Stratigraphy and Structural Geology of Central New York.

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STRATIGRAPHY AND STRUCTURAL GEOLOGY OF CENTRAL NEW YORK

by

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The writer has benefited greatly by field and laboratory discussions with Dr. Winifred Goldring, State Paleontologist and Dr. R. H. Flower, Assistant State Paleontologist of New York. C. A. Hartnagel, retired State Geologist of New York, graciously made available some of his field notes on the Richfield Springs quadrangle.

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INTRODUCTION

THE PROBLEM

In central New York, with Otsego County in its midst, is a large area of nearly flat-lying Lower and Middle Devonian sedimentary rocks. The area lies northeast of gently folded Upper Devonian sediments which locally yield commercial quantities of oil and gas. The possibility of similar structures of lesser magnitude in central New York, and the bearing of such structures on the accumulation of gas and oil in substantial amounts, prompted this study.

The original problem of the determination of geologic structures in the Middle Devonian rocks of Otsego County, was extended north during the second field season to include the Upper Silurian and Lower Devonian rocks. Although the problem is primarily one of structure, emphasis has been placed on stratigraphy, for all the field evidence of geologic structures in this area is based upon stratigraphic interpretations.

The work was done as a part of the Oil and Gas Resources program of the New York State Science Service, under the supervision of Dr. J. G. Broughton, State Geologist. Preliminary results of this work have been published as Reports of Investigation of the New York State Science Service [Stevenson 1948, 1949].

FIELD WORK

Field work was done during July and August of 1947 and June, July, and August of 1948. W. S. Skinner, Temporary Geologist of the New York State Science Service, assisted the writer in the field during 1947 and 1948. J. M. Montgomery and R. LaFleur joined the party as field assistants for the summer of 1948.

LOCATION

This report covers an irregular area in central New York between the Schoharie and Chenango Valleys (Figure 1). The area includes most of Otsego County; all of northwestern Schoharie County; the southern parts of Herkimer and Montgomery Counties; the south-eastern corner of Oneida County; the northeastern corner of Chenango County; and the eastern edge of Madison County.

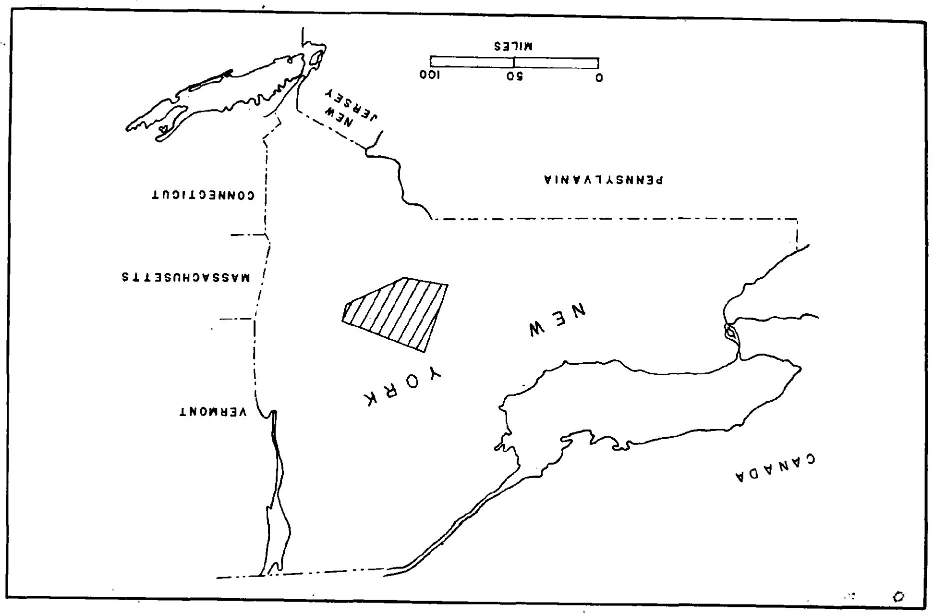

Figure 1. Outline map of the State of New York showing the location of the area studied.

GEOGRAPHY

The major portion of the area lies in the watershed of the north branch of the Susquehanna River, but small streams along the northern border and Schoharie Creek on the east drain into the Mohawk River. Principal tributaries to the Susquehanna are the Unadilla River, Butternut Creek, Otego Creek, Cherry Valley Creek, and Schenevus Creek. The Susquehanna has been dammed 6.3 miles south of Milford, forming Goodyear Lake. Two large, elongate lakes, Otsego and Canadarago are the sources of the

Susquehanna River.

This portion of central New York is a well-populated farming region with many small villages and towns concentrated along the stream valleys. The principal towns are Norwich, Oneonta, Cooperstown, and Cobleskill. North of the region studied lies the Mohawk Valley with the industrial cities of Utica, Ilion, Herkimer, Little Falls, Fort Plain, and Canajoharie.

U. S. Highway 20 runs east-west through the northern part of the area; New York State Highway 7 cuts through the southeastern section of this region; and State Highways 8 and 28 run in a north-south direction in the western and central parts of the area, respectively. Besides these primary roads, the region is covered by a network of paved and graveled secondary roads. The Delaware and Hudson Railroad's main line parallels State Highway 7 with branch lines serving Cooperstown, Cherry Valley, and Sharon Springs. The Delaware, Lackawanna and Western Railroad has a branch line running eastward into Richfield Springs. To the north in the Mohawk Valley is the main line of the New York Central Railroad.

PHYSIOGRAPHY

Following the physiographic classification of Fenneman [1917], the whole area lies within the Appalachian Plateau Province. With the exception of the northern edge, the area is confined to the Southern New York section[1] (glaciated section). The northern boundary of this section with the Mohawk section is well marked by a 200-300 foot high extension of the Helderberg escarpment as far west as Jordanville where it is replaced by a low divide. This escarpment, passing through the northern part of the, area was caused by the resistance to erosion of the Upper Silurian and Lower Devonian limestones in comparison with the underlying Ordovician shales. The surface of this Southern New York section lies between 1,000 and 2,400 feet above sea level and is characterized by (1) low rolling hills mantled by glacial debris; (2) wide, shallow (600 feet), south to southwest trending valleys partially filled with glaciofluvial deposits; (3) two large finger lakes; and (4) small lakes in glacier-formed depressions. These south to southwest trending valleys are glacially modified pre-Pleistocene stream valleys. The modifica-

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[1]Miller's [1913] Southwestern Plateau province of New York.

tion consisted of first, widening and deepening by the erosive action of the glacier and second, the partial filling of the enlarged valleys by fluvioglacial sands and gravels during retreat of the glacier.

That part of the area lying to the north of the extension is the Mohawk section[2] of the Appalachian Plateau Province. It is a region of gently rolling topography, occasionally cut by a deep gorge (_e.g._ Ilion Gulf). The sedimentary bedrock is mantled by glacial debris.

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[2]Miller's [1913] Mohawk Valley province of New York.

PART II

STRATIGRAPHY

INTRODUCTION

Detailed stratigraphic studies, which were necessary in order to determine the structure and the possibility of oil and gas, are described in this section. The stratigraphy is divided into two sections; subsurface and surface rocks. As there are no data available from deep wells in the area, the subsurface stratigraphy is inferred entirely from published reports of surface geology to the north. The interpretation of the surface stratigraphy is based principally on the writer's field observations.

In the surface stratigraphy, a method of presentation not often used is followed, which, the writer believes, will allow a greater ease in reading and will facilitate its use as a reference work. This method is modified from one used by Hedberg [1937], whose formation descriptions were subdivided under eight headings: (1) Name and Type Locality, (2) Lithology, (3) Formation Boundaries, (4) Thickness, (5) Mineralogy, (6) Paleontology and Age, (7) Stratigraphic Relations, and (8) Distinguishing Features. The writer is using a similar set of headings for the description of both members and formations where they have not been subdivided into members. It is as follows: (1) Introduction, including the type locality, (2) Lithology, (3) Thickness, (4) Contacts, (5) Paleontology, (6) Age, and (7) Remarks[1], which includes correlation, faunal relations, and paleoecology. A condensed version of this method of presentation is used in the section on subsurface stratigraphy. The subheadings used in this section are: (1) Lithology, (2) Thickness, (3) Diagnostic Fossils, and (4) Remarks[1].

The writer has adopted certain procedures of zoölogical nomenclature for use in descriptive stratigraphic nomenclature. These are as follows: (1) each group, formation, or member name is followed by the name of the original describer and the year of the original description and (2) if the group, formation, or member has been redefined, the name of the original describer and year of original description is placed in parentheses. This is quite similar to the method used by Goldring [1931] and Schuchert [1935, 1943].

STRATIGRAPHY OF THE SURFACE ROCKS

Central New York is famous for its complete section of Middle Paleozoic rocks (See Table 1). Since the days of James Hall and Lardner Vanuxem, it has been used as the Silurian and Devonian type section for the eastern United States. These rocks, separated into groups, formations,

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[1]This item appears only in the description of formations.

and members are described below as they occur in the area.

As the object of this project was the structural mapping of certain Middle and Lower Devonian stratigraphic horizons[2], detailed field observations were limited to the strata immediately overlying and underlying these horizons. The starred formations and members in the list of Middle Paleozoic stratigraphic terms (Table 1) are those whose descriptions are based on semi-detailed field studies. The remaining descriptions are based on observations from three or more outcrops, sometimes augmented by material from other workers in this area.

The fossils listed under each formation or member by no means represent the entire faunal content, but principally those forms identified in the field by the writer and his assistants.

MIDDLE SILURIAN

CLINTON GROUP (Conrad 1839)

The name was first used by Conrad in 1839 for the rocks between the Niagara shale (= Rochester shale) and the Niagara sandstone (= Medina sandstone), but in 1842 it was redefined by Vanuxem to include approximately its present limits; that is Rochester shale to Oneida conglomerate inclusive. For the next 100 years there was

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[2]In this paper, horizon is used as meaning a particular stratigraphic position (e.g. a bedding surface or a thin fossil zone).

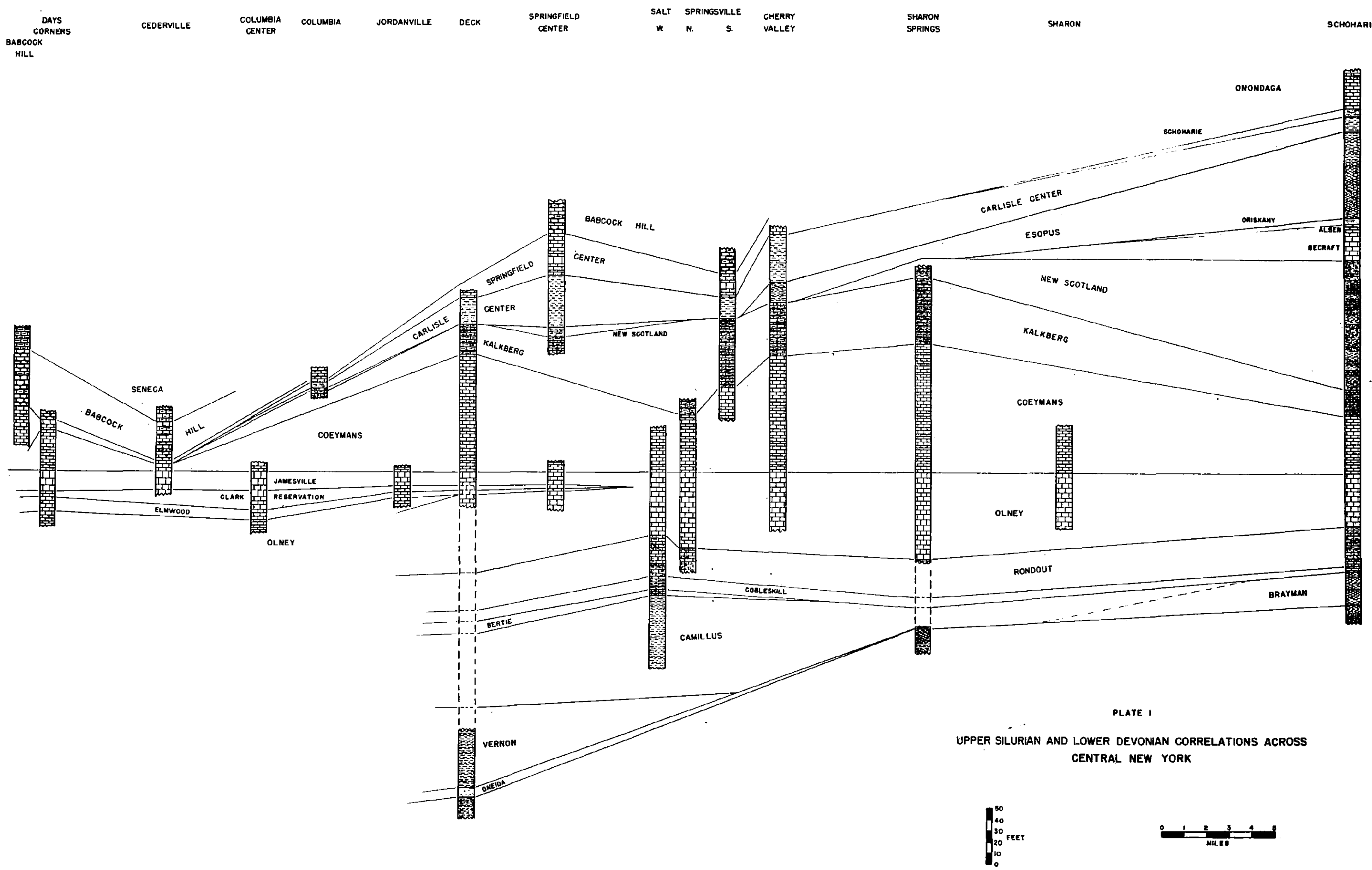

PLATE I

UPPER SILURIAN AND LOWER DEVONIAN CORRELATIONS ACROSS CENTRAL NEW YORK

TABLE 1-. SILURIAN AND DEVONIAN STRATA OF CENTRAL NEW YORK

Time	Groups	CENTRAL NEW YORK WEST		CENTRAL NEW YORK EAST	
UPPER DEVONIAN		Unadilla formation		Unadilla and Gilboa formations	
		Geneseo formation			
		Tully formation	West Brook member	Tully formation	West Brook member
			Apulia and Laurens* members		Laurens* member
			New Lisbon* member		New Liston* member
MIDDLE DEVONIAN	HAMILTON	Moscow formation	Windom* member	Moscow formation	Windom* member
			Portland Point member		Portland Point member
		Panther Mountain formation		Panther Mountain formation	
		Marcellus formation	Pecksport member	Marcellus formation	Pecksport member
			Solsville member		Solsville member
			Bridgewater member		Otsego member
			Chittenango* member		Chittenango* member
			Cherry Valley* member		Cherry Valley* member
			Union Springs* member		Union Springs* member
	ONONDAGA	Onondaga formation	Seneca member	Onondaga forma-	Seneca member
			Babcock Hill* member		Babcock Hill* member
			Springfield Center* member		Springfield Center* member
				Schoharie formation	
LOWER DEVONIAN	ORISKANY	Carlisle Center formation*		Carlisle Center formation*	
				Esopus formation	
		Oriskany Sandstone		Oriskany Sandstone	
	HELDERBERG			Alsen Limestone	
				Becraft Limestone	
		New Scotland formation		New Scotland formation	Normal facies
			Kalkberg facies?		Kalkberg facies
		Coeymans Limestone*		Coeymans Limestone*	
UPPER SILURIAN	CAYUGA	Manlius formation	Jamesville* member	Manlius formation	
			Clark Reservation member		
			Elmwood member		
			Olney* (coarse member facies)		
			Olney* (dense member facies)		Olney* member (dense facies)
		Rondout formation		Rondout formation	
		Cobleskill formation		Cobleskill formation	
		Salina formation	Bertie member	Salina formation	Bertie member
			Camillus member		Camillus member
			Syracuse Salt member		
			Vernon member		
MIDDLE SILURIAN	CLINTON	"upper Clinton"	Herkimer formation (Rochester)		
			Williamson formation		
			Otsquago formation		
		Oneida formation			

* Descriptions based on semi-detailed field studies.

continual argument as to the upper and lower boundaries. The limits used in this paper, based on the recent detailed studies of Gillette [1947] are essentially those of Vanuxem [1842].

In the following descriptions, only the basal Oneida conglomerate is treated as a separate formation. The rest of the lower Clinton is missing. The other units are grouped together and described as the "upper Clinton beds".

ONEIDA FORMATION Vanuxem 1840

This name was given by Vanuxem [1840] to the conglomerate beds of Oneida County. The type locality is near Verona, Oneida County, New York.

Description

Areal Extent: Outcrops in this area under study are restricted to a narrow, irregular band trending southeast from Ilion Gulf to one and one-half miles north of Vanhornsville. The fairly abundant exposures of this rock form many small waterfalls and ledges.

Lithology: The formation consists of thick-bedded, coarse, white, quartzitic sandstone with interbedded lenses and beds of pebble conglomerate.

Thickness: The thickness varies from 8 to 10 feet.

Contacts: The basal contact with the Upper Ordovician shales (Frankfort formation) is a clear-cut, lithological break. The upper and lateral contacts show a sharp lithologic change between the sandy shale at the "upper Clinton beds" and the conglomeratic sandstone of the Oneida.

Paleontology: No fossils were observed.

Age: The age, based on stratigraphic position in west central New York is early middle Silurian.

Remarks

This formation marks the beginning of the Middle Paleozoic in this area. It represents coarse detritus, derived from the Adirondack land mass to the north, deposited in the slowly transgressing meso-Paleozoic sea.

These beds represent local sedimentation and cannot be correlated definitely with strata to the south or west in New York.

"UPPER CLINTON BEDS"

As the writer was chiefly concerned with the Lower and Middle Devonian, he did not attempt to separate the various formations of the upper Clinton which are described below. They include, in descending order, the Herkimer sandstone, Williamson shale, and the Otsquago formation. For more detailed information on the Clinton beds in this area, the reader is referred to Sanford [1936], who described a section of Clinton strata at Vanhornsville.

Description

Areal Extent: The upper Clinton beds are found in a sinuous band trending southeast from Ilion Gulf to Vanhornsville. Exposures are abundant in the deep gullies.

Lithology: The beds consist of a great variety of lithologic types: green and red shales; prominently cross-bedded sandstones; brown, shaly sandstones with interbeds of grey, fine-grained sandstones and shales.

Thickness: The writer did not examine any complete sections. Sanford [1936] gives 95 feet as the thickness at Vanhornsville.

Contacts: The basal and lateral contacts with the Oneida are sharp lithologic changes (sandy shale overlying conglomeratic sandstone). The upper contact with the Camillus member of the Salina formation is a gradational lithologic change (sandstone to shale). The upper contact with the Vernon red beds was not seen by the writer.

Paleontology: No fossils were collected by the writer, although Sanford [1936] mentions two forms, *Mastigobolbina typus*, *Bonnemaia oblonga* from this area.

Age: The age, middle Silurian, is based upon stratigraphic position and faunal evidence.

Remarks

These beds are near-shore or perhaps even strand deposits overlying and changing laterally into the coarse conglomerate of the Oneida that represents the first deposit of an advancing sea.

They can be correlated lithologically with the Clinton beds of eastern Pennsylvania. They extend westward to the Detroit River in Michigan.

CAYUGA GROUP Clark and Schuchert 1899

The upper Silurian strata, the Manlius, Rondout (later divided into Rondout and Cobleskill), and Salina formations, in descending sequence form the Cayuga group of Clarke and Schuchert in 1899. The type exposures are at the north end of Cayuga Lake.

Since the question of whether the Manlius belongs to the Cayuga or Helderberg group has not yet been definitely decided, the writer is following the general consensus of opinion and placing the Manlius formation in the Cayuga group.

SALINA FORMATION (Dana 1863)

Dana [1863] in originally describing this formation included all strata between the base of the Guelph limestone and the base of the Rondout. Later the Guelph was transferred to the Niagara group [Wilmarth 1938]. The Salina formation has been subdivided into five members in ascending order: Pittsford, Vernon, Syracuse salt, Camillus, and Bertie [Clarke 1903]. All the members but the Pittsford shale occur in this area. The Syracuse salt, because of its great solubility, fails to crop out. The type locality for the Salina formation is at Syracuse.

Descriptions

Vernon member Clarke 1903

Clarke [1903] gave this name to the red and green beds of the Salina formation. The type locality is in the town of Vernon.

Areal Extent: Exposures of this member are limited in the area under study to Ilion Gulf and adjacent Steels Creek where they are abundant along the sides of these valleys.

Lithology: The Vernon member consists of fissile, red shales with interbeds and lenses of green shales, and green and red, fine-grained sandstones. Many of the sandstone beds show cross-bedding. The contacts between the red and green shales are often gradational.

Thickness: In this area the Vernon is 192 feet thick.

Contacts: Both the lower contact with the "upper Clinton beds" and the upper contact with the Syracuse salt beds are concealed in this area. It is assumed that the lower contact is lithologically gradational. The upper is placed under the first appearance of salt beds.

Paleontology: No fossils were observed.

Age: The age is early, late Silurian based on the stratigraphic position.

Syracuse salt member Clarke 1903

Clarke [1903] used this name to indicate the horizon of the salt beds as determined by wells and shafts which penetrate the rock salt at Syracuse. This description is based on Clarke [1903].

Areal Extent: This member has an unknown areal extent since, because of its solubility, it does not crop out.

Lithology: The member consists of alternating thick beds of rock salt and red to brown shale.

Thickness: The writer estimates its thickness at about 40 feet for this area.

Contacts: The contacts were not seen.

Paleontology: The member is nonfossiliferous.

Age: The age based on stratigraphic position is late Silurian.

Camillus member Clarke 1903

This name, Camillus, was given by Clarke [1903] to the strata lying between the Syracuse salt beds and the Bertie waterlime. The exposures near Camillus, New York, have been designated as the type locality.

Areal Extent: Outcrops of this member are limited to a narrow irregular band trending southeast from Ilion Gulf to the vicinity of Salt Springsville. Exposures are not abundant in this area, and are restricted to stream gorges.

Lithology: Grey to brown shales make up the bulk of the member, but they contain interbeds of grey, fine-grained, in part platy, sandstone and thin-bedded, limy sandstone. Locally, in the upper part of the formation, the shales may be green or reddish.

Thickness: Where exposed the member varies in thickness from 80 to 226 feet. All sections are incomplete.

Contacts: The basal contact with the Syracuse salt beds is covered (in wells to the west, the contact is placed above the first salt bed), and that with the "upper Clinton beds" is gradational (sandstone to shale). The upper contact with the Bertie formation is a sharp lithologic change illustrated in Figure 3.

Paleontology: The member is unfossiliferous.

Age: The age based on stratigraphic position is late Silurian.

Bertie member (Chapman 1864)

Although Chapman [1864] in a non-technical publication suggested the name Bertie for these beds, the member was officially defined and named by Schuchert [1903]. He included the beds lying between the Salina proper (Camillus) and the Cobleskill. The type locality is at Bertie, Ontario, 6 miles west of Buffalo, New York.

Areal Extent: The outcrop area of this member is a narrow sinuous band trending southeast from the vicinity of Jerusalem to near Salt Springsville. Exposures are rare.

Lithology: The member consists of medium-bedded, shaly, in part sandy, dolomitic limestone.

Thickness: In this area, the estimated thickness varies from 6 to 10 feet.

Contacts: The lower contact with the Camillus member and the upper with the Cobleskill formation are shown in Figure 3. They both show a sharp lithologic change.

Paleontology: No fossils were observed by the writer; however, Goldring [1931] lists the following diagnostic eurypterids: *Eurypteris lacustris*, *E. remipes*, *Eusarcus scorpionis*, *Pterygotus buffaloensis* and *Dolichopterus macrochirus*.

Age: The age is late Silurian based on stratigraphic position and faunal content.

Remarks

The members of the Salina formation in this area, except the Bertie, are unfossiliferous, and differ markedly in lithology--the red clastics of the Vernon, the sands and shales of the Camillus, and the "waterlime" of the Bertie.

The Vernon and Camillus members indicate saline lagoons and neighboring deltas in an arid climate.

Grabau [1924] thought the Vernon red shales might be loessal in origin. Ruedemann [1925] suggested that the Bertie waterlime was deposited in a lagoon behind east-west trending coral reefs lying south of this area.

