unlikely that the fault would occur at the contact between the marble sequence (Vermont Valley) and the overlying phyllites if that contact is gradational. It must be in some other position and this opposes the klippe hypothesis. They may agree that the western fault probably does arc to the east and south in the Castleton quadrangle. The fault cannot, however, continue its southward direction for any considerable distance, in the view of these workers.

It would appear that the two hypotheses are unreconcilable. The fault either is or is not present. Yet Zen (1960) believes that such reconciliation is necessary in view of the conflicting data.

Hewitt (Vermont Geol. Surv. Bull., in press) has suggested an interpretation which may in fact reconcile both views. This theory assumes general agreement about the fault (Fault A) along the western edge of the "High Taconics" (Plate 5). The "High Taconics" ("Slice A") has been thrust over the "Low Taconics" ("Slice B"). If the "High Taconics" is in its normal position relative to the marble sequence, then the entire mass, including those rocks east of Fault A (the Taconic Range, marble sequence, and the Green Mountains) is part of the same "slice". These rocks have been thrust westward as a unit over the "Low Taconics" which was previously also faulted into its present site. Fault A then is on the eastern boundary of the "Low Taconics" and Fault B, which trends north-eastward from the Troy area, is the western or leading edge of the klippe.

According to this hypothesis the area west of Fault B is the autochthone, "Slice B" the allochthone and "Slice A" (Also allochthonous) is thrust over "Slice B". In this fashion the klippe is entirely exposed at the north end as Zen (1961) states. As one tries to follow the klippe southward it is buried on the east by the "High Taconics" ("Slice A") which has been thrust over the trailing or eastern side of the klippe. The eastern part of the klippe can no longer be observed for it is overlain by the "High Taconics" (Plate 4, Figure AA.) and is cut off by the later fault (Fault A). Reference to an adaptation of Zen's cross-section (Plate 4, Figure A.) shows the klippe exposed on both east and west. Fault B is the major fault marking the western edge of the klippe. At its northern extremity it bends east then south and is covered in the rest of its southerly extent by Fault A which then becomes the major fault. The "Low Taconics" is allochthonous; the "High Taconics" is a second, more easterly, thrust sheet.

The value of this interpretation is that it simplifies the highly complex structure and stratigraphy required by the usual klippe hypothesis. At the same time it avoids the unusual sedimentologic conditions required by the facies change concept since all of the elements (the autochthone, "Slice A" and "Slice B") were originally deposited separately and are not necessarily related sedimentologically.

Some evidence that the Green Mountains and marble sequence as well as the Taconic Range have been thrust in should be presented also. Diment (1956, p. 1688) indicated in his gravity studies of a portion of that area that a very high gravity exists in the region of the northern part of the Green Mountains and a very low gravity under the Taconic Range. He suggested faulting as one possible explanation for these gravity anomalies. In addition Fisher (personal communication) reports that several Precambrian hills in the Schunemunk and Poughkeepsie quadrangles are probably rootless. Offield (personal communication) believes that gravity measurements of Stissing Mountain in Duchess County indicate that this Precambrian is also separated from the basement, although he suggests that lateral movement was probably not great.

If the Precambrian were formerly more extensive at the surface due to faulting, these rocks would have been an excellent source area for later (Ordovician) sediments and may provide a source for such units as the Rensselaer graywacke. These would then not necessarily be of Cambrian age but possibly of later Ordovician age. A full discussion of the historical sequence is included in the report on the Equinox quadrangle, Vermont (Hewitt, Vermont Geol. Surv. Bull., in press).

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