The Salina formation extends to the western part of the State and is correlated with the Salina shales of Michigan. Southward it is the correlative of the Wills Creek-Bloomsburg-McKenzie strata of Pennsylvania. It may be correlated with the Sneedville limestone of Tennessee.

COBLESKILL FORMATION Hartnagel 1903

This name was given by Hartnagel in 1903 for the limestone underlying the Rondout waterlime in Schoharie Valley. Two years later, Clarke and Luther [1905] described it from the Tully quadrangle as lying between the Bertie and Rondout waterlimes. The type locality is on Cobleskill Creek near Howe's Cave, New York.

Description

Areal Extent: The Cobleskill crops out in a narrow, sinuous band trending southeast from near Salt Springsville to Schoharie Valley near Howe's Cave. Outcrops are rare in this area.

Lithology: The formation consists of thick-bedded, fine-grained, sandy limestone. (See Figure 3)

Thickness: The Cobleskill formation is 6 feet thick in this area.

Contacts: The lower contact with the Bertie member and the upper contact with the Rondout formation are drawn on lithologic bases. The Cobleskill is thick-bedded and fossiliferous, whereas the overlying and underlying formations are medium-bedded and essentially non-fossiliferous.

Paleontology: The writer identified the following forms from a small collection made at Salt Springsville:

Favosites helderbergiae Hall
Stromatopora sp.
Atrypa reticularis (Linnaeus)
Stropheodonta bipartita Hall
Leptostrophia sp.

Age: The age is late Silurian based on stratigraphic position and faunal evidence.

Remarks

The Cobleskill formation is a return to the fossiliferous character that marked the formations of the Middle Ordovician. This formation is a shallow water, near-shore limestone deposit of a sea which was receiving a small amount of detritus from the lands to the north.

Correlations can be made with the Akron dolomite of western New York and Ohio and with the lower part of the

Decker sandstone formation of northern New Jersey, and the Keyser of Pennsylvania, Maryland, West Virginia, and Virginia.

RONDOUT FORMATION (Clarke and Schuchert 1899)

This name was given by Clarke and Schuchert in 1899 to the beds underlying the Manlius and overlying the Salina formation. Later, Schuchert [1903] redefined the formation to exclude the lower part, the Cobleskill. The type locality is at Rondout, New York.

Description

Areal Extent: Exposures of the Rondout are confined to a narrow, sinuous band trending southeast from Litchfield township to Schoharie in the Schoharie Valley. In this band, outcrops are sparse, usually appearing in stream valleys.

Lithology: The formation consists of a buff, medium- to thin-bedded, sandy and shaly limestone with interbedded, buff, limy shales. The upper beds in Schoharie Valley show mud cracks [Grabau 1906].

Thickness: The Rondout varies in thickness from 33 to 60 feet.

Contacts: The basal contact with the Cobleskill is a paleontologic and lithologic change marked by a shift from massive, fossiliferous, sandy limestones to thin- and medium-bedded, non-fossiliferous, sandy limestone. The upper contact with the Manlius is also based upon paleontology and lithology and is placed beneath the first appearance of a massive, dense, *Tentaculites* limestone.

Paleontology: The formation is unfossiliferous.

Age: The late Silurian age is based upon stratigraphic position.

Remarks

The Rondout formation was deposited in a shallow, epicontinental sea, the eastern part of which was occupied by large tidal flats in late Rondout time. The formation extends westward as far as Seneca County. To the south it can be correlated with the Keyser formation of Eastern Pennsylvania, Maryland, West Virginia, and Virginia.

MANLIUS FORMATION (Vanuxem 1839)

In 1839, Vanuxem described the waterlime group of the Manlius as overlying the "saliferous group of Onondaga" (= Salina formation) and underlying the Oriskany sandstone. In 1840, he redefined it, leaving out the "Upper Helderberg formations", but it was not until 1899, that the Manlius received its present day definition by Clarke and Schuchert. Since the early 1900's there have been attempts to use Manlius as a group term, but they have not met with universal favor.

Smith in 1929 divided the Manlius at its type locality into six formations, given here in descending order; Bishops Brook, Pools Brook, Jamesville, Clark Reservation, Elmwood, and Olney. In this paper the writer considers these divisions as members rather than formations. Only the lower four members are present in this area.

Descriptions

Olney member Smith 1929

This name was given by Smith [1929] to the basal portion of the Manlius. The type section is in a quarry one and three-quarters miles east of Olney Station on the Auburn and Syracuse Electric R. R. In the eastern part of the area under study, this member makes up the entire thickness of the formation.

Areal Extent: Outcrops are confined to a narrow, irregular band extending from Days Corners southeastward to the vicinity of Schoharie. This member of the Manlius is the principal cliff-maker of this area where it is responsible for the extension of a lesser Helderberg escarpment from the east to the vicinity of Vanhornsville. Along this escarpment outcrops are abundant, and they are also numerous west of Vanhornsville.

Lithology: This member consists of two lithofacies in this area, which are described as follows: The principal lithofacies is a massively-bedded, dark grey, dense limestone (calcilutite), but does contain locally, in its upper part, stromatoporoid biostromes. The other lithofacies limited to the upper part of the Olney, directly under the Elmwood member, is found only in the western part of the area. It consists of thin, irregular beds of grey, medium- and coarse-grained, shelly and crinoidal, semi-crystalline limestone with occasional thin interbeds of dense limestone. At Days Corners, a two inch interbed of dark grey, impure chert was found.

Thickness: In this area, the member varies in thickness from 44-1/2 to 75 feet.

Contacts: The basal contact with the Rondout is sharp, marked by a lithologic change from sandy limestone to a dense limestone and the first appearance of the *Tentaculites* fauna. The upper contact of the Olney with the Elmwood member in the west is a fairly sharp lithologic change (coarse limestone to sandy limestone). However, in the east the contact with the overlying Coeymans formation at many localities is gradational with a mixing of both the lithology and faunas in zones varying from 3 to 15 feet in thickness. Elsewhere in the east, the contact is fairly sharp (dense limestone to coarse limestone).

Paleontology: The two lithofacies have marked differences in faunal content. The dense limestone contains a typical Manlius fauna:

> Stromatopora (Syringostoma) barretti Girty
> Howellella vanuxemi (Hall)
> Tentaculites cf. T. gyracanthus (Eaton)
> Leperdita alta (Conrad)

However, the coarse limestone lithofacies is characterized by a fauna with a distinct Helderbergian affinity[3] as follows:

> Crinoid columnalls
> Atrypa rectularis (Linnaeus)
> Meristella sp.
> Gipidula cf. G. coeymanensis (Schuchert)
> Howellella vanuxemi (Hall)
> Strophonella punctilifera (Conrad)
> McLearnites sp.
> Actinopteria sp.
> Phacops sp.
> Dalmanites cf. D. litchfieldensis Delo

Age: The age based on stratigraphic position is late Silurian. Paleontologically, it appears to be an intermingling of late Silurian and early Devonian forms.

Elmwood member Smith 1929

The Elmwood member was defined by Smith [1929] as the waterlime beds underlying the Clark Reservation and

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[3]This is not the first time Helderbergian fossils have been found in the Manlius. Ruedemann [1930] reports the occurrence of Stropheodonta varistriata and Camerotechia semiplicata, typical Coeymans forms in the Manlius of the Albany area.

overlying the Olney member. Sweet quarry in the Elmwood district, northeast of Onondaga Hill (Syracuse quadrangle) was designated as the type locality. In the western part of this area the Elmwood lies between the Olney and Clark Reservation, but is absent to the east.

Areal Extent: Exposures of this member are restricted to a narrow, sinuous band trending southeast from Days Corners to Willse Four Corners, 2.2 miles northwest of Salt Springsville. Outcrops in this belt are rare, being found only in quarries.

Lithology: The Elmwood consists of thick-bedded, buff, fine-grained, sandy limestone, locally cross-bedded. It contains several thin limestone beds and, at the Jordanville quarry, the upper part of the member is massive, dense limestone similar to the Olney.

Thickness: The member varies in thickness from 20 inches to 12 feet.

Contacts: The lower contact, with the Olney member, is a lithologic change between the buff sandy limestone of the Elmwood and the dark grey limestones of the underlying member. The upper contact with the Clark Reservation member is generally a sharp lithologic change (sandy limestone to dense limestone), but in the Jordanville quarry the contact is based on the appearance of the characteristic, diagonal fracturing of the Clark Reservation member.

Paleontology: This member is nearly barren but the writer did notice, at one locality, trilobite fragments and a few specimens of Howellella vanuxemi (Hall).

Age: The age, based on stratigraphic position and paleontologic evidence, is late Silurian.

Clark Reservation member Smith 1929

Smith [1929] gave this name to the thin bed of jointed limestone lying above the Elmwood member and designated as a type section, a cliff in Clark Reservation State Park, one mile west of Jamesville, New York.

Areal Extent: Outcrops of this member are confined to a very narrow, sinuous band trending southeast from Days Corners to Willse Four Corners, 2.2 miles northwest of Salt Springsville. Like the rest of the upper members of the Manlius, its few exposures are restricted to quarries in this region.

Lithology: This member consists of a massive bed of dark grey, dense limestone (calcilutite) which tends to break along diagonal fractures forming roughly tetrahedral blocks.

Thickness: The member ranges in thickness from 2 to 6 feet.

Contacts: The Clark Reservation member is distinguished from the underlying Elmwood member and the

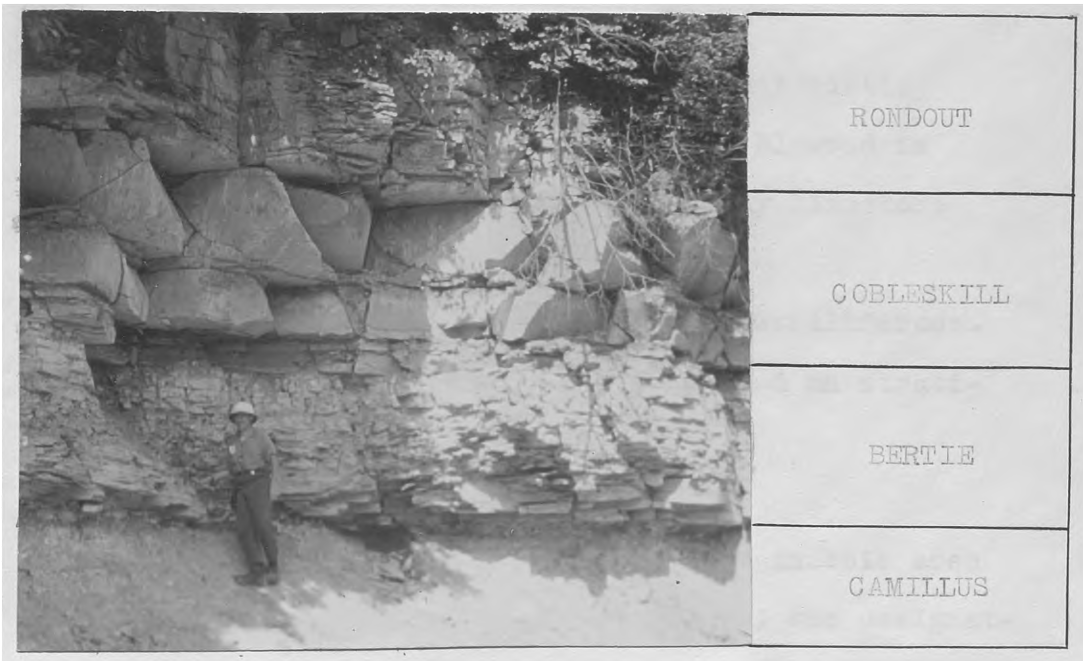

Figure 2. Road-cut, 1 mile southwest of Salt Springsville illustrating the lower Cayuga and upper Salina sequence of the area.

Figure 3. Outcrop of the stromatoporoid biostrome of the Jamesville member of the Manlius. Days Corners quarry, Herkimer County.

overlying Jamesville member by its characteristic fracturing. The lower contact with the Elmwood is also, in part, a lithologic change (sandy limestone to dense limestone).

Paleontology: This member is non-fossiliferous.

Age: The age is late Silurian based on stratigraphic position.

Jamesville member Smith 1929

The uppermost member of the Manlius in this area was named the Jamesville by Smith [1929], who designated Clark Reservation State Park, 1 mile west of Jamesville, as the type locality.

Areal Extent: The few exposures of this member are limited to quarries in a narrow, sinuous band extending from Days Corners southeastward to Willse Four Corners, 2.2 miles northwest of Salt Springsville.

Lithology: In this area, the Jamesville is composed principally of stromatoporoid biostromes (see Figure 3) and dark grey, dense limestone (calcilutite). At some localities the biostromes comprise the entire thickness.

Thickness: Where exposed, the member varies in thickness from 10 to 30 feet.

Contacts: At its lower contact, the Jamesville is set off from the Clark Reservation member by the latter's characteristic fracturing. The upper contact with the Coeymans formation is a sharp to gradational lithologic change (dense to coarse limestone). Paleontologically the biostromes give place to the Gipidula fauna.

Paleontology: This member is characterized by the abundance of stromatoporoid biostromes. Following is a faunal list for the member:

Stromatopora (Syringostoma) barretti Girty
Favosites helderbergaie Hall
Howellella vanuxemi (Hall)
Leperditia cf. L. alta (Conrad)

Age: The age is late Silurian based on stratigraphic position and faunal evidence.

Remarks

The faunas and lithology of the fossiliferous members of the Manlius, with the exception of the coarse facies of the Olney, are identical and have long been used as a criterion for the recognition of the Manlius or, as it was formerly called, the "Tentaculites limestone". The occurrence of the coarse limestone lithofacies of the Olney member with its different lithology and alien fauna has created a stratigraphic problem. A discussion of the significance of this problem will have to await additional, detailed field studies. The semi-clastic Elmwood member indicates an increase in the amount of detritus entering the area from nearby

Adirondack landmass.

The Manlius sediments were near-shore deposits of a shallow, epicontinental sea. The Adirondack landmass was low and contributed little sediment to this sea. Ruedemann [1930] suggested that the Manlius strata were principally lagoonal deposits or tidal flats, formed between and behind reefs.

To the south, the Manlius has been correlated with the upper part of the Keyser limestone of Pennsylvania, Maryland, and West Virginia. Westward it lenses out before reaching the Niagara Falls area.

LOWER DEVONIAN

HELDERBERG GROUP (Conrad 1839)

Conrad in 1839 included the Esopus sandstone, Helderberg sandstone, and the New Scotland formation in his Helderberg limestone. The Helderberg group of Mather [1840] and Hall [1842] extended from the base of the Marcellus down to the top of the Salina group. In 1851, Hall divided this group to include the "Upper Helderberg", or present-day Onondaga limestone, and the "Lower Helderberg", which extended from the base of the Oriskany to the base of the Manlius. In 1899, Clarke and Schuchert redefined the Helderberg group to include beds between the base of the Oriskany and top of the Manlius. These beds were Kingston (= Port Ewan and Alsen), Becraft, New Scotland, and Coeymans in descending sequence. Some believe that the Manlius should be in the Helderberg, but the writer is following the usage of the U. S. Geological Survey and the New York State Science Service in excluding it from this group.

COEYMANS FORMATION (Clarke and Schuchert 1899)

Clarke and Schuchert in 1899 gave this name to the strata lying between the New Scotland and Manlius formations, the "Lower Pentamerous beds" of earlier reports. In 1908, Chadwick redefined the formation and transferred the upper chert-bearing beds to the Kalkberg facies of the New Scotland formation. The type location is at Coeymans, Albany County.

Description

Areal Extent: The Coeymans and Manlius (Olney) are consistent cliff-makers and good exposures can be found along the low extension of the Helderberg escarpment from Schoharie Valley to the vicinity of Vanhornsville. West of Vanhornsville, numerous outcrops are scattered throughout a sinuous band of irregular width extending northwestward to Days Corners.

Lithology: This formation consists of a thick-bedded, semi-crystalline, coquinal limestone. Parts of the formation may be calcarenaceous. In a few localities it is slightly shaly. There is an irregular (corregated) sub-bedding, brought out by weathering.

Thickness: In this area, the Coeymans ranges from 6 feet to 110 feet in thickness.

Contacts: Both the lower contact, with the Olney or Jamesville members of the Manlius, and the upper contact with the Kalkberg facies of the New Scotland formation are gradational lithologically and paleontologically. Lithologically, the Coeymans is distinguished by its coarse texture and absence of chert and paleontologically by the presence in abundance of Gipidula coeymanensis[4] and the absence of stromatoporoid biostromes.

Paleontology: The diagnostic fossil of this formation is Gipidula coeymanensis. Following is a faunal list:

Favosites helderbergiae Hall
Uncinulus nucleolatus Hall
U. mutabilis (Hall)
Strophonella punctulifera (Conrad)
Brachyprion varistriata (Conrad)

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[4]A Gipidula very similar to G. coeymanensis appears in the coarse grained facies of the Olney member of the Manlius in the western part of this area, but the presence of the overlying upper Manlius with Howellella vanuxemi and Stromatopora barreti distinguish this coarse grained facies from the true Coeymans.

<u>Atrypa</u> <u>reticularis</u> (Linnaeus)
<u>Rhychonella</u> sp.
<u>Rhipidomella</u> sp.
<u>Gipidula</u> <u>coeymanensis</u> (Schuchert)
<u>Dalmanites</u> sp.

<u>Age</u>: The age, based on stratigraphic position and faunal evidence, is early Devonian.

Remarks

The fauna of the Coeymans is similar to that of the overlying New Scotland formation, but with fewer species.

The abundant, fragmentary remains indicate that the shells, crinoids, etc., were broken by wave action. This suggests that the Coeymans limestone in this area was a shallow water deposit.

The formation extends westward to Manlius, New York, and as far south as Gala, Virginia. The Olive Hill formation of Western Tennessee is a correlative of the Coeymans.

NEW SCOTLAND FORMATION (Clarke and Schuchert 1899)

The New Scotland strata, the "Delthyris shaly limestone" of early geologists, are well exposed in New Scotland township, Albany County, and were named by Clarke and Schuchert in 1899. In 1908, Chadwick redefined the New Scotland, placing its basal chert-bearing beds and the upper strata of the Coeymans in the

Kalkberg formation. Goldring[5] considers the Kalkberg to be a facies of the New Scotland, and the writer has used it as such in a previous publication [Stevenson 1949]. In this report, for the purposes of description, the New Scotland formation will be divided into two facies, the lower or Kalkberg and the upper "normal facies".

Description

Kalkberg facies Chadwick 1908

The name Kalkberg was given to the chert-bearing beds of the lower New Scotland formation and upper Coeymans limestone by Chadwick in 1908, who designated Catskill Creek in Greene County as the type area. Although many authors consider the Kalkberg a separate formation, the writer holds it to be a facies of the New Scotland.

Areal Extent: Exposures of the Kalkberg in this area are confined to a narrow, irregular, sinuous band trending southeast from the vicinity of Columbia Center to the neighborhood of Schoharie in the Schoharie Valley. Outcrops are fairly abundant because of the erosional resistance of the chert.

Lithology: This facies consists of thin-bedded,

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[5]Personal communication 1948.

grey, medium- to fine-grained, siliceous and partly shaly limestone with nodular interbeds of dark chert, three to seven inches thick. An exposure of the upper part of the facies is shown in Figure 4.

Thickness: The thickness ranges from 17 feet to 60 feet in this area.

Contacts: The lower contact with the Coeymans and the upper with the chert-free New Scotland are principally gradational. The absence of *Gipidula coeymanensis* sets it off from the Coeymans limestone. When the Kalkberg is overlain by the Esopus or Carlisle Center formations in the absence of the "normal facies", the contact is drawn at the first appearance of *Taonurus*-bearing clastic sediments.

Paleontology: The limestone of this facies is very fossiliferous. Following is a list of the common forms as identified by the writer:

Streptolasma strictum Hall
Favosites helderbergiae Hall
Fenestella sp.
Leptaena rhombodalis (Wilckens)
Uncinulus nucleolatus Hall
Dalmanella pereglans Hall
"*Spirifer*" *cyclopteris* Hall
Atrypa reticularis (Linnaeus)
Brachyprion cf. *B. varistriata* (Conrad)
Rhipidomella oblata Hall

Age: Based on stratigraphic position and faunal evidence, the age is early Devonian.

"Normal facies"

The "normal facies" is the chert-free or restricted New Scotland of Chadwick [1908].

Areal Extent: The chert-free New Scotland is exposed in several sections in a band trending southeast from 2 miles north of Springfield Center to West Hill in Schoharie Valley, but is missing in other sections in this area. Outcrops are generally restricted to road cuts and quarries.

Lithology: This facies is a thin-bedded, grey, shaly limestone with a few rare interbeds of coarser limestone.

Thickness: In this area it varies from 8 to 50 feet in thickness.

Contacts: Its basal contact with the cherty Kalkberg facies is gradational and based on lithology. The upper contact is disconformable, and this facies is overlain by Becraft, Esopus[6], and Carlisle Center[6] in succession westward. The contacts are sharp and based primarily upon lithology.

Paleontology: These are the strata in which the most typical Helderberg fauna occurs. Following is a

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[6] A thin bed of Oriskany sandstone may be present between the Esopus or Carlisle Center and the New Scotland "normal facies", but it does not appear in outcrop.

list of the more common species in this area:

Favosites helderbergiae Hall
Atrypa reticularis (Linnaeus)
Delthyris perlamellosus (Hall)
Leptaena rhomboidalis (Wilckens)
Eospirifer macropleura (Conrad)
Uncinulus nucleolatus Hall
Meristella laevis (Vanuxem)
Rhipidomella oblata Hall
Nucleospira ventricosa Hall
Actinopteria textilis Hall

Age: The age, early Devonian, is based on stratigraphic position and faunal evidence.

Remarks

The New Scotland fauna is much more varied than those of the overlying Becraft limestone and the underlying Coeymans. The principal difference between the two facies of the New Scotland formation is lithologic. This difference between the two facies is the presence of chert and siliceous limestone in the Kalkberg facies. The interbedded appearance of the chert in the Kalkberg facies tends to indicate that it is syngenetic in origin. It was probably formed by the precipitation of the silica carried in solution to the sea by streams. The writer believes that the silica was precipitated as a gel during the mingling of the salt water and the silica-rich fresh water (see Twenhofel, 1939). Later hardening and dehydration formed the chert. The New Scotland sediments are the result of near-shore limestone deposition in the quiet waters of the early Devonian sea.

The New Scotland, though not extending west of Columbia Center, Herkimer County, New York, extends southward through New Jersey, Pennsylvania, Maryland, West Virginia, and Virginia into eastern Tennessee. It has been correlated with the Bailey limestone of Illinois and Missouri, the Birdsong shale and Flat Gap limestone of west Tennessee, and the New Scotland formation in northeast Mississippi.

BECRAFT LIMESTONE Darton 1894

ALSEN FORMATION Grabau 1919

These two formations are discussed together because of their faunal similarity and close association. Also, there is only a small area in which they crop out in this region.

The Becraft limestone, formerly called the "Upper Pentamerous limestone", was redefined and named by Darton in 1894 from exposures on Becraft Mountain. The cherty limestones overlying the Becraft in the hills above Alsen, New York, were called the Alsen formation by Grabau [1919].

Description

Areal Extent: In this area, these two formations are restricted to the Schoharie Valley in the vicinity of Schoharie where outcrops are scarce.

Lithology: The Becraft is a thick-bedded, coarse, coquinal limestone. The Alsen is a dark grey shaly limestone with cherty interbeds.

Thickness: In the Schoharie Valley, the Becraft has a thickness of 21 feet, and the Alsen 9 feet 3 inches [Grabau 1906].

Contacts: The contact between these two formations is gradational. The contact of the Becraft with the underlying New Scotland is a gradational lithologic change. There is also a great decrease in the number of species present [Goldring 1935]. The upper contact of the Alsen with the Oriskany was not seen by the writer.

Paleontology: Fossils were not collected by the writer from either of these formations, but the Becraft is characterized by Aspidocrinus scutelliformis (crinoid root bases) and Gipidula (Sieberella) pseudogaleata [Goldring 1935]. The Alsen fauna is a modified Becraft fauna.

Age: The age is early Devonian based on stratigraphic position and paleontologic evidence.

Remarks

The environment during the deposition of the Becraft and Alsen sediments was similar to that of Coeymans-Kalkberg time resulting in near-shore limestone deposition with an introduction of clastics and an increase in the amount of dissolved silica in streams entering the shallow continental sea (see discussion of chert under the New Scotland formation).

The Becraft and Alsen formations extend no further west than Schoharie, but the Becraft extends south into New Jersey and eastern Pennsylvania. These two formations can be correlated with the Mandata shale of Pennsylvania and with the Licking Creek limestone of Maryland and Virginia. The Decaturville chert of west Tennessee has also been correlated with the Becraft [Cooper 1942].

ORISKANY GROUP Merrill 1898

In 1898, Merrill defined the Oriskany group as including the "Cauda-galli grit" (= Esopus in the old sense, including Carlisle Center) and the Oriskany sandstone. Later authors modified this to include the Port Ewan formation at the base which is the present interpretation of the U. S. Geological Survey [Wilmarth 1938]. However, the writer is following the original interpretation of Merrill, which is the present inter-

Figure 4. Road-cut in the Kalkberg facies of the New Scotland formation. U.S. Highway 20, 0.3 mile west of Sharon Springs.

Figure 5. An outcrop of the Oriskany formation illustrating the dual lithology, coarse sandstone above, chert and siliceous limestone below. 2 miles southeast of Columbia Center, Herkimer County.

pretation of the New York State Science Service [Goldring 1931].

ORISKANY FORMATION Vanuxem 1839

The white sandstone exposed at Oriskany Falls was named the Oriskany by Vanuxem in 1839. In the State of New York the formation is thin, but it thickens southward.

Description

Areal Extent: Exposures of this formation are extremely scarce because of its thinness. The writer examined outcrops on West Hill in Schoharie Valley and near Columbia Center, Herkimer County, but found none in the intervening 36 miles. For this distance, the Oriskany may be missing.

Lithology: This formation, on the basis of lithology, can be divided into upper and lower portions. The lower part consists of a dark grey, dense siliceous or sandy limestone with thin chert interbeds at some localities, and the upper is a light-colored, hard, quartzitic sandstone, in part pebbly (see Figure 5).

Thickness: The formation varies in thickness from 16 inches in the west to 6 feet 3 inches in the east.

Contacts: The lower contact with the Becraft limestone in the Schoharie Valley and the New Scotland formation elsewhere is a sharp lithologic change (New

Scotland shaly or Becraft coarse limestone to the Oriskany siliceous or sandy limestone). This lower contact is also a paleontologic change where the Helderbergian fauna of the underlying beds is replaced by the Oriskany fauna. The upper contact with the Esopus or Carlisle Center formations is a sharp lithologic (sandstone-shale) and paleontologic (Oriskany fauna to "Taonurus" fauna) change.

Paleontology: No fossils were collected from the Schoharie Valley exposures, but the following forms were noted in the outcrop near Columbia Center:

Acrospirifer murchisoni (Castelnau)
Hipparionyx proximus Vanuxem

The Oriskany has a characteristic fauna dominated by thick-shelled forms in central New York [Grabau 1906].

Age: The age is early Devonian based on stratigraphic position and paleontologic evidence.

Remarks

The Oriskany sandstones and limy sandstones with their thick-shelled fauna represent near-shore deposition above wave base in an advancing epicontinental sea. The sea at this time was receiving clastics from the northern land mass.

This formation extends westward into Canada and is the equivalent of the Glenerie limestone of southeastern New York. The Oriskany extends southward through Pennsylvania, Maryland, and West Virginia into Virginia as the Ridgeley sandstone and Shriver chert. It can also be correlated with the Backbone limestone of Illinois, the Little Salina limestone of Missouri and the Harriman chert of western Tennessee.

ESOPUS SHALE (Darton 1894)

Darton in 1894, following the suggestion of James Hall, named the "Cauda-galli grit" of previous reports the Esopus shale. The name was taken from the good exposures on Esopus Creek and near Esopus, New York. In 1942, Goldring and Flower redefined the formation in central New York, to include only the lower shales, at the same time calling the upper sandy shales the Carlisle Center formation.

Description

Areal Extent: The formation occasionally crops out in a narrow band trending southeast from one mile north of Cherry Valley to Schoharie in the Schoharie Valley.

Lithology: In this area, the Esopus consists of grey, fissile to semi-fissile, slightly sandy shale. Near the base, it is locally limy and cherty.

Thickness: The formation varies in thickness from 15 to 90 feet.

Contacts: The lower contact with the Oriskany formation is a sharp lithologic (shale to sandstone) and paleontologic (disappearance of Oriskany fauna) change. The upper contact with the Carlisle Center is fairly definite, usually marked by a basal glauconitic bed in the overlying Carlisle Center formation.

Paleontology: The writer found no fossils in the Esopus shales, however Esopus fossils have been reported from Ulster County by Howell [1942].

Age: The age is middle Devonian based on stratigraphic position.

Remarks

The Esopus sedimentation resulted from near-shore deposition of fine clastics derived from the Adirondack landmass to the north.

In this paragraph on correlation, the Esopus and Carlisle Center (see below) formations will be discussed together as "Esopus". The "Esopus" extends southward into New Jersey and eastern Pennsylvania and grades westward into the Palmerton sandstone and Bowmanstown chert. It is also correlated with the Saltville chert of West Virginia, Huntersville chert of Virginia and the Clear Creek chert of Illinois [Cooper 1942].

CARLISLE CENTER FORMATION Goldring and Flower 1944

In 1942 Goldring and Flower divided the Esopus upon lithology into the Esopus (restricted) below and the Sharon Springs formation above. This latter name was found to be preoccupied and was replaced by Carlisle Center in 1944 [Goldring and Flower]. A type locality for this formation was not designated by Goldring and Flower [1942] who instead described several scattered sections in the eastern part of the area under study in this paper.

Description

Areal Extent: Outcrops of Carlisle Center can be found in a narrow band, extending southeast from the vicinity of Columbia Center to the vicinity of Schoharie in Schoharie Valley. In this area, exposures are more abundant than those of underlying New Scotland, but less so than the Onondaga limestone.

Lithology: The formation consists of a series of buff to brown sandy shales underlying a 6 inch bed of greenish glauconitic sandy shale. At some localities, the base is marked by a similar glauconitic sandy shale. At an exposure near Vanhornsville, these buff sandy shales are slightly limy.

Thickness: The formation varies in thickness from 5 to 45 feet.

Contacts: The lower contact no matter whether it is with the Esopus, Oriskany, or New Scotland formations is a sharp lithologic change, often marked by a basal glauconitic bed in the Carlisle Center. The contacts with the fossiliferous Oriskany and New Scotland formations are also recognizable as paleontologic breaks. The upper contact with the Springfield Center member is sharp, marked by the upper glauconitic bed of the Carlisle Center formation.

Paleontology: This formation is non-fossiliferous with the exception of *Taonurus cauda-galli*, which can be found on almost all bedding surfaces.

Age: The age is middle Devonian (?) based on stratigraphic position.

Remarks

The beds represent near-shore deposits in the early Devonian sea of detritus from the landmass to the north. The presence of the two glauconitic beds indicates that the temperature was above 59° F and the salinity was normal [Takahashi 1939].

A discussion of the correlatives of this formation is presented in the preceding description of the Esopus formation.

ULSTER GROUP (Clarke and Schuchert)

This group was defined in 1899 by Clarke and Schuchert as including the Onondaga limestone, Schoharie grit and Esopus grit, but in 1901, Merrill placed the Esopus in the Oriskany group leaving the Onondaga and Schoharie in the Ulster group. It is this redefinition that is generally accepted today [Goldring 1931, Wilmarth 1938]. It should be noted here, that in Pennsylvania, the formations of the Oriskany and Ulster (Onondaga) groups differ from those in New York [Willard 1939]. This difference is shown in Table 2.

TABLE 2. COMPARISON OF LOWER MIDDLE DEVONIAN TERMINOLOGY IN NEW YORK AND PENNSYLVANIA

<table>
<tr><th colspan="2">Eastern Pennsylvania</th><th colspan="2">Central New York</th></tr>
<tr><td rowspan="4">ONONDAGA</td><td>Buttermilk Falls limestone</td><td>Onondaga limestone Schoharie formation</td><td>ULSTER</td></tr>
<tr><td>Esopus shale</td><td>Carlisle Center formation</td><td rowspan="4">ORISKANY</td></tr>
<tr><td>Palmerton sandstone</td><td rowspan="2">Esopus shale</td></tr>
<tr><td>Bowmanstown chert</td></tr>
<tr><td>ORISKANY</td><td>Ridgeley sandstone</td><td>Oriskany sandstone</td></tr>
</table>

SCHOHARIE FORMATION Vanuxem 1840

Vanuxem [1840] gave this name to the fossiliferous, siliceous beds lying between the Onondaga limestone and the "Cauda-galli" grit (= Esopus shale) in the Schoharie Valley. The following description is based on the writer's examination of one outcrop in Schoharie Valley and data obtained from Goldring and Flower [1942].

Description

Areal Extent: The few exposures in this area are limited to the eastern edge of the area in the vicinity of Cobleskill and Schoharie.

Lithology: The formation varies in lithology from a massive dark grey sandy limestone to a massive dense siliceous limestone.

Thickness: The thickness of the Schoharie formation in this region is estimated at 5 to 6 feet.

Contacts: Its lower contact with the Carlisle Center formation is a sharp lithologic (sandy limestone to sandy shale) change marked by the uppermost glauconitic bed of the Carlisle Center formation. The upper contact with the Springfield Center member of the Onondaga is a gradational lithologic change (sandy limestone to limestone).

Paleontology: Although the formation is fossiliferous, no collections of fossils were made in this area by the writer. Goldring [1931] lists the following as common Schoharie forms: Zaphrentis, Streptelasma, Atrypa impressa, Pentamerella arata, Meristella nasuta, Strophonella ampla, Stropheodonta demissa, Leptostrophia perplana, Rhipidomella alsa, Delthyris raricostata, Chonetes hemisphericus, Pandenka dichotoma, Conocardium cuneus, Goniophora perangulata, Bellerophon pelops, Pleurotomaria arata, Orthoceras thoas, O. pelops, O. zeus, Cyrtoceras eugenium, Trochoceras eugenium, T. clio, Dalmanites anchiops, Phacops cristata, and Calymene platys.

Age: The age is middle Devonian based on stratigraphic position and reported paleontologic evidence.

Remarks

The Schoharie fauna (See Goldring [1935], Grabau [1906]) shows a great deal of similarity to the overlying Onondaga fauna, but is definitely a cephalopod fauna, whereas the Onondaga is dominated by corals. The Schoharie formation indicates an influx of clastics from the east at the beginning of Onondaga time. It extends southeastward to Port Jervis, but as far as the writer knows, it has not been reported in surface outcrops outside of New York.

ONONDAGA FORMATION (Hall 1839)

The Onondaga formation is the most extensive Devonian limestone in the eastern United States and is well exposed in this area. In 1839, the lower part of the formation was named the Onondaga limestone by Hall, however, Vanuxem in 1840 made a threefold lithologic division of the limestones lying between the Schoharie grit and the Marcellus shale; the Onondaga limestone of Hall, the corniferous limerock of Eaton [1824], and the Seneca limestone. In 1846, Emmons redefined Onondaga to include these three limestones, and discarded the other two formational names. However, reference has been made to the Seneca limestone from time to time [Goldring 1935, Cooper 1942]. This threefold lithology is so well shown in Herkimer and Otsego Counties, that the writer [1948] has separated the Onondaga formation of this area into three members: Springfield Center, Babcock Hill, and Seneca. This division follows Vanuxem's closely, the Springfield Center member is equivalent to Hall's Onondaga limestone and the Babcock Hill member is the corniferous limerock of Eaton. Seneca limestone, Vanuxem's name has been retained for the upper member following Cooper [1942].

Description

Springfield Center member New name

The Springfield Center member is equivalent to

Hall's [1839] original Onondaga described and named from its occurrences in Ontario County, New York. The writer is here designating, as the type locality for this member, a large quarry 0.25 miles north of the junction of U. S. Highway 20 and New York Highway 80 and 1 mile north of the village of Springfield Center from which the name is taken.

Areal Extent: The Springfield Center covers a narrow band extending southeast from Days Corners to Schoharie. The outcrops are not abundant, but the Mt. Tom biostrome which occurs in the eastern part of the area produces better exposures than the rest of the member, usually forming small cliffs.

Lithology: The Springfield Center is fine- to medium-grained, grey to dark-grey limestone, thin- to medium-bedded, in part shaly, with occasional lenses of dark grey chert. In the eastern part of the area a 5- to 7-foot thick massive bed of grey, medium-grained, coralline limestone is found five feet above the base (see Figure 7). It has been named the Mt. Tom biostrome for its excellent exposures at Mt. Tom.

Thickness: The Springfield Center varies in thickness from 5 to 37 feet. Eight localities give an average of 26 feet.

Contacts: The basal contact of the Springfield Center member with the glauconitic zone that marks the top of the Carlisle Center formation, is a well-defined lithologic change best seen at the Springfield Center quarry. The upper contact with the Babcock Hill member is gradational, drawn beneath the first appearance of the abundant chert nodules that characterize the Babcock Hill.

Paleontology: This member is very fossiliferous and has a fauna composed principally of brachiopods, tetraeorals, and dalmanitid trilobites. The fauna is rich in individuals rather than species. The Mt. Tom biostrome is dominated by corals (see Figure 7). Following is a list of identified forms:

Cystiphyllum sp.
Zaphrentis cf. Z. prolifica Billings
Favosites sp.
Atrypa reticularis (Linnaeus)
Stropheodonta sp.
Leptaena rhomboidalis (Wilckens)
Spirifer raricostatus Conrad
Odontocephalus selenurus (Eaton)
Dalmanites sp.

Age: The age is middle Devonian on the basis of paleontologic evidence and stratigraphic position.

Babcock Hill member New name

This is the corniferous limerock of Eaton [1824] who described it from occurrences along the Erie Canal in western New York. The type locality is in a pasture 1/2 mile north of the crossroads of Babcock Hill in southeastern Oneida County.

Areal Extent: This member crops out over a fairly narrow band varying in width from 500 feet to 2 or more miles across the area from Days Corners to Schoharie. The band widens irregularly to the west. Outcrops are not abundant, but are more numerous than those of the Springfield Center and Seneca members.

Lithology: The Babcock Hill is a chert-bearing, fine- to medium-grained grey limestone. The chert, dark grey or light grey, occurs as irregular nodules and lenses aligned parallel to the bedding planes. Figure 8 shows the irregularity of the chert masses. Both the chert and the limestones are fossiliferous, the former with a coralline fauna.

Thickness: The member varies in thickness from 42 to 50 feet in the few localities where complete sections could be measured.

Contacts: The Babcock Hill conformably overlies the Springfield Center member, and the contact is placed beneath the last bed of abundant chert. The upper contact with the Seneca member is placed on top of the last bed with abundant chert. This contact is gradational and is difficult to determine when the Seneca contains chert lenses.

Paleontology: This member, in most outcrops, is fossiliferous, and its fauna is dominated by corals and brachiopods:

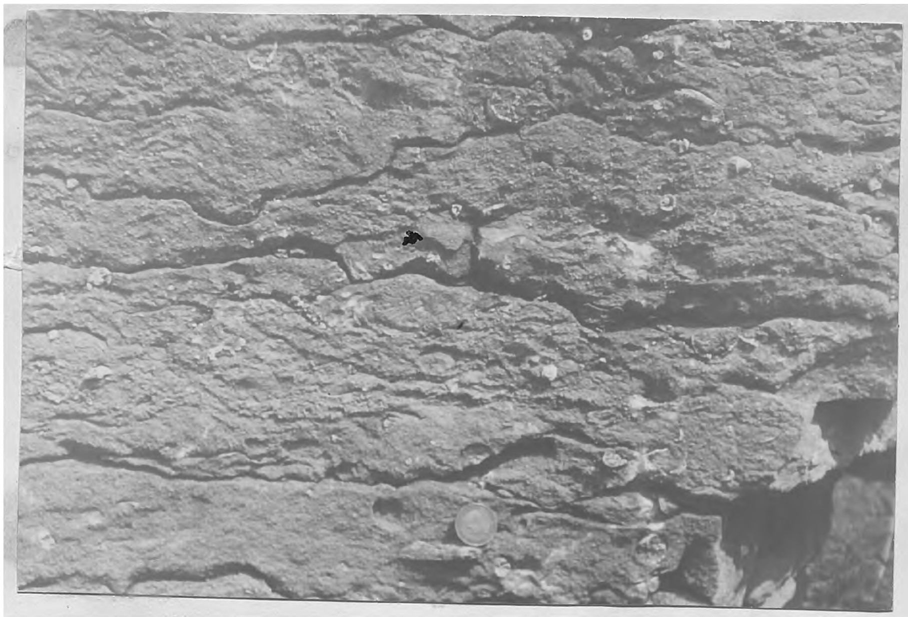

Figure 7. The Mt. Tom coral biostrome of the lower part of the Springfield Center member of the Onondaga formation. Springfield Center quarry, Otsego County.

Figure 8. Irregular chert nodules of the Babcock Hill member of the Onondaga formation at the type locality, Babcock Hill crossroads, Oneida County.

Zaphrentis cf. *Z. prolifica* Billings
Cystiphyllum sp.
Favosites sp.
Atrypa reticularis (Linnaeus)
Delthyris perlamellosus (Hall)
Leptaena rhomboidalis (Wilckens)
Stropheodonta sp.
Meristella nasuta (Conrad)
Platyceras dumosum Conrad
Goldringia sp.
Dalmanites sp.
Phacops cf. *P. logani* Hall

Age: See the discussion under Springfield Center member.

Seneca member Vanuxem 1839

Vanuxem [1839] named these beds the Seneca limestone from exposures in Seneca County. The writer retains the name Seneca following its appearance on the Devonian correlation chart [Cooper 1942], but designates it a member.

Areal Extent: The Seneca member extends as an irregular band southeastward from near West Winfield to Schoharie. The band varies in width from one mile in the west to 500 feet in the east. Outcrops are not abundant, and the best exposures occur in stream cuts.

Lithology: The member is grey, medium- to thin-bedded, medium- to fine-grained limestone with occasional beds and lenses of dark grey chert.

Thickness: This lithofacies has a thickness of 27 feet in the central part of the area, elsewhere it was not seen in its entirety.

Contacts: The Seneca conformably overlies the Babcock Hill and in places is separated therefrom at the first appearance of abundant beds of chert. In other areas the Seneca contains some chert, and the contact cannot be placed at a specific bed, but rather within a narrow zone. The upper disconformable contact with the Union Springs member of the Marcellus, is a sharp lithologic change (limestone to shale) which can be seen in a few exposures.

Paleontology: This member is less fossiliferous than the rest of the Onondaga. Its fauna contains fewer individuals and species:

Zaphrentis cf. *Z. prolifica* Billings
Delthyris perlamellosus (Hall)
Leptaena rhomboidalis (Wilckens)
Dalmanites sp.
Proetus clarus Hall

Age: The age based on stratigraphic position and paleontologic evidence is middle Devonian.

Remarks

The only faunal similarity common to all three lithofacies found in the small incomplete fossil collections made by the writer, is that they each contain abundant *Zaphrentis* cf. *Z. prolifica* and dalmanited trilobites. The Babcock Hill fauna has some species found in the Springfield Center fauna and other species that are found in the Seneca fauna.

The presence of included unsilicified fossils in the Babcock Hill chert nodules indicates that the precipitation of the silica (chert) was probably contemporaneous with the limestone deposition. The best theory to allow for such contemporaneous deposition is the precipitation of the silica, as a gel of the silica in solution, by electrolytes in sea water or through bacterial elimination of stabilizing organic colloids [Twenhofel 1939].

The Onondaga limestone is a deposit of a large epicontinental sea. The ecologic requirements for the extensive coral and brachiopod fauna indicate that the sea was shallow, warm and clear with the surrounding land areas at a low level. During middle Onondaga time there was an excess of silica in solution (See above paragraph).

Correlation of the members of the Onondaga formation for central New York is shown in Figure 6. The sections show that in the Springfield-Salt Springsville area, the thicknesses of the different members remain fairly constant, while the sections that are farther apart show considerable fluctuations. It should be remembered that the boundaries between different members are not chronologic, but based only on lithologic differences.

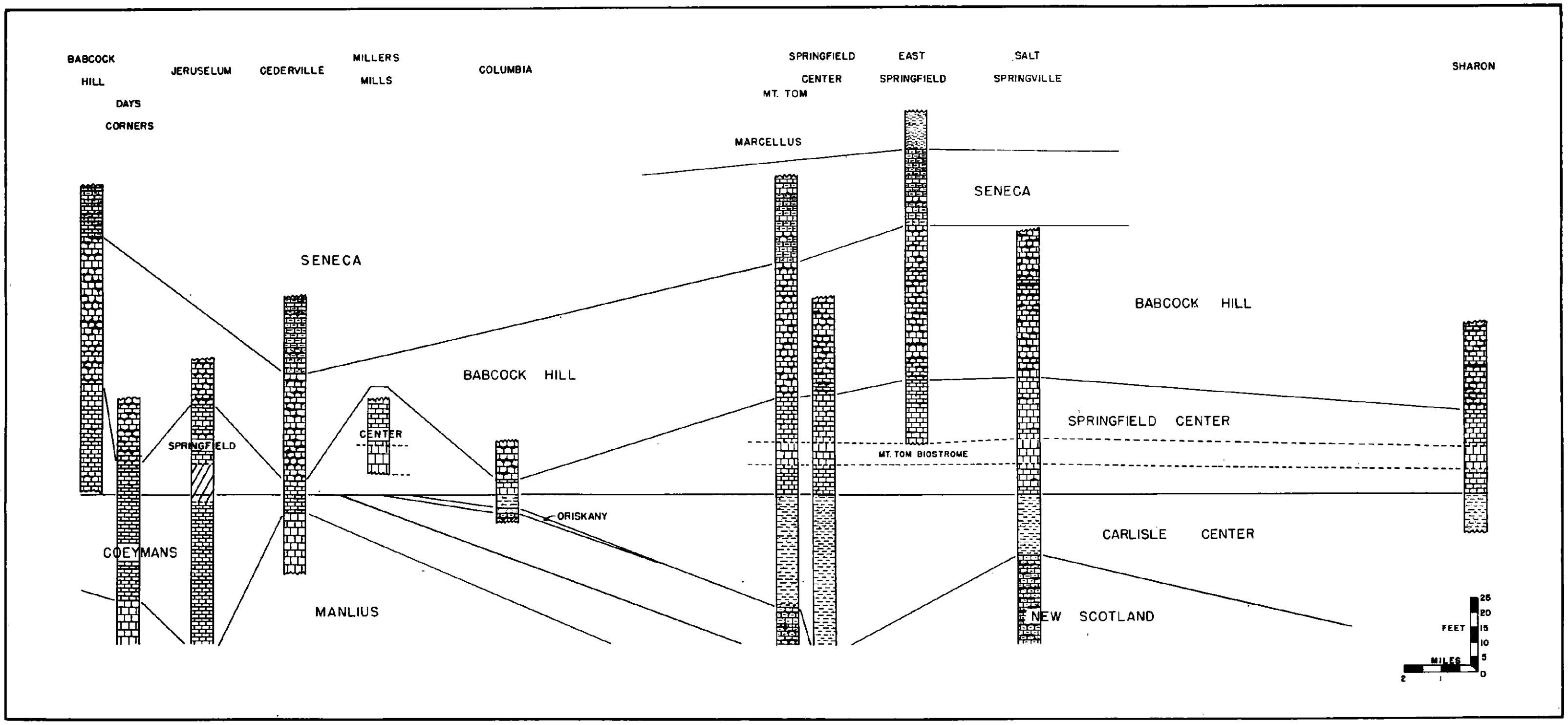

Figure 6. Onondaga correlations across central New York from Sharon to Babcock Hill.

Correlation of faunas with beds to the south indicates that the formation goes from a northern limy facies to a southern clastic facies [Kindle 1912]. The change occurs in south-central Pennsylvania where the limestone (Selinsgrove) fingers out into the upper part of the Needmore shale [Willard 1939]. The Onondaga limestone extends westward to northern Michigan and southwestward to Tennessee [Cooper 1942].

HAMILTON GROUP (Vanuxem 1840)

Vanuxem [1840] named the shales and sandstones lying between the Moscow shales and the Skaneateles shales (present day Ludlowville formation) the Hamilton group, but in 1842, he redefined the name to include everything between the top of the Moscow and the base of the Skaneateles. The underlying Marcellus shales were placed in the Hamilton group by some geologists and left out by others until 1930, when Cooper, following a detailed study, redefined the Hamilton group, with the Marcellus shales as the basal formation. The type locality is at West Hamilton, New York.

MARCELLUS FORMATION Hall 1839

In 1839, Hall gave the name Marcellus to the black shales lying above his Seneca limestone (Onondaga formation) and below the slaty, fossiliferous shales (Skaneateles) at Marcellus in Onondaga County.

Clarke and Luther [1904] divided the formation into three parts; lower slaty Marcellus, middle Stratford limestone, and the upper or Cardiff shales. Cooper in 1930, resubdivided the Marcellus of the type area into the following members in ascending order, Union Springs, Cherry Valley, Chittenango, and Cardiff. In Chenango Valley, he replaced the Cardiff by the Bridgewater, Solsville, and Pecksport members. In 1933, Cooper working in Otsego County, called the sandy shales equivalent to the Bridgewater to the west, the Otsego member. These recent divisions by Cooper are used in this paper.

Description

Union Springs member Cooper 1930

This member was first described in 1930 by Cooper who designated Woods Quarry, 1 mile south of Union Springs, New York, as the type locality. In 1933 he described this member from the region under study.

Areal Extent: Exposures are confined to a sinuous band, trending southeast from the Unadilla Valley, 0.2 miles wide, to the vicinity of Richmondville, where it is 0.7 miles wide. Outcrops are rare, restricted to a few stream cuts.

Lithology: This is a dark grey to black, carbonaceous shale which becomes limy near its upper and lower contacts. It occasionally shows a slight sand content.

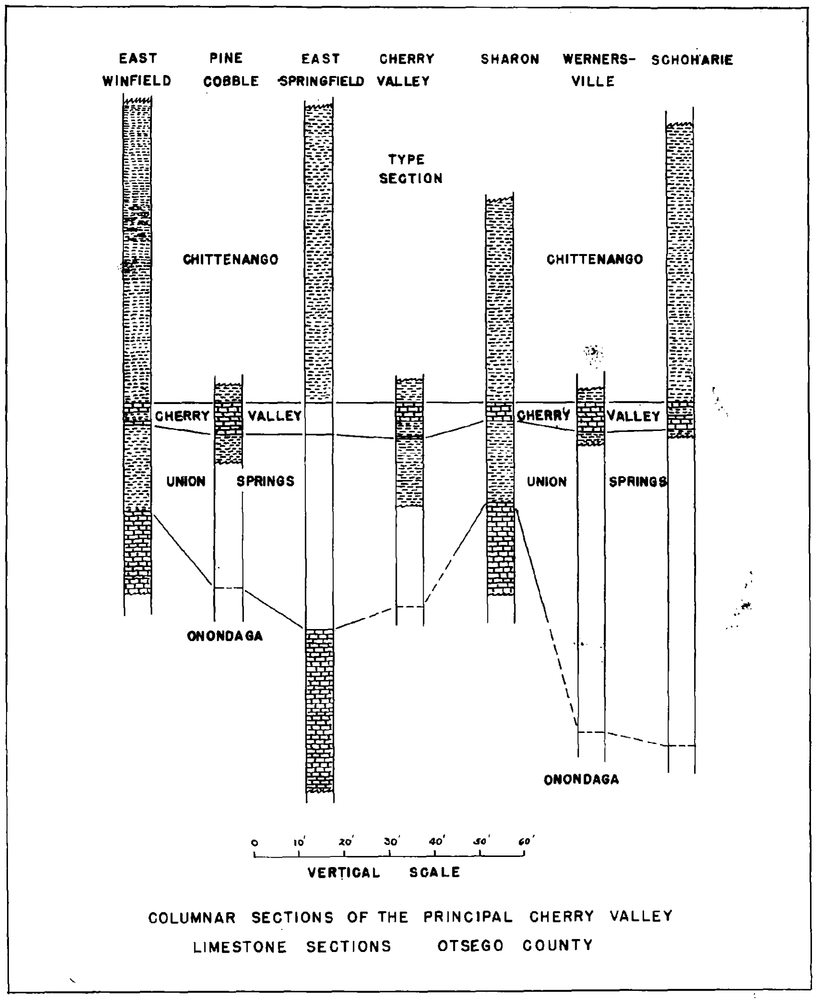
EAST WINFIELD
PINE COBBLE
EAST SPRINGFIELD
CHERRY VALLEY
TYPE SECTION
SHARON
WERNERS-VILLE
SCHOHARIE
CHITTENANGO
CHITTENANGO
CHERRY VALLEY
CHERRY VALLEY
UNION SPRINGS
UNION SPRINGS
ONONDAGA
ONONDAGA
0 10' 20' 30' 40' 50' 60'
VERTICAL SCALE
COLUMNAR SECTIONS OF THE PRINCIPAL CHERRY VALLEY LIMESTONE SECTIONS OTSEGO COUNTY

Figure 9

Thickness: The thickness varies from 19 to 70 feet.

Contacts: Both the lower contact with the Seneca member of the Onondaga and the upper contact with the Cherry Valley member are sharp lithological (shale to limestone) changes (see Figure 10).

Paleontology: According to Cooper [1933], the Union Springs member is slightly fossiliferous with *Leiorhynchus limitare* and a number of small forms. In the few outcrops examined by the writer, no fossils were noted.

Age: The age is middle Devonian based on stratigraphic position and paleontologic evidence.

Cherry Valley member Clarke 1903

The Cherry Valley member was named by Clarke in 1903[7] from exposures in Cox's Ravine, 1 mile west of Cherry Valley, New York. It was formerly called the "Agoniatites limestone". The upper contact of this member was used by the writer as a horizon in structural contouring.

Areal Extent: The Cherry Valley member extends as a narrow, sinuous band from the Unadilla Valley near West Winfield to the vicinity of Schoharie in Schoharie Valley. Outcrops are rare. The writer and his

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[7] See Wilmarth [1938]

assistants after two and one-half weeks search found only five exposures, four of them in stream beds.

Lithology: The member consists of medium-bedded, dense, black, carbonaceous limestone with or without a carbonaceous limy shale interbed (see Figures 10 and 11).

Thickness: It varies in thickness from 4 to 8 feet.

Contacts: The lower contact with the Union Springs member, (see Figure 10) and the upper with the Chittenango member, are sharp lithological changes between limestone and shale. Figure 9 shows the contact relationships of the member over the map area.

Paleontology: This member is characterized by a cephalopod fauna admirably described by Flower in 1936. Goldring [1931] lists as diagnostic Cherry Valley forms the following: Orthoceras marcellense, Gomphoceras (Poterioceras) oviforme, Nautilus (Discites) marcellensis, Agoniatites expansus, Anarcestes plebeiformis, and Paradoceras discoideum. The only fossils found by the writer were cephalopod fragments and indeterminate brachiopods.

Age: The age is middle Devonian based on stratigraphic position and paleontologic evidence.

Chittenango member Cooper 1930

This name was given by Cooper [1930] to the shales overlying the Cherry Valley member. He designated a small gully 0.7 mile north of Chittenango Falls, New York, as

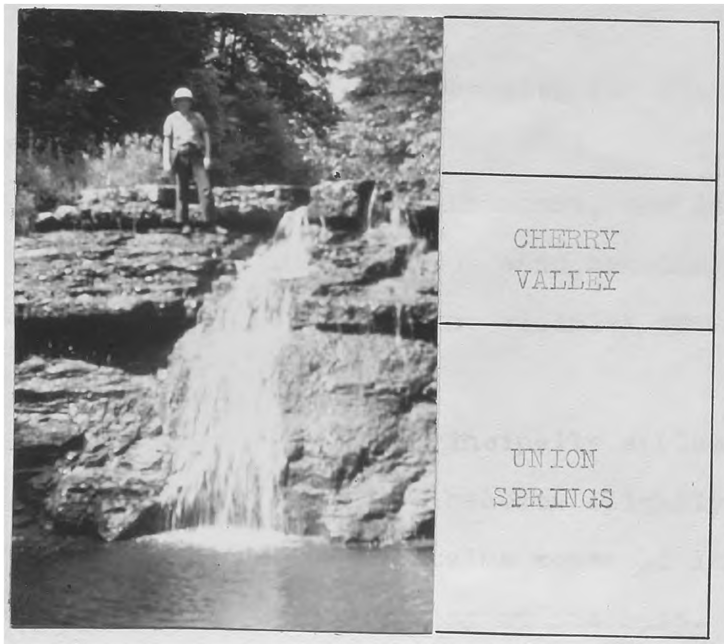

Figure 10. The type section of the Cherry Valley member of the Marcellus formation. Cox's Ravine, 0.7 mile west of Cherry Valley.

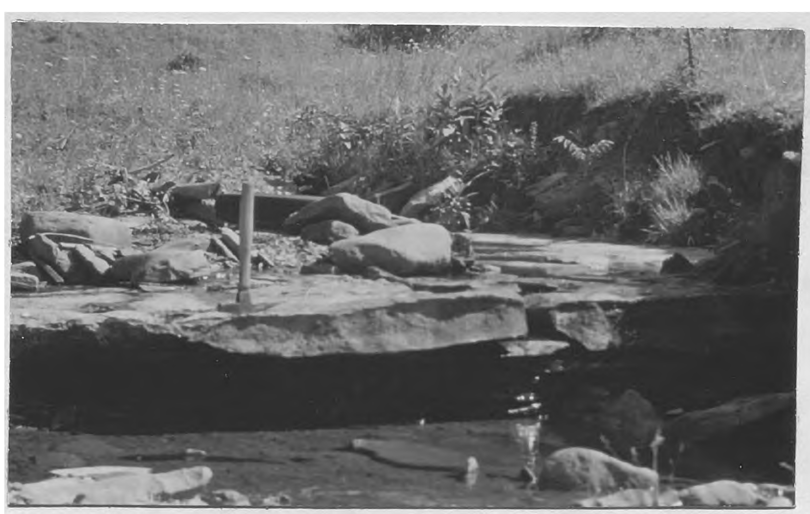

Figure 11. Basal bed of the easternmost exposure of the Cherry Valley member of the Marcellus formation. 1.6 miles west of Schoharie.

the type locality. In 1934, he described the Chittenango from the area under study.

Areal Extent: Outcrops, not abundant, are limited to a 1.2 mile wide irregular sinuous band trending southeast from the Unadilla Valley to the vicinity of Schoharie.

Lithology: This member is principally a black, carbonaceous, fissile shale which becomes slightly sandy in the east. It occasionally contains zones of limestone nodules and is invariably limy at its base. In the Schoharie Valley, it appears to merge with the overlying sandy shales of the Otsego member.

Thickness: It varies in thickness from 100 to 150 feet [Cooper 1933].

Contacts: The lower contact with the limestone of the Cherry Valley member is sharp. The upper contact with the Otsego and Bridgewater is lithologically sharp in the west but gradational in the east.

Paleontology: The member for the most part is barren of fossils, however Cooper [1933] reports a few small brachiopods and the writer has noted *Leiorhynchus limitare*.

Age: The age is middle Devonian based on stratigraphic position and faunal evidence.

Otsego member Cooper 1933

In 1933 Cooper proposed this name for the lower part of the Bridgewater member (see below) to the west. The type section is in the "Dugway" on the east side of Otsego Lake. Eastward it includes all the beds between the Chittenango and Solsville members.

Areal Extent: It is exposed in a sinuous two and one-half mile wide band trending southeast from Otsego Lake to Schoharie Valley. Outcrops are not abundant.

Lithology: The Otsego member consists of thin-bedded sandy shales and fine sandstones.

Thickness: The thickness varies from 256 to 385 feet [Cooper 1933].

Contacts: The lower contact with the Chittenango member is fairly sharp lithologically while the upper contact is gradational. In the Schoharie Valley this upper gradational zone is fairly thick.

Paleontology: Cooper [1933] lists as diagnostic of this member the following forms: *Leiorhynchus multicostata*, *Mucrospirifer mucronatus*, *Chonetes vicinus*, *Chonetes*, cf. *C. coronatus*, *Athyris* cf. *A. cora* and *Rhipidomella vanuxemi*. The few exposures the writer examined were unfossiliferous.

Age: The age is middle Devonian based on stratigraphic position and paleontologic evidence.

Bridgewater member Cooper 1930

Cooper [1930] gave the name Bridgewater to the beds lying between the Chittenango and Solsville members in the Chenango and Unadilla valleys. The type section consists of several outcrops in the vicinity of Bridgewater and West Winfield.

Areal Extent: Outcrops, limited to a two and one-half mile wide band between Bridgewater and West Winfield, are not abundant.

Lithology: The member consists of shales and sandy shales.

Thickness: It varies in thickness from 200 to 360 feet [Cooper 1930].

Contacts: The lower contact with the Chittenango member is a fairly sharp lithological change, while the upper contact with the Solsville is gradational and based upon both lithologic and faunal evidence.

Paleontology: This formation is slightly fossiliferous. Cooper [1930] has noted *Leiorhynchus limitare*, *Conularia* and *Styliolina fissurella* in the shales and *Leiorhynchus laura* in the sandy shales. At one locality the writer found *Mucrospirifer mucronatus* and *Leiorhynchus* sp.

Age: The age is middle Devonian based upon stratigraphic position and faunal evidence.

Solsville member Cooper 1930

The beds lying between the Bridgewater and Pecksport members, which contain an unusual Hamilton faunal assemblage, were named Solsville by Cooper in 1930. The type section is in Wood's Gully, 2 miles northwest of Solsville, New York.

Areal Extent: The exposures are limited to a 2-1/2 mile wide sinuous band extending from near Unadilla Forks in Unadilla Valley southeast to the vicinity of Richmondville. Outcrops are not numerous.

Lithology: Interbedded sandy shales, shaly sandstones, and fine-grained sandstones make up the member. Cooper [1933] reports fissile shale at the base of this member in the Susquehanna Valley.

Thickness: The thickness varies from 140 to 250 feet.

Contacts: The upper contact with the Pecksport and the lower contact with the Otsego and Bridgewater members are gradational, based upon paleontological and lithological features.

Paleontology: Cooper [1930] listed for this member the following diagnostic fossils: *Nephriticeras maximum*, *Paracylas lirata*, *Gosselettia triquetra*, *Pterina flabellum*, and *Conularia continens*. The few outcrops which the writer visited were unfossiliferous.

Age: The age, based upon stratigraphic position and faunal evidence, is middle Devonian.

Pecksport member Cooper 1930

This name was given by Cooper [1930] to the uppermost member of the Marcellus formation. The type section is in Livermore Gully, 1 mile east of Pecksport, New York.

Areal Extent: Outcrops are limited to a two-thirds mile wide band trending southeast from Leonardsville in the Unadilla Valley to the vicinity of Richmondville. Outcrops are not numerous.

Lithology: The member consists of sandy shales that become sandier eastward. At some exposures there are nodules of ironstone.

Thickness: The thickness varies from 50 to 100 feet.

Contacts: The lower contact with the Solsville member is gradational, based upon lithology and paleontology. The upper contact with the Panther Mountain formation is marked by the "*Paraspirifer acuminatus*" zone [Cooper 1933].

Paleontology: The member is fossiliferous in part, and in 1933, Cooper listed the diagnostic fossils. The following forms were found by the writer in the few outcrops examined:

Mucrospirifer mucronatus (Conrad)
Paraspirifer acuminatus (Conrad)
Camerotechia congregata (Conrad)

Nucula opima (Hall)
Cornellites sp.

Age: On the basis of stratigraphic position and paleontologic evidence, the age is middle Devonian.

Remarks

The paleontological and lithological characters of the lower members of the Marcellus differ markedly from the upper members. The lower part of the formation with its barren to slightly fossiliferous (small forms) black shales and dense, black, cephalopod limestones gradually give way to sandy shales with the larger, thicker-shelled, Hamilton fauna. This change effects progressively older beds as it goes eastward.

These beds represent the near-shore shales of the regressing Middle Devonian sea, which began to diminish in size at the end of the Onondaga lime deposition. The Cherry Valley member indicates a brief somewhat modified return of the lime-producing condition of Onondaga time. As the shallow, epicontinental sea regressed, the beds became sandier and with this lithologic change, came faunal differences, as animals, characteristic of a fairly sandy environment, moved into the area.

This formation can be roughly correlated with the Marcellus shales to the south in Pennsylvania, Maryland and West Virginia on paleontologic and lithologic evidence and with the Bellvale sandstone of Green Pond Mountain, New Jersey, on paleontological evidence [Willard 1937]. To the west, the formation has been determined by paleontologic means to be the equivalent of the Dundee limestone of Michigan, the Delaware limestone of Ohio, the Speed limestone of Kentucky, and the Pegram limestone of west Tennessee.

PANTHER MOUNTAIN FORMATION Cooper 1933

Cooper [1933] suggested this name for the Ludlowville and Skaneateles and portions of the Marcellus formations where they cannot be separated lithologically. The exact content of the Panther Mountain formation varies somewhat in this area; in the Unadilla Valley, it consists of the Ludlowville and Skaneateles formations, while in the Schoharie Valley the Solsville and Pecksport members of the Marcellus are also included. The type section starts about one-half mile south of Fultonham, on the face of Panther Mountain along the "Towpath" and extends up Panther Creek to its head. This formation covers essentially the same beds as the Moheganter formation of Grabau [1930].

Description

Areal Extent: Outcrops are restricted to a sinuous band, trending southeast from the Unadilla Valley (vicinity of West Edmeston), where it is 7.5 miles wide to the Schoharie Valley, (vicinity of Blenheim) where it is 12.5 miles wide. Throughout this area roadcuts and quarries afford good exposures.

Lithology: The formation is dominantly thin-bedded dark-grey, sandy shale with interbeds of shale, shaly sandstone, thin-bedded sandstone, and coquinites.

Thickness: The thickness varies from 800 feet in the Unadilla Valley to 1303 feet in the Schoharie Valley.

Contacts: The lower contact with the Marcellus formation is at a fairly sharp paleontological change marked by the "*Paraspirifer acuminatus*" zone [Cooper 1933]. The upper contact with the Portland Point member of the Moscow formation is a sharp lithological change (sandy limestone to sandy shale) where exposed.

Paleontology: This formation is fossiliferous, but does contain many barren beds. It is characterized by no single fossil, but rather by its general assemblage. A faunal list follows:

Mucrospirifer mucronatus (Conrad)
M. consobrinus (d'Orbigny)
Brachyspirifer audaculus (Conrad)
Paraspirifer cf. *P. acuminatus* (Conrad)
Ambocoelia umbonata (Conrad)
Chonetes syrtalis (Conrad)
C. coronatus (Conrad)
Camarotechia congregata (Conrad)
Tropidoleptus carinatus (Conrad)
Meristella cf. *M. barresi* (Hall)
Athyris spiriferoides (Eaton)

Productella dumosa Hall
Glyptodesma erectum (Conrad)
G. sp.
Palaeoneilo emarginata (Conrad)
P. muta Hall
Modiomorpha sp.
Cornellites flabella (Conrad)
Actinopteria decussata Hall
Pterinopecten cf. P. princeps (Conrad)
Leiopteria cf. L. dekayi Hall
Cypricardella bellistriata (Conrad)
Nucula opima (Hall)
Orthonota sp.
Goniophora hamiltonensis Hall
Bembexia cf. B. trillix (Hall)
B. sp.
Orthoceras sp.
Greenops boothi (Green)
Dipleura dekayi (Green)

Age: The age of the formation is middle Devonian based on paleontologic and stratigraphic evidence.

Remarks

The fauna of the Panther Mountain formation is identical with that of the Windom member of the overlying Moscow formation and similar to that of the upper sandy facies of the underlying Marcellus formation.

The fauna and lithology indicate an environment where quiet shallow water covered a bottom composed of fairly fine sediments. The Panther Mountain beds are the near-shore deposits of the regressing Middle Devonian sea. During most of Panther Mountain time there appears to be essentially stillstand.

The Panther Mountain formation can be correlated with the lower part of the Mahatango formation of eastern Pennsylvania [Willard 1939], the Hamilton of Maryland, and the Rommey formation (in part) of northern Virginia [Cooper 1942]. Westward, it is correlated with the Prout limestone and Plum Creek shale in northern Ohio and with a series of shales and limestones (including the lower part of the Traverse group) in Michigan [Cooper 1942].

MOSCOW FORMATION (Hall 1839)

The shales underlying the Tully limestone and overlying the "Encrinal" limestone (Tichenor limestone), at Moscow (now Leicester), Livingston County, were called the Moscow shales by Hall in 1839. In 1930, Cooper redefined the formation to exclude the beds between the Tichenor and Menteth limestone members, which up to this time had been included in both the Moscow and Ludlowville formations. In 1934, Cooper subdivided the Moscow formation in Otsego County into two members, the upper Windom member and the basal Portland Point member.

Description

<u>Portland Point member</u> Cooper 1930

This is the basal member of the Moscow formation named by Cooper [1930] from the excellent exposures at Portland Point on Cayuga Lake. Later, by Cooper [1934] the member was extended east of Chenango Valley.

Areal Extent: The few outcrops in this area (a total of 6 were found) are limited to a very narrow sinuous band extending southeast from New Berlin in the Unadilla Valley, through Milford to near North Blenheim in Schoharie Valley.

Lithology: In the western part of the area, the Portland Point is a massive bed of sandy limestone with limy shales, but this changes to fine sandstone with calcareous lenses in the east.

Thickness: The thickness varies from 8 inches to 6 feet.

Contacts: Both of the contacts, the lower with the Panther Mountain formation and the upper with the Windom member, are sharp lithologic changes. These contacts are also based on faunal differences.

Paleontology: This member has a fauna characterized by *Centronella impressa*. At one locality, however, the only form present was a horn coral, *Zaphrentis* ? sp. A faunal list follows:

Zaphrentis ? sp.
Centronella impressa Hall
Spinocyrtia granulosa (Conrad)
Camarotechia congregata (Conrad)
Athyris cora Hall
Chonetes coronatus (Conrad)
Rhipidomella sp.
Cypricardella cf. *C. bellistriata* (Conrad)

Age: The age is middle Devonian on the basis of stratigraphic position and paleontology.

Windom member Grabau 1917

Grabau [1917] gave this name to the shales lying between the Tichenor limestone and the "Tully" pyrite in the vicinity of Windom, Erie County. Cooper [1930, 1934] extended this formation to the east. The upper contact of this member (the base of the Tully formation) was used by the writer as one of the horizons structurally contoured.

Areal Extent: Exposures are restricted to a sinuous band which widens from 2.5 miles in the west to 3.2 miles in the east. This band trends southeast from Sherburne in the Chenango Valley to the vicinity of North Blenheim in the Schoharie Valley. Exposures, including quarries and road-cuts, are fairly numerous.

Lithology: The member is dominantly a sandy shale with a few interbedded shaly sandstones. Thin interbedded sandstones, however, begin to appear in the eastern part of the area. The member also contains many sandy and shaly coquinite layers.

Thickness: The thickness of the member varies from 265 feet in the west to 435 feet in the east.

Contacts: The lower contact with the Portland Point member is a sharp lithologic change between shale and limestone, while the upper contact is identified by the first appearance of the Tully fauna, characterized by either Leiorhynchus mesacostale or Hypothyridina venustula. This upper contact is a lithological change in some localities.

Paleontology: This extremely fossiliferous member is characterized by numerous species and individuals of brachiopods and pelecypods. There is one zone, 6 inches to 2 feet thick, lying from 0 to 53 feet below the upper contact, that is characterized by numerous individuals of Pustulina pustulosa. This Pustulina horizon was an aid in locating the Windom-Tully contact in parts of the area under study. A faunal list follows:

Zaphrentis sp.
Camarotechia congregata (Conrad)
Tropidoleptus carinatus (Conrad)
Pustulina pustulosa (Hall)
Elytha fimbriata (Conrad)
Chonetes syrtalis (Conrad)
C. coronatus (Conrad)
C. scitulus Hall (?)
Ambocoelia umbonata (Conrad)
Spirifer tullius Hall
Fimbrispirifer cf. F. venustus (Hall)
Brachyspirifer audaculus (Conrad)
Mucrospirifer mucronatus (Conrad)
M. consobrinus (d'Orbigny)
Platyrachella mesastrialis (Hall)
Spinocyrtia granulosa (Conrad)
Athyris cf. A. spiriferoides (Eaton)
A. angelica Hall
A. sp.
Atrypa sp.
Productella truncata (Hall)
Roemerella grandia (Vanuxem)
Paleonielo emarginata (Conrad)
Orthonota undulata (Conrad)

Modiomorpha concentrica (Conrad)
M. mytiloides (Conrad)
Goniophora hamiltonensis Hall
Grammysia arcuata (Conrad)
G. alveata (Conrad)
Nucula opima (Hall)
Glyptodesma erectum (Conrad)
Cornellites flabella (Conrad)
Actinopteria boydi (Conrad)
A. cf. *A. decussata* Hall
Cypricardinia cf. *C. indenta* (Conrad)
Pterinopecten princeps (Conrad)
Bembexia sulcomarginata (Conrad)
Diaphorostuma sp.
Orthoceras sp.
Greenops boothi (Green)
Dipleura dekayi (Green)
Phacops rana (Green)

Age: The age of this member is late middle Devonian based on stratigraphic and paleontologic evidence.

Remarks

The lithology of the two members of the Moscow formation differ markedly in the west, where one is a sandy limestone, and the other a sandy shale. In going east, they both become sandier and partially lose their distinguishing features. Paleontologically the two faunas show some similarity, but it is not as great as that between the Windom and Panther Mountain faunas.

Based upon paleontologic and lithologic observations, the environment of the Windom depositional time was one of quiet shallow water over a bottom of silt and sand. These conditions would be found in the near-shore portion of an epicontinental sea which was receiving clastics from near-by coastal mountains. The Portland Point limestone, like the Cherry Valley limestone of the Marcellus formation, indicates a brief and partial return of the lime-producing conditions of the Onondaga sea.

The Moscow can be correlated with the upper part of the Hamilton group in Pennsylvania [Willard 1939] and Maryland. The Windom member extends as far west as northern Ohio [Cooper 1942].

UPPER DEVONIAN

TULLY FORMATION Vanuxem 1838

The Tully formation, a thin limestone unit, has long been accepted by many as the initial deposit of the Upper Devonian in western New York State. It was named by Vanuxem [1838] from the exposures near the village of Tully. It was not known in central New York until Cooper and Williams in 1935 extended the Tully formation eastward by including a thick series of clastics containing the characteristic Tully faunas. In Otsego County, the whole clastic facies of the Tully is exposed (see Figure 12). Because of faunal differences it is separated into three members, New Lisbon, Apulia or Laurens, and West Brook

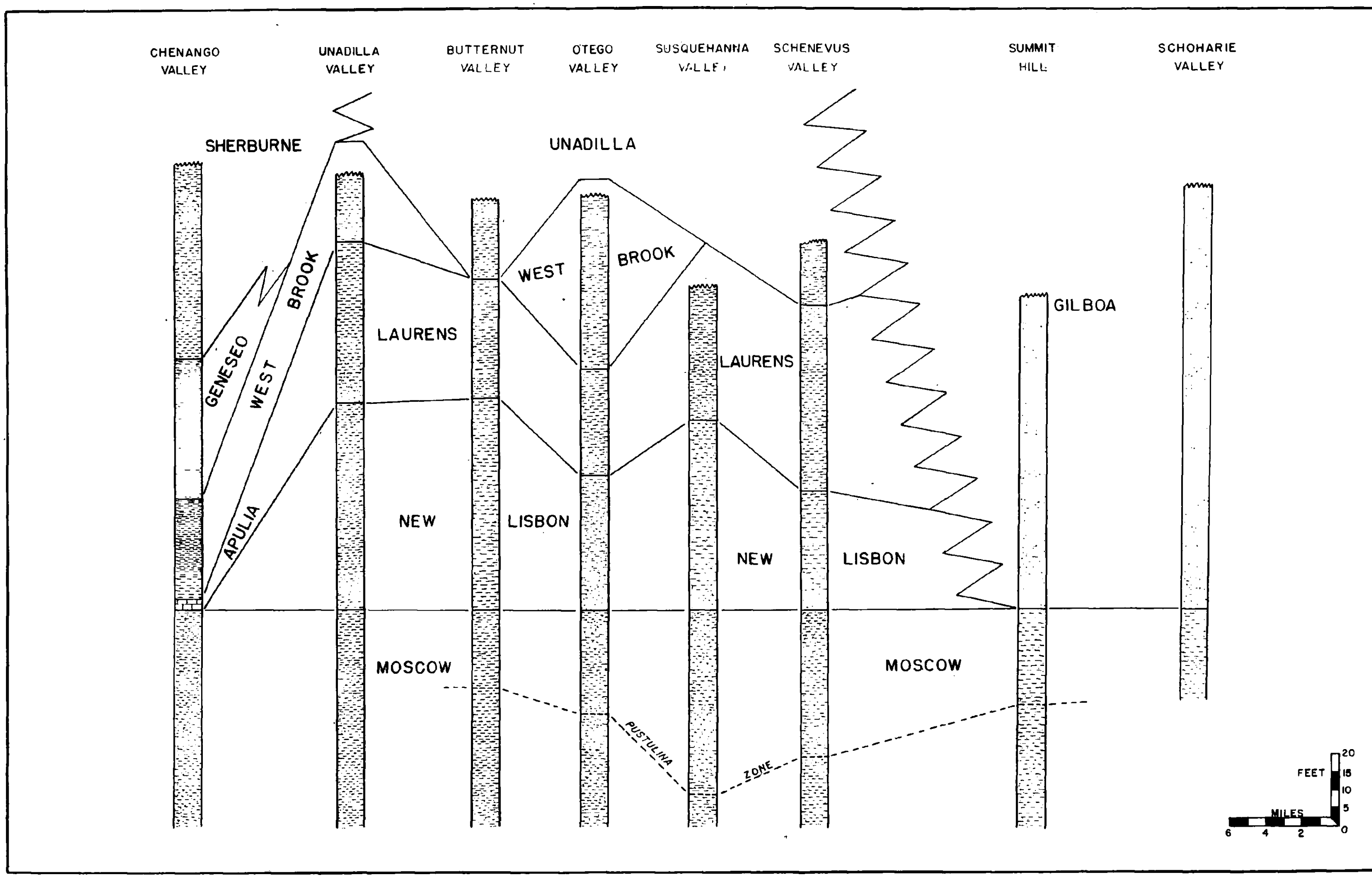

Figure 12. Tully correlations across Otsego Co.

in ascending order [Cooper and Williams 1935]. The correlation of these members with those of the type section in western New York is shown in Table 3.

Description

New Lisbon member Cooper and Williams 1935

This member was first described by Cooper and Williams [1935] from exposures in the Butternut Creek valley, 1 mile northeast of New Lisbon. It was originally limited to the Butternut valley but the writer in a previous paper [1948] extended it eastward.

Areal Extent: New Lisbon outcrops are limited to a narrow, irregular, sinuous band, trending N. 78 W., from near Harrisville, 2 miles east of Sherburne, to the vicinity of Schenevus. Exposures in this band are few and scattered and in most cases limited to stream and road-cuts.

Lithology: In the western part of the area the member is predominantly thin-bedded, dark-grey, sandy shale and shaly sandstone associated with grey, platy sandstone. Occasionally well-developed ripple marks can be seen. Westward, the member becomes sandier, and in several localities, the lower part of the member is characterized by massive beds of sandstone with storm rollers associated with thin- and medium-bedded, fine-grained sandstone.

Thickness: The member varies in thickness from 33 to 60 feet.

Contacts: The New Lisbon conformably overlies the Windom member of the Moscow formation, with a gradational contact based primarily on the first appearance of *Leiorhynchus mesacostale*. This contact in many places shows also a lithologic change to the sandier facies of the Portage group. The upper contact with the Laurens member is also paleontologic. It is identified by the first appearance of abundant *Hypothyridina venustula*. Although the writer did not find *Hypothyridina venustula*, Cooper and Williams [1935] reported it from the New Lisbon beds in Houghtalings Gorge, Otego Valley. Here there is no noticeable lithologic change.

Paleontology: This member is characterized by a great abundance of *Leiorhynchus mesacostale*, which in some instances is the only species present. The New Lisbon fauna listed below is composed principally of brachiopods and pelecypods:

Brachyspirifer sp.
B. audaculus (Conrad)
Mucrospirifer mucronatus (Conrad)
M. consobrinus (d'Orbigny)
Platyrachella mesastrialis (Hall)
Spirifer tullius Hall
Tropidoleptus carinatus (Conrad)
Camarotechia congregata (Conrad)
Leiorhynchus mesacostale (Hall)
Cyrtina hamiltonensis Hall
Chonetes syrtalis (Conrad)
C. sp.

Productella spinulicosta Hall
Athyris cora Hall
Atrypa sp.
Paleoneilo emarginata (Conrad)
Modiomorpha sp.
Actinopteria boydi (Conrad)
Grammysia sp.
Cornellites flabella (Conrad)
Loxonema delphicola Hall
Bembexia sulcomarginata (Conrad)
Orthoceras sp.
Phacops rana (Green)
Greenops boothi (Green)
Dipleura dekayi (Green)

Age: The age is early late Devonian determined by stratigraphic position and paleontologic evidence.

Apulia member Cooper and Williams 1935

This member was named and described from the June's Quarry, 1 mile east of Tully. In the area under study it appears only on the western edge, being replaced by the Laurens member in going east.

Areal Extent: In this area, the outcrops of the Apulia member are limited to Chenango Valley, but it does extend westward [Cooper and Williams 1935]. Only two exposures were examined by the writer.

Lithology: This member consists of thin-bedded, oölitic limestone, hard, calcareous sandstone and shale with calcareous lenses. It is part of the western limestone facies of the Tully.

Thickness: The exposures of the Apulia vary in thickness from 1 foot to 2 feet 10 inches with the base not seen at either locality.

Contacts: The lower contact with the Moscow formation is covered, but the upper contact with the West Brook member is gradational and based on the disappearance of Hypothyridina venustula and the appearance of the Elytha fimbriata fauna.

Paleontology: The member is only slightly fossiliferous and is characterized by Hypothyridina venustula. The faunal list follows:

Hypothyridina venustula (Hall)
Atrypa spinosa (Hall)
Chonetes aurora (Hall)

Age: The age is early late Devonian determined by stratigraphic position and faunal evidence.

Laurens member Cooper 1934

Cooper [1934] proposed this name for the Hypothyridina-bearing sandstones of Tully age in Otego Valley. In 1935, Cooper and Williams published a measured section from Houghtailing Gorge in Otego Valley in which they had 73 feet of Laurens overlying the Moscow formation. However, on the basis of other exposures of Laurens in this valley, the writer is restricting the Laurens to the upper 41 feet of the Houghtailing Gorge exposure and assigning the lower 32 feet to the New Lisbon. This member is found both east and west of this type area.

Areal Extent: The New Lisbon crops out in a narrow, sinuous band from the Unadilla Valley to the vicinity of Schenevus. Exposures are not abundant, being limited to deep gulleys and a few road-cuts.

Lithology: This member consists of sandy shales, thin-bedded shaly sandstones, platy fine sandstone, and medium-bedded fine sandstone. From the Unadilla Valley in the west where the Laurens is predominantly shaly it becomes progressively more sandy as it is traced to the east. Occasional thin sandy, shaly coquinite beds are found throughout the area.

Thickness: The Laurens varies in thickness from 30 to 52 feet.

Contacts: The upper and lower contacts are gradational and based on faunal differences. The basal contact with the New Lisbon is identified by the first appearance of Hypothyridina venustula and its upper contact by the disappearance of this form and the first occurrence of the Elytha fimbriata-Lopholasma fauna of the overlying beds of the West Brook or the Ithaca fauna if the member is overlain by the Unadilla sandstone.

Paleontology: This member is not consistently fossiliferous, but varies from bed to bed and locality to locality. The characteristic member of the Laurens fauna is Hypothyridina venustula, individuals of which are so abundant in some localities that they form semi-coquinites. The fauna of the Laurens is as follows:

Mucrospirifer mucronatus (Conrad)
Brachyspirifer auducalus (Conrad)
Ambocoelia umbonata (Conrad)
Platyrachella mesastrialis (Hall)
Hypothyridina venustula (Hall)
Leiorhynchus mesacostale (Hall)
Productella sp.
Camarotechia congregata (Conrad)
Echinocoelia ambocoeloides Cooper and Williams
Chonetes sp.
Tropidoleptus carinatus (Conrad)
Buchiola speciosa (Hall)
Modiomorpha concentrica (Conrad)
Paleoneilo emarginata (Conrad)
Actinopteria boydi (Conrad)
Cornellites flabella (Conrad)
Leptodesma cf. L. rogersi (Hall)
Paracyclas lirata (Conrad)
Nucula opima (Hall)
Bembexia sulcomarginata (Conrad)
Orthoceras sp.
Phacops rana (Green)

Age: The age is early, late Devonian determined both by stratigraphic position and paleontologic evidence.

West Brook member Cooper and Williams 1935

The Cooper and Williams [1935] type locality of this member is on West Brook, three miles south of Sherburne in the Chenango Valley. This member is present in the lime facies of western New York as well as in the clastic facies to the east. The member is restricted to the western part of the area under study.

Areal Extent: The West Brook crops out in a narrow, sinuous band from Chenango Valley to the Otego Valley. Exposures, limited to road-cuts, quarries and stream gullies, are not numerous.

Lithology: In the Chenango Valley, the member consists of limestone, calcareous sands and shales, sandy shales and shaly sandstones. Eastward, the lime disappears and the member contains thin-bedded shale, sandy shale, shaly sandstone and fine sandstone.

Thickness: The West Brook varies in thickness from 0 to 67 feet.

Contacts: The lower contact with the Apulia or Laurens members is gradational, based on the disappearance of the middle Tully _Hypothyridina_ fauna and the appearance of the _Elytha fimbriata-Lopholasma_ fauna of the West Brook. Conversely, the upper contact is marked by the disappearance of this _Elytha fimbriata-Lopholasma_ fauna. The member is overlain by the Sherburne formation in the Chenango and Unadilla Valleys and by the Unadilla formation in the Otego Valley.

Paleontology: This member is characterized by what Cooper and Williams [1935] call the _Elytha fimbriata_ zone after _Elytha fimbriata_ and the _Lopholasma_ zone after _Lopholasma tullium_. The writer has not differentiated between these two and has called the West Brook faunal zone the _Elytha fimbriata-Lopholasma_ zone. This member has a larger and more diversified fauna than the other members [Cooper and Williams 1935]. Following is a list of the forms identified by the writer from this member:

- Lopholasma tullium Williams
- Aulopora sp.
- Gennaeocrinus percrinatus Goldring
- Leptaena rhomboidalis (Wilckens)
- Productella truncata Hall
- Mucrospirifer mucronatus (Conrad)
- Brachyspirifer auducalus (Conrad)
- Cyrtina hamiltonensis Hall
- Elytha fimbriata (Conrad)
- Chonetes lepidus Hall
- C. sp.
- Ambocoelia umbonata (Conrad)
- Tropidoleptus carinatus (Conrad)
- Camarotechia congregata (Conrad)
- Paleoneilo emarginata (Conrad)
- Goniophora hamiltonensis Hall
- Cornellites flabella (Conrad)
- Grammysia sp.
- Modiomorpha sp.
- Bembexia sulcomarginata (Conrad)
- Phacops rana (Green)
- Greenops boothi (Green)

Age: The age is early, late Devonian determined by stratigraphic position and faunal evidence.

Remarks

The three members of the Tully have similar faunas, but are distinguished from one another by the abundance of certain characteristic species. Leiorhynchus mesacostale, an Ithaca form makes its first appearance in the New Lisbon, where its numerous individuals make up the principal portion of the fauna. The Laurens and Apulia members of middle Tully age are characterized by abundant Hypothyridina venustula. The occurrence of the Elytha fimbriata-Lopholasma tullium zone marks the West Brook member of the Tully. In general, the Tully fauna is a merging of Hamilton and Ithaca forms in the presence of a few indigenous and exotic forms.

Excluding the Chenango Valley exposures which represent the eastern edge of the Tully limy facies, the Tully formation in this area is clastic, growing sandier eastward and finally merging with the Gilboa sandstone in Schoharie Valley. The sedimentary structures found (storm roller beds, ripple marks, and coquinites) are characteristic of shallow water clastics.

The shallow epeiric Tully sea occupied the Penn-York embayment of late Devonian time. In the area under study the sea was receiving sands and silts from Appalachia. These sediments were carried by currents as far west as the Unadilla Valley. Eastward these clastics grew coarser until they merged with the near-shore sandstones of the Gilboa formation. At the same time to the west the Tully sea was depositing lime.

Correlation of these beds with the limy facies to the west is well shown by Cooper and Williams [1935].

TABLE 3.- CORRELATION CHART OF THE MEMBERS OF THE TULLY FORMATION

	Western New York [Cooper & Williams 1935]	Eastern New York (This paper)	Eastern Pennsylvania [Stevenson & Skinner 1949]	
T U L L Y	West Brook	West Brook	Lehighton	T U L L Y
	Apulia	Laurens	Brodhead Creek	
	Tinkers Falls	New Lisbon	Weissport	

These correlations are shown in Table 3 which also includes correlations with the Tully clastics of eastern Pennsylvania, which have been separated into three members [Stevenson and Skinner 1949]. The formation may be correlated with the Duffin limestone of Kentucky, the Potter Farm shale and limestone of Michigan and the Little Rock Creek limestone of Indiana.

GENESEO FORMATION Chadwick 1920

In 1920, Chadwick changed the name of the beds underlying the Genundewa limestone from Genesee to Geneseo as the former was already in use as a group name. In 1935, Cooper and Williams applied this change in names to the beds overlying the Tully. The type section is on Fall Brook, Geneseo, New York.

Description

Areal Extent: The Geneseo crops out in this area and is confined to the Chenango Valley south of Sherburne. Exposures are not abundant.

Lithology: The formation consists of thin-bedded, grey, sandy shale and black, fissile shale.

Thickness: The formation varies from 0 to 40 feet in thickness in this area.

Contacts: The lower contact with the West Brook member is a sharp lithologic and paleontologic change determined by the highest calcareous beds of the Tully which are characterized by Lopholosma. The upper contact with the Unadilla is a gradational lithologic change to sandier beds.

Paleontology: No fossils were seen by the writer in the few outcrops examined.

Age: The age is late Devonian based on stratigraphic position.

Remarks

For a discussion of this formation, see Remarks, Gilboa formation on Page 97.

UNADILLA FORMATION (Prosser 1903)

This name was proposed by Prosser in 1903 to include the indivisible Ithaca and Sherburne members, lying between the Oneonta red beds and the Geneseo.

Cooper and Williams [1935] amended this definition to include, east of Chenango Valley, all beds between the Tully and Oneonta formations.

Description

Areal Extent: Outcrops are abundant in a wide (3-10 miles) sinuous band trending southeast from Unadilla Valley, south of New Berlin, to the vicinity of Summit.

Lithology: The beds consist of shaly sandstone and sandy shale with abundant thin-bedded fine sandstone. Interbedded are sandy coquinites and occasional massive beds of storm-roller sandstone.

Thickness: The formation was not seen in its entirety in this area, but incomplete measurements varied between 103 and 171 feet.

Contacts: In the Chenango Valley, the Unadilla is underlain by the Geneseo shale. The contact is a lithologic change. Elsewhere the lower contact of the Unadilla with the West Brook member of the Tully is a fairly sharp paleontologic change determined by the disappearance of the *Elytha fimbriata*-*Lopholasma* fauna. The contact with the overlying Oneonta formation is a transitional lithologic break (grey sands and shales to red sands and shales).

Paleontology: The formation has a large fauna, some of which is listed as follows:

Mucrospirifer mucronatus? (Conrad)
M. consobrinus (d'Orbigny)
Brachyspirifer auducalus (Conrad)
Spinocyrtia granulosa (Conrad)
Platyrachella mesastrialis (Hall)
Productella sp.
Tropidoleptus carinatus (Conrad)
Camarotechia congregata (Conrad)
Chonetes sp.
Leiorhynchus mesacostale (Hall)
Goniophora hamiltonensis Hall
Grammysia bisulcata (Conrad)
Paracyclas lirata (Conrad)
Cornellites flabella (Conrad)
Cimitaria recurva (Conrad)
Paleoneilo emarginata (Conrad)
Bembexia sulcomarginata (Conrad)
Phacops rana (Green)
Greenops boothi (Green)
Dipleura dekayi (Green)
Orthoceras sp.

Age: The age is late Devonian based on stratigraphic position and paleontologic evidence.

Remarks

For a discussion of this formation, see Remarks, Gilboa formation on Page 97.

GILBOA FORMATION (Cooper 1934)

Cooper [1934] originally defined this formation as the beds between the Ithaca (_Platyrachella mesastrialis_ beds) and the Hamilton formations in Schoharie Valley, but in 1935, Cooper and Williams redefined it to include all beds between the Oneonta red beds and the Hamilton formation. The type locality is in the west face of Reed Hill near Gilboa Reservoir.

Description

Areal Extent: The Gilboa crops out abundantly in the region around the Gilboa Reservoir in Schoharie Valley extending westward to Summit.

Lithology: The formation consists of thin- to thick-bedded, fine- to medium-grained sandstone, locally cross-bedded. Interbedded are shales, sandy shale, and shaly sandstones.

Thickness: Cooper and Williams [1935] give 325 feet as the thickness of the Gilboa for this area.

Contacts: The lower contact with the Moscow shale is a paleontologic change based upon the top of the "*Pustulina*" zone in the Summit area and its equivalent, the "*Rhipidothyris*" zone [Cooper and Williams 1935], of Schoharie Valley. It is also a lithologic change, sandy shales and interbedded sandstones of the Moscow formation to the buff sandstones of the Gilboa. The upper contact with the Oneonta formation is a gradational lithologic break (grey and buff sandstones to red beds).

Paleontology: The writer did not make any paleontologic collections from this formation.

Age: The age is late Devonian based on stratigraphic position.

Remarks

These three formations, the Geneseo, Unadilla and Gilboa are in part contemporaneous in age and represent facies variation during a single depositional period. The Gilboa sandstones represent the strand line deposits, a combination of shore and near-shore deposits which grade westward slowly into the sandy shales of the Unadilla which were deposited off-shore in the Devonian sea. Westward, these Unadilla clastics give way to the Geneseo shales. Such a gradation in clastic size, with the fine material increasing westward, suggests that the bulk of the sediments came from Appalachia to the east.

The Geneseo formation can be correlated southward with the Burkett shale of eastern Pennsylvania, the "Genesee" shale in Maryland, West Virginia, and Virginia. They extend as far west as Lake Erie. The Unadilla formation and the Gilboa sandstone can be correlated with the Trimmers Rock sandstone of eastern Pennsylvania.

SUBSURFACE STRATIGRAPHY

This section deals with the Lower Paleozoic strata that would be penetrated by a well drilled in the area. The stratigraphic descriptions are based upon the work done at the surface north of the area by other investigators. These Lower Paleozoic strata and the Pre-Cambrian basement complex are described by formations and members in the order noted in Table 4.

The Adirondack arch is an Ordovician foreland fold running southwest from the main Adirondack mass in the vicinity of Little Falls to Pennsylvania. It divided the Lower Paleozoic sea from time to time into two separate basins of deposition, one on either side of the arch, which have similar but not identical stratigraphic sections, as can be seen in Table 4. In the following formation descriptions, reference is made to the location of the formations with respect to the arch.

PRE-CAMBRIAN

BASEMENT COMPLEX

Lithology: The basement complex consists of meta-igneous and meta-sedimentary rocks. The meta-igneous rock is a coarse gneissic syenite locally having large phenocrysts of feldspar. The meta-sedimentary rocks (the Grenville series) are crystalline limestones, quartzites, and garnet-pyroxene gneiss. Many of these meta-sediments contain flakes of graphite.

Thickness: The thickness is unknown.

Diagnostic Fossils: None.

Remarks: The above information was obtained from Cushing [1905]. This basement complex of highly metamorphosed igneous and sedimentary rocks underlies this area of depths of 2,000 to 5,000 feet.

UPPER CAMBRIAN

POTSDAM SANDSTONE (Emmons 1838)

Lithology: The formation consists of thin-bedded, fine-grained, grey sandstone. In several localities there is a basal conglomerate, derived from the underlying basement complex. Many bedding surfaces show ripple marks. In a few rare instances, there are thin shale interbeds.

Thickness: The thickness varies from 0 to 50 feet.

Diagnostic Fossils: *Lingulepsis acuminata* and *Palaeacmea typica* are found in these strata.

Remarks: The above information was obtained from Miller [1911] and Goldring [1931]. This is the basal formation of the sedimentary rock section in the eastern part of the area but it wedges out to the west.

TABLE 4--PROBABLE SUBSURFACE CAMBRIAN AND ORDOVICIAN STRATA OF CENTRAL NEW YORK

Time Scale		West Flank Adirondack Arch		East Flank Adirondack Arch	
Upper Ordovician		Frankfort formation		Frankfort formation	
MIDDLE ORDOVICIAN	TRENTON	Utica formation	Holland Patent member	Utica formation	Holland Patent member
		Cobourg formation	Stuben member		Loyal Creek member
			Rust member		Nowadaga member
		Denmark formation	Russia member	Canajoharie formation	Fairfield member
			Poland member		Minaville member
			Rathburn member		
		Shoreham Limestone Kirkfield (Hull) Limestone		Glens Falls formation	Shoreham member
					Larrabee member
		Rockland formation	Napanee member	Rockland formation	Amsterdam member
	Black River	Lowville Limestone		Lowville Limestone	
Lower Ordovician		Tribes Hill Limestone		Tribes Hill Limestone	
Upper Cambrian		Little Falls Dolostone		Little Falls Dolostone	
		Theresa formation		Theresa formation	
		Potsdam Sandstone		Potsdam Sandstone	
Pre-Cambrian		Basement complex		Basement complex	

From Goldring [1931] and Kay [1937, 1943]

THERESA FORMATION (Cushing 1908)

Lithology: The formation consists of alternating beds (about 1 foot thick) of fine-grained quartzose sandstone and fine-grained dolomitic limestone. The bedding surfaces often show ripple marks. In the basal, portion the limestone becomes sandy.

Thickness: It ranges from 0 to 200 feet in thickness.

Diagnostic Fossils: Lingulepsis acuminata is the dominant fossil of this formation.

Remarks: The above information was obtained from Miller [1911] and Goldring [1931]. This formation wedges out further west than the Potsdam, allowing it to lie directly on the Pre-Cambrian in the western part of the area. It represents the transition beds between the overlying Little Falls dolomite and the underlying Potsdam sandstone.

LITTLE FALLS DOLOMITE (Clarke 1903)

Lithology: The formation consists of thin-bedded, grey, fine-grained dolomite and sandy dolomite with occasional pebbly layers in the basal portion in the central and western part of the area. There are two layers of cherty dolomite, one in the upper part of the formation and the other in the lower.

Thickness: The thickness varies from 200 feet in the east to 450 feet in the west.

Diagnostic Fossil: The fossil alga, *Cryptozoön*, abounds in this formation.

Remarks: The above information was obtained from Cushing [1905] and Miller [1911]. The Little Falls dolomite, which to the east overlies the Theresa formation, lies directly upon the Pre-Cambrian basement complex in the western portions of the area.

LOWER ORDOVICIAN

TRIBES HILL FORMATION (Ulrich and Cushing 1910)

Lithology: Sandy dolomitic limestone, thin-bedded limestone, and shaly limestone with interbeds of dense limestone (calcilutite) and oölitic limestone comprise this formation.

Thickness: The formation varies from 0 to 40 feet in thickness.

Diagnostic Fossils: The formation is characterized by *Ophileta complanata*, *Finkelnburgia wemplei*, and *Eccyliomphalus multiseptarius*.

Remarks: The above information was obtained from Ulrich and Cushing [1910] and Swartz [1948]. This formation lenses out to the west of the Adirondack arch, not occurring along the western edge of the area under study.

MIDDLE ORDOVICIAN

BLACK RIVER GROUP (Vanuxem 1842)

LOWVILLE FORMATION (Clarke and Schuchert 1899)

Lithology: In the west the formation consists of sandy and shaly limestone followed by massive sub-lithographic limestone. Eastward it is a light grey, thick-bedded, dense, brittle limestone (calcilutite) characterized by vertical tubes filled with calcite.

Thickness: The Lowville varies in thickness from 0 to 40 feet.

Diagnostic Fossils: The characteristic fossil forms are *Phytopsis tubulosum*, *Tetradium cellulosum*, and *Eoleperdita*.

Remarks: The above information was obtained from Cushing [1905], Miller [1911], and Kay [1943]. The formation is thin or missing in the Mohawk Valley.

TRENTON GROUP (Vanuxem 1838)

ROCKLAND FORMATION (Raymond 1914)

Amsterdam member Ruedemann 1910

Lithology: The Amsterdam member consists of pure grey massive crystalline limestone.

Thickness: The thickness varies from 0 to 10 feet.

Diagnostic Fossils: This limestone is characterized by *Columnaria alveolata*.

Remarks: The above information was obtained from Miller [1911] and Kay [1937]. This member appears only on the east side of the Adirondack arch.

Napanee member Kay 1937

Lithology: West of the Adirondack arch the Napanee consists of 4 to 8 inch beds of black, medium-grained limestone with shale partings of equal thickness, but farther west it is a dense, chert-bearing limestone.

Thickness: The member varies in thickness from 0 to 13 feet in this area.

Diagnostic Fossils: *Triplecia cuspidata* is the guide fossil for this member. Other diagnostic forms are *Phragmolites compressus* and *Bathyurus spiniger*.

Remarks: The above information was obtained from Cushing [1905] and Kay [1937, 1943]. This member is present in lenses to the west of the Adirondack arch, but does not appear east of the arch.

KIRKFIELD (HULL) FORMATION (Johnston 1911)

Lithology: This formation is composed of thick-bedded, medium- to coarse-grained limestone[8] with shaly partings and interbedded coquinites. Some of the coarse-

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[8]Kay [1937] calls it a calcarenite.

grained beds have pararipples with a preponderant NW-SE trend.

Thickness: The thickness varies from 0 to 45 feet.

Diagnostic Fossils: The index fossils for this formation are *Parastrophina hemiplicata*, *Encrinurus cybeleformis*, *Hemiarges paulianus*, and *Bathyurus ingalli*.

Remarks: The above information was obtained from Kay [1937, 1943]. This formation is only found to the west of the Adirondack arch, but is the correlative of the Larrabee member of the Glen Falls formation (see below).

GLENS FALLS FORMATION (Ruedemann 1912)

Larrabee member Kay 1937

Lithology: Thin-bedded, medium-grained limestone, coarser in the upper part, comprises this member.

Thickness: In this area, it ranges in thickness from 15 to 25 feet.

Diagnostic Fossils: This member has the same index fossils that are listed above for the Kirkfield formation.

Remarks: The above information was obtained from Kay [1937]. This member, appearing only to the east of the Adirondack arch, is the equivalent of the Kirkfield formation to the west.

Shoreham member Kay 1937

See the description of the Shoreham formation below.

SHOREHAM FORMATION (Kay 1937)

Lithology: The formation consists of dark grey, calcareous claystones and shales in the east, changing to coarse limestones west of the Adirondack arch. There are many interbedded coquinites throughout the formation.

Thickness: The thickness varies from 16 to 41 feet.

Diagnostic Fossils: The characteristic fossils of these rocks are *Cryptolithus tesselatus*, *Praesopora orientalis*, and *Trematis terminalis*.

Remarks: The above information is from Kay [1937]. These *Cryptolithus tesselatus*-bearing limestones in the eastern part of the area are considered part of the Glens Falls formation and so have member status, but in the western part of the area, these limestones have been given formational rank. These Shoreham limestones occur throughout the entire area and appear to be the first of the Middle Ordovician formations to extend across the Adirondack arch.

DENMARK FORMATION (Kay 1937)

Rathbun member Kay 1943

Lithology: This lower member consists of a basal calcarenite (calcite sandstone) above which are inter-bedded coquinites, calcareous shale and dense lime-stone.

Thickness: It varies in thickness from 0 to 10 feet.

Diagnostic Fossils: The guide fossil for this member is *Cryptolithus quadrilineus*.

Remarks: The above information was obtained from Kay [1943]. The member is restricted to the west side of the Adirondack arch.

Poland member Kay 1943

Lithology: In the west, dense black limestone occurs at the base and the rest of the member is a shaly, fossiliferous limestone. Eastward it changes to thin-bedded, dense limestone (the "Dolgeville facies"). This member contains three thin bentonite beds.

Thickness: The member averages 60 feet in thickness in this area.

Diagnostic Fossils: The index fossils of this member are *Trocholites ammonius*, *Geisonoceras tenuistriatum*, *Endoceras proteiforme*, and *Calymene senaria* with the following forms characteristic of the lower part of the member: Sinuites cancellatus and Diplograptus amplexicaulis.

Remarks: The above information is from Kay [1937, 1943]. This member, restricted to the west side of the Adirondack arch grades laterally into the Minaville member of the Canojoharie shale (see below) lying to the east.

Russia member Kay 1943

Lithology: This member consists of shaly limestones and calcareous shales in the west which grade eastward into thin-bedded platy dense limestone (the "Dolgeville facies").

Thickness: The average thickness of this member is about 70 feet.

Diagnostic Fossils: None reported.

Remarks: The above information was obtained from Kay [1943] . This member, like the underlying Poland member, lies on the west side of the Adirondack arch. Eastward it grades laterally into the Fairfield member of the Canajoharie shale.

CANOJOHARIE FORMATION (Clarke 1911)

Minaville member Kay 1937

Lithology: This member consists of black, thin-bedded, graptolite-bearing, slightly calcareous shale.

Thickness: In this area, the thickness varies from

0 to approximately 750 feet.

Diagnostic Fossils: This member includes two of Ruedemann's graptolite zones, the basal Morphy zone characterized by Monograptus mohawkensis and the Sprakers zone with Diplograptus amplexicaulis.

Remarks: The above information was obtained from Miller [1911], Kay [1937, 1943], Ruedemann [1921], and Ruedemann and Chadwick [1935]. This member, lying on the east side of the Adirondack arch, grades laterally westward into the Poland member of the Denmark formation.

Fairfield member Vanuxem 1842

Lithology: Black, graptolitic shales and silty shales compose the entire member.

Thickness: It varies from 0 to 400 feet.

Diagnostic Fossils: This member contains the three remaining graptolite zones of Ruedemann. The lowest one is the Gansevoort zone with Glossograptus coronatus, followed by the Chutanunda or Lasiograptus eucharis zone and the Ft. Plain zone characterized by Climacograptus spiniferus. Other index fossils for this member are Diplograptus strictus and Triarthrus becki.

Remarks: The above information was obtained from Kay [1937, 1943], Ruedemann [1921], Ruedemann and Chadwick [1935]. This member lies to east of the Adirondack arch and westward it grades into the Russia member of the Denmark formation.

COBOURG FORMATION (Raymond 1921)

Rust member Kay 1943

Lithology: Interbedded, argillaceous and coquinal limestones comprise the member in this area.

Thickness: The average thickness of this member is about 115 feet.

Diagnostic Fossils: *Rafinesquina deltoides* is the guide fossil for this member.

Remarks: The above information was obtained from Kay [1943]. This member only appears along the western edge of the area grading laterally into the lower Utica shale on the west side of the Adirondack arch.

Steuben member Kay 1943

Lithology: The Steuben member consists of coarse-grained limestone and calcarenite.

Thickness: This member is approximately 60 feet thick.

Diagnostic Fossils: The most characteristic fossils are *Homotoma trentonensis* and *Fusispira subfusiformis*.

Remarks: The above information was obtained from

Kay [1937, 1943]. This member, like the underlying Rust member, appears only along the western edge of the area, grading laterally eastward into the lower Utica shale on the west side of the Adirondack arch.

UTICA FORMATION (Emmons 1842)

Nowadaga member Ruedemann and Chadwick 1935

Lithology: The Nowadaga member consists of a black, somewhat calcareous shale.

Thickness: The thickness varies from 0 to about 500 feet.

Diagnostic Fossils: The index fossils for this member are *Climacograptus typicalis*, *Glossograptus approximatus*, and *Lasiograptus eucharis*.

Remarks: The above information was obtained from Ruedemann [1925] and Kay [1937]. This member underlies the entire area, except for the western margin where it grades laterally into the Rust member of the Cobourg formation.

Loyal Creek member Ruedemann and Chadwick 1935

Lithology: The member consists of a black, laminated shale.

Thickness: It varies in thickness from 0 to 170 feet.

Diagnostic Fossils: The guide fossil for this member is *Dicranograptus nicholsoni*.

Remarks: The above information was obtained from Kay [1937, 1943]. This member underlies the entire area, except for the western margin where it grades laterally into the Steuben member of the Cobourg formation.

Holland Patent member. Ruedemann and Chadwick 1935

Lithology: The formation is black to grey, laminated,graptolite-bearing shale.

Thickness: The thickness in this area ranges from 150 to 400 feet.

Diagnostic Fossils: The fossils which characterize this member are Climacograptus pygmaeus and Glossograptus quadrimucronatus timidus.

Remarks: The above information was obtained from Ruedemann [1925] and Kay [1937, 1943]. This member underlies the entire area.

FRANKFORT FORMATION (Vanuxem 1842)

Lithology: This formation consists of alternating thin beds of black, laminated shale and dark grey, fine-grained sandstone.

Thickness: The average thickness is about 300 feet.

Diagnostic Fossils: The guide fossils for this formation are Climacograptus typicalis, Leptobolus insignis, and Triarthurus eatoni.

Remarks: The above information was obtained from Vanuxem [1842], Miller [1911], and Ruedemann [1912, 1925]. The formation underlies the entire area.

PART III

STRUCTURAL GEOLOGY

INTRODUCTION

It has been known, since the pioneer studies of Hall and Vanuxem, that the Devonian beds of central New York dip very gently toward the southwest. It has also long been known that in south central New York, a series of gentle folds are imposed on these southwestward dipping beds. Prior to Stevenson's [1948, 1949] work, however, little was known of the structural geology of Otsego County. At that time, Stevenson [1948] described several small flexures in the Upper Devonian rocks of Otsego County and later Stevenson, [1949] traced them northward into Oneida, Herkimer, and Montgomery Counties. He also noted that these flexures were not confined to the Upper Devonian.

FIELD METHODS

Because of the low dips prevalent in the region, it was necessary to contour key horizons in order to determine structural features that might be present.

Horizons for contouring were chosen on the basis of ease of recognition and widespread occurrence. The most practicable type was a contact between distinct lithologic units (e.g. sandstone and shale or shale and limestone). In the Lower and lower Middle

Devonian, three horizons were available, the Manlius-Coeymans contact, the base of the Onondaga, and the Chittenango-Cherry Valley contact. Excluding a few areas where the Manlius-Coeymans contact is transitional, each of these contacts shows clear-cut lithologic changes. The elevations determined for these horizons are given in Tables 7, 8, and 9, which appear in the appendix.

In the upper Middle Devonian sediments of Otsego County, there are, however, no extensive distinct lithologic contacts. The Moscow-Tully contact was contoured on the basis of the following stratigraphic biozones; the Pustulina zone of the uppermost Moscow, the Leiorhynchus zone of the lower Tully, the Hypothyridina zone of the middle Tully, and the Lopholasma zone of the upper Tully. At each locality, where the contact could not be recognized, its elevation was estimated by using the presumed distance above or below one or more of these recognized biozones. These determinations of elevation are listed in Table 10 in the appendix.

THE OTSEGO FOLDS

The structural contour maps of the four horizons (Plates 2, 3, 6, and 8) show 14 gentle anticlines and synclines superimposed on the southwest (S.20°W.)

regional dip of 110 ft./mi. These flexures, called the Otsego folds, are normal to the regional strike, and their magnitude decreases eastward. The representation of these structures varies on the different structural contour maps. This is due to the distribution and amount of data available. Plate 4 is a structural map of central New York with the contours drawn to represent the base of the Onondaga. Where this horizon was not visible, its approximate elevation was estimated from the available stratigraphic data. All contacts seen were in the northern portion of the map.

The effect of the southwest regional dip was removed following the method of Nevin [1942, p. 67] and the area recontoured (Plate 5). The major structures are more clearly defined after removal of the regional dip.

Following are descriptions of each of the Otsego folds from west to east.

West Winfield Anticline: The West Winfield structure extends from the northern map border to South New Berlin, a distance of 40 miles, with the axis passing 1.2 miles west of West Winfield. The trend of the axis of this anticline is more irregular than any of the other Otsego folds. At the northern end the axis strikes S.30°W., changing in the center to S.65°W. and at the southern end it strikes S.10°E. The amplitude is about 100 feet except for a pronounced increase in the vicinity of Chenango Lake caused by the deepening of the New Berlin syncline to the east. The structure is slightly asymmetrical with the steeper flank to the east. This anticline does not appear on the Cherry Valley-Chittenango horizon, probably because of lack of data, but it is well defined on all the others.

New Berlin Syncline: The New Berlin syncline extends a distance of 35 miles from the northern boundary of the mapped area to 10 miles south of New Berlin. It lies between and is about parallel to the West Winfield and Cedarville anticlines. The trend of the axis is S.22°W. to the north, changing to S.10°W. before passing through New Berlin.

The syncline is narrow and symmetrical with an amplitude of 100 feet except for a broadening and deepening near New Berlin. This enlarged portion of the structure is 15 miles long and has a maximum amplitude of 325 feet. It is well represented on the Moscow-Tully horizon map, and is recognized on the Manlius-Coeymans and base of Onandaga horizon maps, but was not recognized, probably because of lack of data, on the Cherry Valley-Chittenango horizon map.

Cedarville Anticline: The Cedarville anticline is the most pronounced of the Otsego folds. It extends from the northern edge of the area to 10 miles south of Morris. The 32 mile long axis strikes S.15°W. and passes 0.8 miles west of Cedarville. It lies between and roughly parallels the New Berlin and Butternut synclines. This well defined fold is symmetrical and plunges gently to the north. Its maximum amplitude is 420 feet at Morris. It is narrow in the north but widens rapidly southward after passing the Edmeston area. The Cedarville anticline is well shown on all horizons except that of the Cherry-Valley-Chittenango contact.

Butternut Syncline: The axis of the Butternut syncline crosses Butternut Creek in the vicinity of New Lisbon, where the strike changes from S.17°W. to S.12°E. and merges with the Mt. Vision syncline, 3 miles northwest of Oneonta. The Butternut structure is a shallow asymmetrical fold extending from the northern edge of the mapped area to 2 miles west of Oneonta, a distance of 40 miles. In the north, the amplitude is 175 feet, but it decreases to 100 feet for 8 miles in the central portion, and then increases to 225 feet in the New Lisbon area. The dip of the west flank is twice that of the east flank. This structure is well shown on the maps of the base of the Coeymans, Onondaga, and Tully horizons. It is not shown on the map of the base of the Chittenango horizon.

Jordanville Anticline: The Jordanville anticline plunges southward, extending from 4 miles north of

Jordanville to 3 miles south of Gilbert Lake. The axis trends S.15°W., but, after passing through Richfield Springs, it swings to S.50°W. for 4 miles. It plunges south at 25 ft./mi. between the towns of Morris and Laurens. The amplitude of this symmetrical fold, which lies between the Butternut and Mt. Vision synclines, is 200 feet. This flexure is seen on the Manlius-Coeymans and Moscow-Tully horizons, but is not recognized on the base of Onondaga or Cherry Valley-Chittenango horizon maps.

Mt. Vision Syncline: The Mt. Vision syncline extends from 5 miles northeast of Jordanville to 2 miles west of Oneonta, a distance of 40 miles. The axis, trending S.20°W., passes one-half mile west of Mt. Vision. This structure has a shallow saddle, just east of Richfield Springs, with an amplitude of 50 feet. North of the saddle, the amplitude is 125 feet, while south of the saddle it is 225 feet. The Mt. Vision syncline, well shown on the Manlius-Coeymans and Moscow-Tully horizons, is not recognized on the base of Onondaga or Cherry Valley-Chittenango horizons.

Oneonta Anticline: The Oneonta anticline lies between the Mt. Vision and Milford synclines and closely parallels the latter. It extends from 4 miles north of Vanhornsville to Oneonta with an axial trend of S.20°W. This fold is narrow and symmetrical, with an amplitude of 75 feet except in the south, where the amplitude increases to 150 feet; the structure widens and becomes asymmetrical, the western flank dipping more steeply than the east. It is well expressed on the Moscow-Tully horizon map, **poorly** expressed on the base of Onondaga horizon map, and not recognized on the others.

Milford Syncline[1]: The slightly sinuous axis of the Milford syncline trends S.25°W. from 3 miles north of Vanhornsville to one mile west of Cooperstown, where it changes to S.5°W. and continues to West Davenport. It lies between the Oneonta and East Springfield anticlines. For the greater part of its length, the Milford syncline is narrow, but in the vicinity of Milford, it widens and plunges south at a rate of 25 ft./mi. The fold has an average amplitude of 125 feet. It is slightly asymmetrical with the greater slope on the west flank. This structure can be seen on all horizon maps.

East Springfield Anticline[2]: The East Springfield anticline extends 30 miles S.10°W. from two miles north-

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[1] In a preliminary report on this work [Stevenson, 1949] the northern portion of this structure was erroneously called the extension of the Mt. Vision syncline.

[2] In a preliminary report [Stevenson, 1949], this structure was thought to be the northern extension of the Cooperstown anticline; however, additional work has shown the Cooperstown anticline to be nonexistent.

east of Vanhornsville to the vicinity of Schenevus. The sinuous axis passes through East Springfield. The anticline becomes wider and the plunge southward is accentuated in the Schenevus region. The average amplitude is 150 feet. The northern portion of the fold is slightly asymmetrical with a steeper eastern flank. It can be seen on all the horizon maps.

Salt Springville Syncline: The axis of the Salt Springville syncline strikes S.5°W. and passes one mile west of the village of Salt Springville. The structure is 20 miles long, extending from 4 miles northeast of Vanhornsville to 7 miles south of Cherry Valley. The Salt Springville fold is a small syncline entirely within the map area with a maximum amplitude of 150 feet. The plunge is very shallow, approximately 10 ft./mi. The structure is asymmetrical with the axial plane dipping to the west. This fold can be recognized on the Manlius-Coeymans, base of the Onondaga, and Cherry Valley-Chittenango horizon maps.

Sprout Brook Anticline: The Sprout Brook anticline is a minor structure whose axis strikes S.20°W. and passes through Sprout Brook. The structure is 5 miles long, disappearing 3 miles south of Sprout Brook. The anticline lies between the Salt Springville and Sharon Springs synclines. It has an amplitude of 125 feet and plunges south at about 10 ft./mi. It is recognized only on the Cherry Valley-Chittenango horizon map. Lack of data prevents its recognition on the other three horizons.

Sharon Springs Syncline: The Sharon Springs syncline is a gentle symmetrical fold, 7 miles long, with an amplitude of only 75 feet. Its axis strikes S.25°W., passing two miles east of Sharon Springs. It extends two miles south of U. S. Highway 20. The fold is only recognized on the Cherry Valley-Chittenango horizon.

Sharon Center Anticline: The Sharon Center anticline, lying between the Sharon Springs and Sharon synclines, is 4 miles long. From north to south it trends S.45°W. for two miles to Sharon Center, where it changes to a S.15°E. for the remaining two miles. Its amplitude is 50 feet. The structure is present only on the Cherry Valley-Chittenango horizon map.

Sharon Syncline: The Sharon syncline is the smallest of the structures. It is only three miles long with an amplitude of less than 50 feet. The axis strikes S.10°E. and crosses U. S. Highway 20, one mile west of Sharon. Like the three preceding minor structures it appears only on the Cherry Valley-Chittenango horizon.

The Sharon syncline represents the easternmost Otsego fold. No folds are known in the 12 miles between Sharon and the Schoharie Valley.

TECTONIC FEATURES OF CENTRAL NEW YORK

Introduction

It is important to find out whether the Otsego folds of central New York have any tectonic relationship to the surrounding structures. The four possible structural features are: (1) the buried Adirondack arch of central New York, (2) the Mohawk Valley faults to the north, (3) the structures of the Helderbergs, and (4) the Allegheny folds[3] to the south and southwest (see Figure 13). Each of these structural elements is described below.

The Adirondack Arch

The Adirondack arch according to Kay [1936] is an Ordovician foreland fold extending southwest from the Adirondacks through central New York. Its axis, as geographically located by Kay on stratigraphic evidence, is shown in Figure 13. The arch controlled sedimentation even where slightly submerged, separating a great thickness of clastics in the east from a thinner series of carbonates on the west. Its effects were first noted in sediments of Black River age and continued as alternate emergence and submergence took place during Trenton time.

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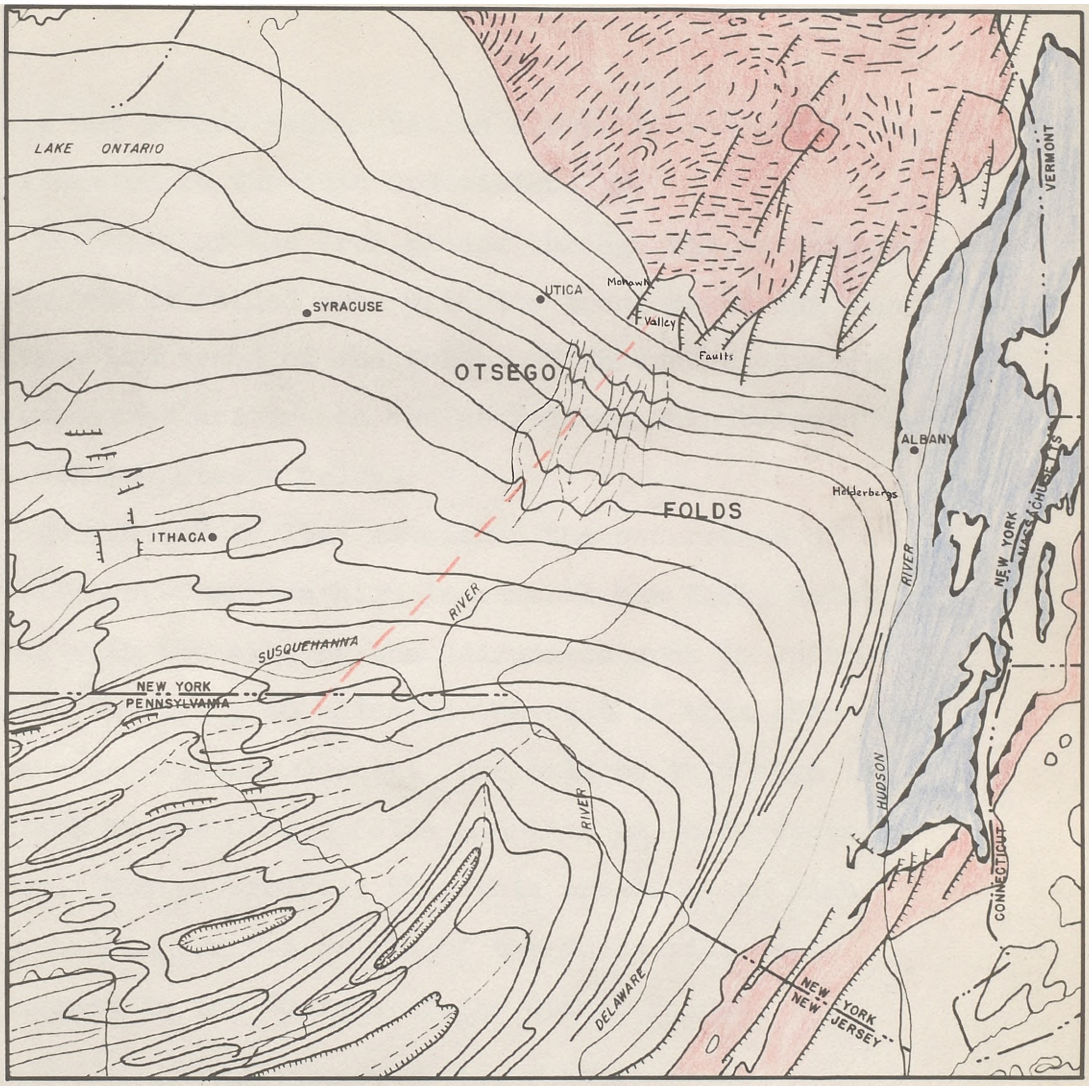
[3]Allegheny folds are the open foreland folds formed by the Appalachian orogeny that characterize the Allegheny Plateau.



LEGEND

- FORM LINES
- THRUST FAULT (TRIANGLES ON UPTHROW SIDE)
- NORMAL FAULT (HACHURES ON DOWNTHROW SIDE)
- ANTICLINAL AXIS
- SYNCLINAL AXIS
- ADIRONDACK AXIS (KAY)
- PRE-CAMBRIAN CRYSTALLINES
- TACONIC THRUST SHEET
- PALEOZOIC SEDIMENTS

FIGURE 13

TECTONIC MAP OF CENTRAL NEW YORK

N

0 25 50
MILES

ADAPTED FROM KING & OTHERS (1944)

It did not effect sedimentation after the retreat of the sea westward in the late Ordovician.

The axis of the arch passes through the western part of the Otsego folded area with its trend deviating about 18° from the trend of the folds. With such a divergence in trend, the writer can see no relationship between the arch and the Otsego folds.

Broughton[4] in 1947 mentioned the occurrence of a possible pre-Cambrian high in central New York, coinciding with the axis of the Adirondack arch in Fulton County, but lying 40 miles to the east of this arch when it reaches Delaware County. The axis of this high is parallel to the Otsego folds and lies on their eastern border. The possibility that this pre-Cambrian high has a bearing on the origin of the folds will be considered in the "Origin of the Otsego Folds".

The Mohawk Valley Faults

Horsts, grabens, and tilted blocks [Megothlin, 1938], the result of normal faulting, exist in the Little Falls-Amsterdam area along the Mohawk River, north and slightly west of the mapped area. These faults extend northward almost to the center of the Adirondack massif and southward across the Mohawk River, cutting both the pre-Cambrian crystallines and the overlying early Paleozoic

[4]Personal communication.

sediments (see Figure 13). The Mohawk Valley faults are parallel to the axis of the Adirondack arch,and Kay [1942] has attributed them to deformation along the northern part of the axis during early Silurian time. Megothlin [1938] ascribed the faulting to tensional stresses in the period of relaxation (early Silurian) following the Taconic orogeny.

Although the Mohawk Valley faults lie but 10 to 20 miles north and east of the Otsego folds, there appears to be no structural continuity between the two sets of structures.

The Structures of the Helderbergs

In the Silurian and Devonian strata of the Helderberg Mountains, there are small scale,local gentle folds and thrust faults [Darton 1894, Goldring 1943]. Although these structures and the Otsego folds may be contemporaneous in age, the area of 35 miles without any known structure which exists between these two areas seems to preclude any tectonic relationship.

Allegheny Folds

West and south of the mapped area,in New York and Pennsylvania, are the gentle open Allegheny folds. These are the foreland folds of Nevin [1949],which decrease in magnitude to the west and north of the

Appalachian structural front. They strike about N.80°E. and are asymmetrical with the axial plane dipping to the northwest. According to Bradley and Pepper [1938], the more northerly folds, although they show the general northeast trend, are shorter in length and less regular in arrangement.

Luther [1909] indicated that Seneca and Cayuga lakes occupied adjacent north-south striking synclines. Torrey [1930] extended this area of north-south gentle open folds east to Wyoming County, New York, and considered the Allegheny folds to be superimposed on them. He attributed these earlier folds to trend lines initiated in the folding of the underlying Ordovician rocks during the Taconic orogeny coupled with additional movement during the Acadian disturbance. Inasmuch as Wedel [1932] found no evidence of these older structures, and other geologists[5] working in southern New York make no mention of them, the writer feels that the existence of these north-south folds has not been proved and, therefore, cannot be considered as the answer to the present problem.

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[5]Kindle [1909], Bradley and Pepper [1938], Richardson [1941], and Woodruff [1942].

South and slightly west of the Otsego folds is the Lackawanna anthracite basin of northeastern Pennsylvania. This is a steep-sided and contorted[6] syncline whose axis changes from a N.70°E. strike in the southwest to a N.30°E. strike in the northeast. Cloos [1940] believes that the northern part of this structure indicates a decrease northward in intensity of the Appalachian folding in Pennsylvania. The southwestern part of this large syncline is parallel to the Allegheny folds, but in the northeast the structure curves until it is essentially parallel to the Otsego folds (see Figure 13).

Discussion

It has been shown that no structural relationship exists between: (1) the Otsego folds and the Adirondack arch, even though the pre-Cambrian high may have affected the origin of the folds; (2) the Otsego folds and the Mohawk Valley faults; and (3) the Otsego folds and the Helderberg structures. The Otsego folds are, however, similar in physical character to the Allegheny folds lying to the southwest in New York and Pennsylvania. The major difference is the lack of parallelism

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[6] Willard [1946]

of their strikes. There is a suggestion in the detailed structural contour map accompanying the paper by Bradley and Pepper [1938], that, north of Ithaca, the fold axes swing more northeasterly similar to the curving of the Lackawanna anthracite basin in Pennsylvania. Extension of the fold axes of the Ithaca-Elmira-Cortland area approximately 25 miles eastward might show a similar swing to the north. Both the Allegheny and Otsego folds are shallow open structures whose flank dips are measured in feet per mile.

The writer, therefore, believes, on the basis of the preceding indirect evidence and associated inferences, that the Otsego folds are a northeastward extension of the Allegheny folds of New York and Pennsylvania.

ORIGIN OF THE OTSEGO FOLDS

The Otsego folds (Allegheny or foreland folds) are considered to have been formed by the Appalachian orogeny. At that time the land mass, Appalachia, was thrust westward against the great thickness of geosynclinal sediments which yielded by folding and faulting. The most intense deformation took place along the eastern edge of the Appalachian geosyncline, decreasing in magnitude westward. It is possible that the pre-Cambrian high in central New York acted as a obstruction to lateral stress transmission causing the Allegheny folds to curve northward in the Otsego area.

ORIGIN OF THE REGIONAL DIP

The tilting, resulting in the regional dip to the southwest, might be dated as pre-Appalachian folding, contemporaneous with the Appalachian folding, or post-Appalachian folding. The first of these, the most commonly accepted possibility was suggested by Kindle [1909] who attributed the dip to a "great Canadian uplift which elevated the Paleozoic rocks of northern New York and southern Canada" prior to the Appalachian orogeny. Wedel [1932] discusses all three possibilities but does not choose between them, although he does point out that the general preference is for the idea of Kindle. As the present study produced no new information on this point, the writer sees no reason to question the conclusions of former workers.

PART IV

OIL AND GAS POSSIBILITIES IN CENTRAL NEW YORK

INTRODUCTION

Two important commodities in the modern industrialized way of life are oil and gas. The eastern United States with its great population has an increasing need of these two products of the earth. This need for additional supplies of oil and gas was the underlying cause of this investigation.

In the preceding portions of this report, the stratigraphy and structural features of central New York have been described. These descriptions and associated observations are the basis for the discussion of the oil and gas possibilities of the region.

OIL AND GAS IN NEW YORK

Historical

The first reported production of natural gas in New York State was in 1821, when settlers at Fredonia, Chatauqua County, drilled shallow wells for the purpose of securing supplies for household use. Natural gas production in western New York was not great, however, until the discovery of oil in Cattaraugus and Allegheny Counties in the 1870's when wells tapped huge flows of gas as well as oil. This soon resulted in the building of gas pipelines to industrial areas. The profit in these pipeline enterprises caused drilling operations to expand rapidly and gas fields were found in Chatauqua, Erie, Genesee, Livingstone, and other counties as far east as Onondaga and Oswego Counties.

At Limestone, Cattaragus County, in 1864, a well was drilled for oil, but it was unproductive. In the 1870's, the New York portion of the Bradford Pool [Fettke 1938] was exploited and by 1878 there were 250 producing wells in Cattaragus County. Not long after, the oil producing area of New York was enlarged to include Allegheny and Steuben Counties.

Geological

Natural gas has been found in all of the sedimentary strata beginning with the Potsdam and ending with the Chemung, except the following beds: Tribes Hill, Little Falls, Upper Ordovician black shales, Helderberg group, and the upper Hamilton shales. The principal gas zones are the Trenton limestone, the Medina sandstone, and sandstones in the Chemung formation. Oil, however, does not have as great a stratigraphic distribution, and is found only in the Oriskany, Onondaga, Tully, and Chemung formations. The bulk of New York's oil comes from thin sandstone layers in the Chemung formation.

In northwestern New York, most of the gas is produced from stratigraphic traps which are formed by changes in the permeability of the strata. In the Trenton formation the gas, however, occurs at the contact between the limestone and interbedded shale. In southwestern New York, the Allegheny folds have exercised some influence on oil and gas accumulation. Here the oil is found in water free synclines [Hartnagel and Russell, 1929] with gas in the anticlines. Oil and gas are also found in sands which pinch out up dip.

SOURCE BEDS

Source beds are those strata in which the oil and gas originated. In most instances, they are considered to be black carbonaceous shales. In central New York, there are two sets of probable source beds:

Upper Ordovician black shales: Ordovician black shales, such as the Canajoharie and Utica formations, have for sometime been considered as the source of the great quantities of gas in the Silurian Medina sandstone of western New York. Wells drilled in the vicinity of Utica have encountered pockets of gas in the Utica formation [Ashburner 1888, Orton 1899]. The author considers these shales to be the principal source of oil and gas in the Silurian rocks of the mapped area, because of their underlying position and lithologic character.

Middle Devonian shales (Hamilton): Wells passing through the lower Hamilton or Marcellus shales occasionally encounter gas pockets. Newland and Hartnagel [1932] report an oil seepage from these black shales. The upper Hamilton and Marcellus shales probably contributed some of the oil found in the Chemung sands in the New York oil fields.

RESERVOIR BEDS

Reservoir beds are the porous and permeable strata from which oil and gas are produced. Of the various strata in this area having reservoir characteristics, only three are considered able to store oil or gas in commercial quantities. All the possible reservoirs, however, are briefly described as follows:

Potsdam Formation: The Potsdam formation, a fine to medium grained sandstone, overlies the pre-Cambrian crystalline rocks in this area. Although gas has occasionally been found in the Potsdam sandstone, it never occurs in large amounts and the writer considers it a non-commercial reservoir rock.

Ordovician Limestone Facies: Ordovician limestone facies, principally the Trenton limestones, are the more likely reservoir beds. Limestones may become permeable in several ways: (1) original porosity of a reef facies, (2) solution, (3) crushing or fracturing, and (4) dolomitization[1]. In western New York gas is generally produced from contacts of the Trenton limestones with interbedded shales, but at Baldwinsville, gas is produced from two coral? reefs [Torrey 1935]. Similar conditions may prevail in central New York where these limestones underlie the entire area, thickening to the west.

<u>Oneida Formation</u>: The Oneida formation, which underlies the western part of the mapped area, consists of 8 to 10 feet of quartzitic sandstone with lenses of grit and conglomerate. The writer believes that the gas reported from a depth of 550 feet in a shallow well[2], drilled in 1921, 1 mile south of West Winfield, came from the Oneida formation. The writer has not observed the gas seep reported by Ver Wiebe [1949] in the Oneida (Clinton) near Vanhornsville. The Oneida formation is considered in this report to be the most promising reservoir rock in this area, because of its stratigraphic position and lithologic character.

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[1]Much of Ohio's oil is produced from dolomitized Trenton limestone.

[2]Well data obtained from Newland and Hartnagel [1932].

Cobleskill Formation: The sandy limestones of the Cobleskill formation may be the producing horizon in the Zoar Pool, Erie County, but in central New York, because it is not dolomitized or fractured, and does not show any solution, it is not considered a commercial reservoir rock.

Siluro-Devonian Limestone Facies: This facies includes the Manlius, Coeymans, and New Scotland formations. These limestones are neither fractured nor dolomitized to any degree and solution, with a few exceptions is very minor. They are probably not good reservoir beds.

Oriskany Formation: The Oriskany sandstone is the principal gas producing horizon of the northern Appalachians. It produces gas in New York, Pennsylvania, West Virginia, and Ohio. In Ohio it also produces oil. In central New York it is a medium-grained sandstone in part pebbly. The formation has a thickness of 6 feet 3 inches in Schoharie Valley and 1 foot 4 inches 4 miles north of Richfield Springs. Elsewhere in the area it is thin or missing. The Oriskany is considered a possible production horizon, wherever it occurs in the area.

Onondaga Formation: The Onondaga limestones have produced some light oil and a few small flows of gas in southern Erie County and western Genesee County.

This limestone formation is not believed to be fractured or dolomitized and any permeability probably would be the result of solution or the original character of a reef facies. The Onondaga underlies the entire area, but is here considered as a non-commercial reservoir rock.

OIL AND GAS TRAPS

The traps in the south central New York oil and gas fields are principally structural, but in the gas fields of the western part of the state, lithology controls the accumulation of gas.

In central New York, the Otsego folds are not of great enough magnitude to counteract the effect of regional dip and provide closures. Only stratigraphic traps therefore need to be considered. Two types of stratigraphic traps which might be productive in this area are discussed in the following paragraphs:

Lens Trap: An irregular lens-shaped body of permeable rock bounded by impervious strata is a lens trap. The Oriskany formation might form this sort of trap in central New York.

Lithologic Trap: This type of trap is caused by minor lithologic changes within a single rock unit affecting the porosity and permeability of the rock. The majority of the gas fields of western New York produce from this type of trap[3]. In sandstones, the increase or decrease of porosity is most likely caused by the amount of cementing material. An increase in the amount of cement would decrease the porosity and vice-versa. The writer believes that this type of trap can be found in the Oneida beds in the western part of the mapped area.

If the Oneida formation had wedged out up the regional dip rather than eastward, it would have formed a third type, a wedge trap.

The type of trap that produces the gas from the Trenton in western New York is not known. The gas comes from contacts between the limestones and inter-bedded shales. This type may be present in the Trenton limestones of this area.

DRILLING ACREAGE AND OBJECTIVES

It is believed that the best drilling acreage lies in the southwestern portion of the area studied. Figure 14 is a map of central New York showing this acreage and the location of the subsurface log shown

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[3]The Medina sandstone and the Trenton reef facies form this type of trap.

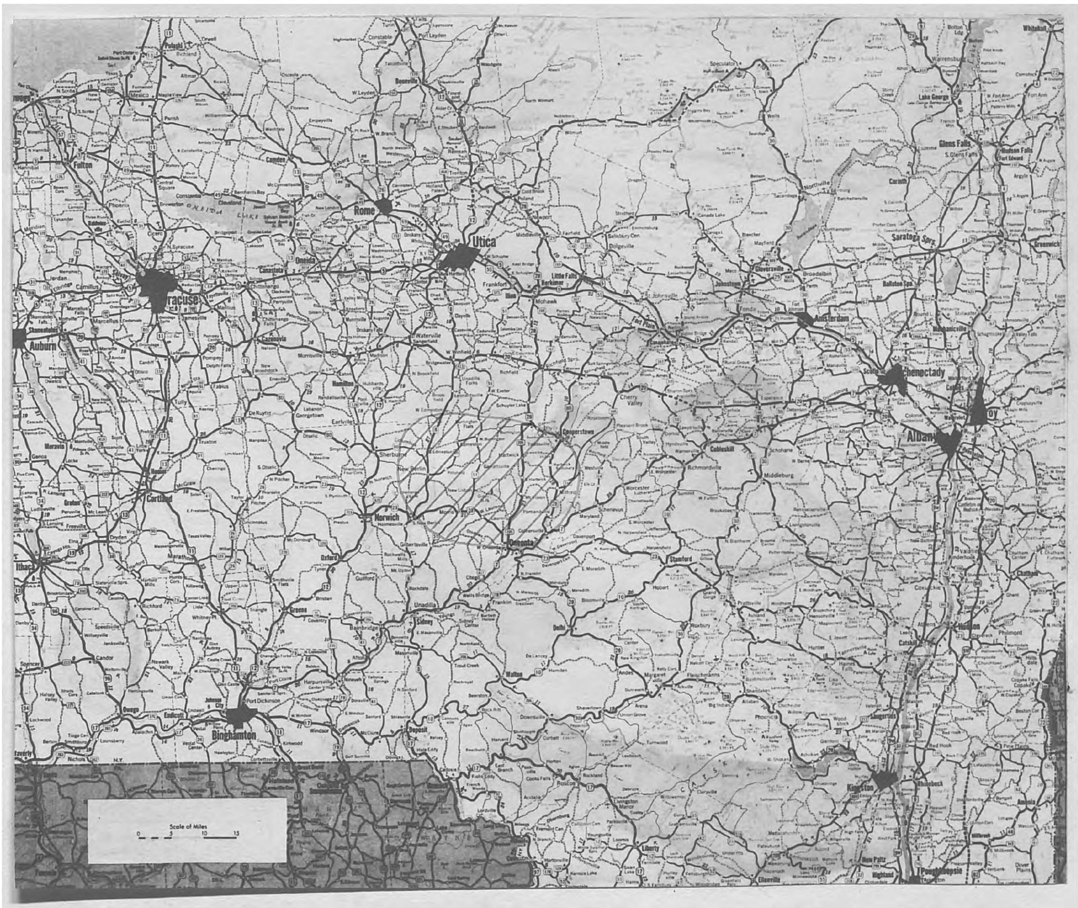

Figure 14. Possible drilling acreage in central New York.

in Table 5.

TABLE 5. PROBABLE GEOLOGIC LOG FOR A WELL LOCATED IN OTEGO VALLEY IN THE VICINITY OF NEW LISBON (NOT ON THE FLOOD PLAIN)

Alluvium	0-20 feet
Moscow sandy shale	20-200
Panther Mountain sandy shale	220-945
Marcellus shale	945-1585
(Cherry Valley limestone at 1559-1565)	
Onondaga limestone and chert	1585-1675
Carlisle Center sandy shale	1675-1680
Oriskany sandstone	1680-1682
New Scotland (Kalkberg) cherty limestone	1682-1697
Coeymans coarse limestone	1697-1747
Manlius dense limestone	1747-1850
Rondout argillaceous limestone	1850-1880
Cobleskill sandy limestone	1880-1889
Bertie argillaceous limestone	1889-1899
Camillus shales	1899-2059
Syracuse salt beds	2059-2089
Vernon red beds	2089-2314
"upper Clinton"	2314-2359
Oneida sandstone and conglomerate	2359-2369
Frankfort-Utica shales	2369-3210
Cobourg-Denmark-Shoreham limestones	3210-3540
Kirkfield coarse limestone	3540-3570
Rockland cherty limestone	3570-3580
Lowville limestone	3580-3600
Tribes Hill sandy dolomite	3600-3620
Little Falls dolomite	3620-3870
Theresa sandy dolomite	3870-3950
Potsdam sandstone	3950-3990
Crystalline basement	3990

The principal objective is the Oneida formation which lies at depths of 1,850 to 3,500 feet. The Oriskany formation at depths of 1,500 to 3,050 feet should be tested in passing. Deep drilling would encounter the Trenton at depths of 3,020 to 4,670 feet. Table 6 shows the geologic section that would be penetrated in this area. Since the horizontal extent and location of the Oneida porous facies is not known, the geographic location of a well drilled in this area cannot be based on geology. Instead, it would be based on cost.

PART V

SUMMARY

The stratigraphy of the Upper Silurian and Lower and Middle Devonian rocks which crop out in central New York[1] has been described. The lower Upper Silurian rocks are continental clastics, followed by impure marine limestones grading upward into the purer limestones of the uppermost Silurian and basal Devonian. These grade upward into cherty and shaly limestones, followed by a series of clastics. Limestone, in part cherty, overlies the clastics and is in turn overlain by a thick Middle and Upper Devonian series of shales grading upward into sandy shales and shaly sandstones with two thin limestone horizons. The Silurian rocks thin eastward, the Lower Devonian sediments thin westward, while the Middle and Upper Devonian rocks grade laterally eastward into continental deposits.

The subsurface stratigraphy of the area does not show such great lithologic variation. The Upper Cambrian sandstone[2] overlies the pre-Cambrian

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[1]For a complete list of the formations present see Table 1.

[2]For a complete list of formations present see Table 4.

crystalline rocks and grades upward through impure Cambrian dolomites to the dolomitic limestones and limestones of the Lower and Middle Ordovician. These are followed by a thick series of graptolite-bearing black shales of middle and late Ordovician age which are overlain disconformably by the Upper Silurian sediments mentioned above. The Middle Ordovician limestones thin eastward and the overlying shales thin westward.

Structural contouring of several stratigraphic horizons in the Devonian rocks disclosed a series of gentle folds, called the Otsego folds, superimposed on and normal to the strike of the gentle southwest regional dip. The Otsego folds consist of 14 parallel folds with an average amplitude of 187 feet (50 to 420 feet) and an average flank dip of 88 ft./mi. These structures are believed by the writer to be a northward extension of the Allegheny folds of the Appalachians in southern New York and northern Pennsylvania. They are later than the block faulting in the Mohawk Valley.

The principal source beds for oil and gas are the Middle and Upper Ordovician black shales. Possible reservoir rocks are the Middle Ordovician limestones, the Silurian Oneida sandstone and conglomerate, and the Devonian Oriskany sandstone. Since there are no closures in the Otsego folds, the most likely oil and gas trap is one established by the changing porosity of the reservoir bed. It is suggested that the best chances for production are in southwestern Otsego County from the Oneida sandstone and conglomerate at depths of approximately 1,850 to 3,500 feet.

A P P E N D I X

TABLE 6. ELEVATION DETERMINATIONS FOR THE MANLIUS-COEYMANS CONTACT IN CENTRAL NEW YORK

Loc. No.	Character of Contact		Elevation	Contact seen	Basis for Contact Location	Error in feet
	Manlius	Coeymans				
N8	Dense black slightly fossiliferous limestone	Coarse grey fossiliferous limestone	1558	Yes	The contact is based on the uppermost Stromatopora beds, here occurring at 1558'.	
N10	Dense black fossiliferous limestone	Coarse-grained grey fossiliferous limestone	1295	No	3' of contact covered, but it is a lithological and faunal change at 1295'-1296'.	$\pm$ 10
N27	Dense black fossiliferous limestone	Grey coarse-grained fossiliferous limestone	730	Yes	A lithological and faunal change at 730'.	$\pm$ 10
N32	Dense black fossiliferous limestone	Grey coarse-grained very fossiliferous limestone	1495	Yes	A lithological and faunal change at 1495'.	$\pm$ 10

TABLE 6 (Continued)

Loc. No.	Character of Contact		Elevation	Contact seen	Basis for Contact Location	Error in feet
	Manlius	Coeymans				
N68	Dense black slightly fossiliferous limestone	Medium-to coarse-grained fossiliferous limestone	1225	Yes	A lithologic and faunal change at 1225'.	± 10
N95	Dense dark grey fossiliferous limestone	Grey coarse slightly shaly fossiliferous limestone	1295	Yes	A lithological and faunal change at 1295'.	± 10
N103	Transition Interbedded dark grey medium-and fine-grained fossiliferous limestone		1490	Yes	A lithological and faunal transition at 1490'.	± 15
N109	Transition Interbedded medium- and fine-grained fossiliferous limestone		1385	Yes	A transitory lithological and faunal change at 1385'.	± 10
N112	Dense black fossiliferous limestone	Coarse grey fossiliferous limestone	910	Yes	A lithological and faunal change at 910'.	± 10

TABLE 6 (Continued)

Loc. No.	Character of Contact		Elevation	Contact seen	Basis for Contact Location	Error in feet
	Manlius	Coeymans				
N114	Dense black fossiliferous limestone	Coarse grey fossiliferous limestone	1527	Yes	A lithological and faunal change at 1527'	± 10
N116	Dense black fossiliferous limestone	Covered	1631	No	Dense black Manlius limestone at 1631'. Coarse Coeymans limestone at 1642'.	± 30
N118	Covered	Coarse grey fossiliferous limestone	1601	No	Coeymans limestone with abundant _Gypidula coeymanensis_ at 1601'. Dense black Manlius limestone at 1590'.	± 30
N122	Dense dark grey fossiliferous limestone	Medium-to coarse-grained grey fossiliferous limestone	1380	Yes	A lithological and faunal change at 1380'	± 10

TABLE 6 (Continued)

Loc. No.	Character of Contact		Elevation	Contact seen	Basis for Contact Location	Error in feet
	Manlius	Coeymans				
N125	Dense black fossiliferous limestone	Grey coarse-grained very fossiliferous limestone	1275	Yes	A lithological and faunal change at 1275'.	± 10
N126	Dense black fossiliferous limestone	Grey coarse-grained very fossiliferous limestone	1290	Yes	A lithological and faunal change at 1290'.	± 10
N128	Transition Medium-to fine-grained grey fossiliferous limestone		1460	Yes	A lithologic and faunal transition at 1460'.	± 10
N130	Transition Medium-to fine-grained grey fossiliferous limestone		1370	Yes	A lithologic and faunal transition at 1370'	± 10
N132	Transition Medium-grained fossiliferous grey limestone		1348	Yes	A lithologic and faunal transition at 1348'	± 10

TABLE 6 (Continued)

Loc. No.	Character of Contact		Elevation	Contact seen	Basis for Contact Location	Error in feet
	Manlius	Coeymans				
N133	Dense black fossiliferous limestone	Grey coarse-grained fossiliferous limestone	1565	Yes	A lithological and faunal change at 1565'.	± 10
N134	Dense black fossiliferous limestone	Grey coarse-grained fossiliferous limestone	1359	Yes	A lithologic and faunal change at 1359'.	± 10
N136	Dense black fossiliferous limestone	Grey coarse-grained fossiliferous limestone	1349	Yes	A lithologic and faunal change at 1349'.	± 10
N140	Dense black fossiliferous limestone	Grey coarse-grained fossiliferous limestone	1200	Yes	A lithologic and faunal change at 1200'.	± 15
N144	Dense black fossiliferous limestone	Grey coarse-grained fossiliferous limestone	1275	Yes	A lithologic and faunal change at 1275'.	± 10

TABLE 6 (Continued)

Loc. No.	Character of Contact Manlius	Coeymans	Elevation	Contact seen	Basis for Contact Location	Error in feet
N146	Dense dark grey fossiliferous limestone	Coarse-grained grey fossiliferous limestone	1410	Yes	A lithologic and faunal change at 1410'.	± 10
N148	Dense black fossiliferous limestone	Coarse-grained shaly grey fossiliferous limestone	1598	Yes	A lithologic and faunal change at 1598'.	± 10
N150	Transition Interbedded dense and medium-grained fossiliferous limestone		1575	Yes	A lithologic and faunal transition at 1575'.	± 15
N152	Transition Interbedded fine- and coarse-grained fossiliferous limestone		1466	Yes	A transitory lithological and faunal change at 1466'.	± 5
N154	Dense black fossiliferous limestone	Covered	1483	No	Middle Onondaga (Babcock Hill) limestone and chert at 1495' and Manlius dense black limestone at 1481'.	± 15

TABLE 6 (Continued)

Loc. No.	Character of Contact		Elevation	Contact seen	Basis for Contact Location	Error in feet
	Manlius	Coeymans				
N156	Dense black fossiliferous limestone	Grey coarse-grained fossiliferous limestone	1580	Yes	A lithologic and faunal break at 1580'.	± 20
N157	Dense black fossiliferous limestone	Coarse grey fossiliferous limestone	1359	Yes	A lithologic and faunal change at 1359'.	± 10
N159	Transition Medium-grained fossiliferous grey limestone		1355	Yes	A lithologic and faunal transition at 1355'.	± 20
N166	Dark-medium- to fine-grained fossiliferous limestone	Coarse grey fossiliferous limestone	1520	Yes	A lithological and faunal change at 1520'.	± 10
N167	Dense black fossiliferous limestone	Coarse grey fossiliferous limestone	1286	Yes	A lithologic and faunal change at 1286'.	± 10

TABLE 6 (Continued)

Loc. No.	Character of Contact		Elevation	Contact seen	Basis for Contact Location	Error in feet
	Manlius	Coeymans				
N168	Dark-grey medium- to fine-grained fossiliferous limestone	Coarse grey fossiliferous limestone	1615	Yes	A lithological and faunal change at 1615'.	± 15
N170	Dense black fossiliferous limestone	Coarse grey fossiliferous limestone	895	Yes	A lithological and faunal change at 895'.	± 10
N171	Dense black slightly fossiliferous limestone	Coarse-grained grey fossiliferous limestone	1305	Yes	A lithologic and faunal change at 1305'.	± 10
N172	Dense black fossiliferous limestone	Coarse grey fossiliferous limestone	911	Yes	A lithological and faunal change at 911'.	± 10
N174	Dense black fossiliferous limestone	Coarse- and fine-grained fossiliferous grey limestone	635	Yes	A lithological and faunal change at 635'.	± 10

TABLE 6 (Continued)

Loc. No.	Character of Contact		Eleva-tion	Contact seen	Basis for Contact Location	Error in feet
	Manlius	Coeymans				
N176	Dense black fossiliferous limestone	Coarse grey fossiliferous limestone	874	Yes	A lithological and faunal change at 874'.	± 10
N178	Dense black fossiliferous limestone	Coarse grey fossiliferous limestone	885	Yes	A lithological and faunal change at 885'.	± 10
N180	Dense dark-grey fossiliferous limestone	Coarse grey fossiliferous limestone	890	Yes	A lithological and faunal change at 890'.	± 20
N182	Dense black fossiliferous limestone	Coarse grey fossiliferous limestone	1590	Yes	A lithological and faunal change at 1590'.	± 15
N183	Transition Interbedded fine-grained and medium-grained fossiliferous limestone		1640	Yes	A lithologic and faunal transition at 1640'.	± 15

TABLE 6 (Continued)

Loc. No.	Character of Contact		Elevation	Contact seen	Basis for Contact Location	Error in feet
	Manlius	Coeymans				
N185	Transition Interbedded fine-grained and medium-grained fossiliferous limestone		1560	Yes	A lithologic and faunal transition at 1560'.	± 15
N189	Transition Interbedded fine-grained and medium-grained fossiliferous limestone		1615	Yes	A lithologic and faunal transition at 1615'.	± 15
N193	Transition Interbedded dark-grey medium- and fine-grained limestone		1397	Yes	A lithologic and faunal transition at 1397'.	± 15
N196	Covered	Covered	1121	No	Coarse fossiliferous Coeymans limestone at 1129' and dense black Manlius limestone at 1110'.	± 20
N197	Dense black fossiliferous limestone	Medium- and coarse-grained fossiliferous grey limestone	1601	Yes	Lithological and faunal change at 1601'.	± 10

TABLE 6 (Continued)

Loc. No.	Character of Contact		Elevation	Contact seen	Basis for Contact Location	Error in feet
	Manlius	Coeymans				
N198	Dense black fossiliferous limestone	Coarse-grained grey fossiliferous limestone	1255	No	2' of contact is covered. A lithological and faunal change at 1255'.	$\pm$ 10
N200	Dense black fossiliferous limestone	Coarse-grained grey fossiliferous limestone	1322	Yes	A lithological and faunal change at 1322'.	$\pm$ 10
N201	Dense black fossiliferous limestone	Medium- to coarse-grained fossiliferous grey limestone	1675	Yes	A lithological and faunal change at 1675'.	$\pm$ 15

TABLE 7. ELEVATION DETERMINATIONS FOR THE ONONDAGA-CARLISLE CENTER CONTACT IN CENTRAL NEW YORK

Loc. No.	Character of the Contact		Eleva-tion	Contact seen	Basis for Contact Location	Error
	Onondaga	Carlisle Center				
N8	Covered	Covered	1586	No	Springfield Center limestone at 1590' and coarse Coeymans limestone at 1580'.	± 10
N20	Covered	Covered	1343	No	Millers Mills biostrome (Springfield Center limestone) at 1452' to 1460'.	± 20
N43	Covered	Covered	1420	No	Springfield Center limestone at 1425' and Carlisle Center sandy shales at 1416'.	± 20
N93	Covered	Covered	1270	No	Babcock Hill limestone and chert at 1315' and Springfield Center limestone at 1275' to 1392'.	± 30
N94	Covered	Covered	1330	No	Springfield Center limestone at 1335' and Carlisle Center sandy shale at 1325'.	± 10

TABLE 7 (Continued)

Loc. No.	Character of the Contact		Elevation	Contact seen	Basis for Contact Location	Error
	Onondaga	Carlisle Center				
N101	Covered	Covered	1357	No	Babcock Hill limestone and chert at 1360' and Coeymans coarse limestone at 1299'.	± 30
N103	Covered	Covered	1567	No	Babcock Hill limestone and chert at 1590' and coarse Coeymans limestone at 1560'.	± 20
N104	Black, shaly fossiliferous limestone	Buff, sandy glauconitic shale	1397	Yes	A sharp lithologic change at 1397'.	± 10
N106	Black, shaly fossiliferous limestone	Buff, sandy shale	1004	Yes	A sharp lithologic change at 1004'.	± 10
N113	Covered	Covered	1505	No	Springfield Center limestone at 1520' and coarse Coeymans limestone at 1500'.	± 15

TABLE 7 (Continued)

Loc. No.	Character of the Contact: Onondaga	Character of the Contact: Carlisle Center	Elevation	Contact seen	Basis for Contact Location	Error
N115	Fine-grained fossiliferous limestone	Glauconitic shaly sandstone	1362	Yes	A sharp lithologic change at 1362'.	± 15
N120	Grey, fossiliferous fine-grained limestone with chert	Buff to brown glauconitic sandy shale	1718	Yes	A sharp lithologic change at 1718'.	± 10
N121	Covered	Covered	1557	No	Springfield Center limestone at 1564' and Carlisle Center sandy shale at 1552'.	± 20
N124	Grey, fossiliferous medium-grained limestone	Buff to brown shaly sandstone	1415	Yes	A sharp lithologic change at 1415'.	± 5
N138	Grey, fossiliferous medium-grained limestone	Greenish-brown, glauconitic sandy shale	1490	Yes	A sharp lithologic change at 1490'.	± 10
N149	Covered	Covered	1458	No	Springfield Center limestone at 1470' and Carlisle Center sandy shales at 1450'.	± 20

TABLE 7 (Continued)

Loc. No.	Character of the Contact		Elevation	Contact seen	Basis for Contact Location	Error
	Onondaga	Carlisle Center				
N151	Covered	Covered	1493	No	Base of Carlisle Center sandy shales at 1450'.	± 30
N154	Covered	Covered	1492	No	Babcock Hill limestone and chert at 1495' and dense Manlius limestone at 1481'.	± 15
N163	Covered	Covered	1480	No	Springfield Center limestone at 1484' and Carlisle Center sandy shales at 1477'.	± 10
N179	Grey, fossiliferous medium-grained limestone	Buff to greenish-brown glauconitic sandy shale	1572	Yes	A sharp lithologic change at 1572'.	± 5
N187	Covered	Covered	1633	No	Springfield Center limestone at 1638' and Carlisle Center calcareous sandy shale at 1625'.	± 15

TABLE 7 (Continued)

Loc. No.	Character of the Contact		Eleva-tion	Contact seen	Basis for Contact Location	Error
	Onondaga	Carlisle Center				
N191	Covered	Covered	1445	No	Springfield Center limestone at 1455' and Carlisle Center sandy shale at 1531'.	± 20
N195	Covered	Covered	1547	No	Springfield Center limestone at 1559' and Carlisle Center sandy shale at 1545'.	± 25
N199	Covered	Covered	1715	No	Springfield Center limestone at 1718' and Carlisle Center sandy shale at 1713'.	± 7
N202	Covered	Covered	1445	No	Springfield Center limestone at 1424' and Carlisle Center sandy shale at 1416'.	± 10

TABLE 8. ELEVATION DETERMINATIONS FOR THE CHERRY VALLEY-CHITTENANGO CONTACT IN CENTRAL NEW YORK

Loc. No.	Character of the Contact		Elevation	Contact seen	Basis for Contact Location	Error
	Cherry Valley	Chittenango				
N1	Dense, black limestone	Black, limy shale	1400	Yes	Type section of the Cherry Valley. A sharp lithologic change at 1400'.	-
N2	Dense, black limestone	Black, fissile shale	1378	Yes	A sharp lithologic change at 1378'.	± 5
N16	Dense, black limestone	Black, fissile limy shale	1280	Yes	A sharp lithologic change at 1280'.	± 5
N18	Covered	Covered	1235	No	Chittenango fissile, limy shale with limy nodules at 1238'.	± 30
N19	Covered	Covered	1518	No	Seneca limestone at 1400' and Chittenango fissile shale at 1602'.	± 30
N23	Dense, black limestone	Black, fissile limy shale	1105	Yes	A sharp lithologic change at 1105'.	± 5
N41	Dense, black slightly shaly limestone	Covered	1690	No	Cherry Valley limestone at 1686' to 1690'.	± 20

TABLE 8 (Continued)

Loc. No.	Character of the Contact: Cherry Valley	Character of the Contact: Chittenango	Elevation	Contact seen	Basis for Contact Location	Error
N69	Covered	Covered	1570	No	Seneca limestone at 1550' and Chittenango fissile shale at 1575'.	± 30
N71	Covered	Covered	1426	No	Seneca limestone at 1385' and Union Springs fissile shale at 1405' to 1421'.	± 30
N73	Dense, black limestone	Black, fissile shale	1549	Yes	A sharp lithologic change at 1549'.	± 5
N74	Dense, black limestone	Black, fissile limy shale	1070	Yes	A sharp lithologic change at 1075'.	± 5
N85	Dense, black limestone	Covered	1232	No	Cherry Valley limestone from 1224' to 1232'.	
N86*	Covered	Covered	1415	No	Cherry Valley limestone at 1410'.	± 20
N194	Dense, black laminated limestone	Black, fissile limy shale	1360	Yes	A sharp lithologic change at 1360'.	± 10

*The data for this locality was obtained from C. A. Hartnagel's field notes of 26 July 1917 as the locality is now covered by an asphalt road.

TABLE 9. ELEVATION DETERMINATIONS FOR THE MOSCOW-TULLY CONTACT IN OTSEGO COUNTY

Loc. No.	Character of the Contact		Eleva- tion	Contact seen	Basis for Contact Location	Error
	Moscow	Tully				
6	Covered	Covered	1140	No	Presence of Hypothyridina venustula at 1178'-1190' in a shaly sandstone of the Laurens.	± 20
10	Covered	Covered	1280	No	Presence of Hypothyridina venustula and Leiorhynchus mesacostale at 1303' in a shaly sandstone of the Laurens.	± 40
38	Covered	Covered	1215	No	Presence of Pustulina pustulosa zone at 1175' in a sandy shale of the Windom.	± 20
52	Covered	Storm-roller sandstone	1122	No?	Presence of Leiorhynchus mesacostale at 1136' in thin-bedded sandstones of the New Lisbon, 14 feet above a storm-roller sandstone.	± 10
66	Covered	Covered	1175	No	Presence of Hypothyridina venustula and Leiorhynchus mesacostale at 1227' in a shaly sandstone of the Laurens.	± 20

TABLE 9 (Continued)

Loc. No.	Character of the Contact		Elevation	Contact seen	Basis for Contact Location	Error
	Moscow	Tully				
101	Thin-bedded sandy shale with fossils	Thin-bedded fine sandstone	1525	Yes	Presence of Pustulina pustulosa zone at 1485' in a thin-bedded sandy shale at the Windom.	± 20
110	Covered	Covered	1710	No	Presence of Hypothyridina venustula and Leiorhynchus mesacostale in a shaly sandstone of the Laurens.	± 20
112	Covered	Thin-bedded shaly sandstone with fossils	1430	No?	Presence of Hypothyridina venustula at 1500' in a shaly sandstone of the Laurens and Leiorhynchus mesacostale at 1430' in a shaly sandstone of the New Lisbon.	± 20
119	Covered	Covered	1590	No	Presence of the fimbriata zone at 1680' in a sandy shale of the West Brook.	± 30

TABLE 9 (Continued)

Loc. No.	Character of the Contact		Eleva-tion	Contact seen	Basis for Contact Location	Error
	Moscow	Tully				
124	Covered	Covered	1230	No	Presence of *Hypothyridina venustula* and *Leiorhynchus mesacostale* at 1230' in interbedded sandy shales and shaly sandstones of the Laurens.	± 40
133	Shaly sandstone and sandy shale	Storm-roller sandstone	2367	Yes	Goldring [personal comm. 1947] reports *Pustulina pustulosa* at 2340', 27 feet below the contact, here marked by a storm-roller sandstone [Cooper and Williams 1935].	-
136	Covered	Shaly sand-stone and sandy shale	1565	No?	Presence of *Leiorhynchus mesacostale* at 1565' in thin-bedded sandy shales and shaly sandstones of the New Lisbon.	± 10
139	Covered	Covered	1647	No	Presence of *Lopholasma* zone at 1707' in sandy shales of the West Brook.	± 30

TABLE 9 (Continued)

Loc. No.	Character of the Contact: Moscow	Character of the Contact: Tully	Elevation	Contact seen	Basis for Contact Location	Error
161	Thin-bedded shaly sandstone	Thin-bedded sandstone	1225	Yes	Presence of Leiorhynchus mesacostale at 1225' in platy, thin-bedded sandstone of the Laurens and the Pustulina pustulosa zone at 1191-93' in shaly sandstone of the Windom.	-
162	Covered	Shaly sandstone	1240	No?	Presence of Hypothyridina venustula at 1240' in shaly sandstone [Cooper and Williams 1935].	± 30
166	Shaly sandstone	Fossiliferous storm-roller sandstone	1280	Yes	Presence of Leiorhynchus mesacostale in a storm-roller sandstone of the New Lisbon.	-
167	Shaly sandstone and sandy shale	Fossiliferous storm-roller sandstone	1790	Yes	Presence of Leiorhynchus mesacostale at 1790' in a storm-roller sandstone of the New Lisbon and the Pustulina pustulosa zone at 1735' in sandy shale of the Windom.	-

TABLE 9 (Continued)

Loc. No.	Character of the Contact		Eleva- tion	Contact seen	Basis for Contact Location	Error
	Moscow	Tully				
175	Thin-bedded sandstone	Fossili- ferous storm-roller sandstone	1457	Yes	Presence of *Leiorhynchus mesacostale* at 1457' in a storm-roller sandstone of the New Lisbon.	± 20
176	Thin-bedded shaly sandstone	Fossili- ferous storm-roller sandstone	1505	Yes	Presence of *Leiorhynchus mesacostale* at 1505' in a storm-roller sandstone of the New Lisbon and the *Pustulina pustulosa* at 1460' in shaly sandstone of the Windom.	-
177	Thin-bedded sandy shale	Shaly sand- stone	1427	Yes	Presence of *Leiorhynchus mesacostale* at 1427' in shaly sandstone of the New Lisbon.	± 30
178	Covered	Fossiliferous thin-bedded shaly sand- stone	1320	No?	Presence of *Leiorhynchus* at 1320' to 1380' in shaly sandstone of the New Lisbon and *Hypothyridina venustula* at 1415' in shaly sandstone of the Laurens.	-

TABLE 9 (Continued)

Loc. No.	Character of the Contact		Elevation	Contact seen	Basis for Contact Location	Error
	Moscow	Tully				
179	Thin-bedded sandy shale	Fine-grained sandstone and sandy shales	1160	Yes	Presence of *Leiorhynchus mesacostale* at 1160' to 1175' in sandy shales and sandstone of the New Lisbon.	± 10
182	Covered	Sandy shale with limestone lenses	1395	No?	Presence of *Hypothyridina venustula* at 1395' in limestone lenses in a sandy shale of the Apulia (Laurens).	-
184	Covered	Thin-bedded shaly sandstone	1379	No?	Presence of *Leiorhynchus mesacostale* at 1379' in shaly sandstone of the New Lisbon and *Lopholasma* zone at 1460' in a thin limestone bed of the West Brook.	± 10
185	Sandy shales and shaly sandstones	Calcareous oölite	1145	Yes	Presence of *Hypothyridina venustula* in calcareous oölite of the Apulia at 1145' and the *fimbriata* zone at 1148' in calcareous shale.	-

TABLE 9 (Continued)

Loc. No.	Character of the Contact		Elevation	Contact seen	Basis for Contact Location	Error
	Moscow	Tully				
187	Covered	Covered	1287	No	Presence of Pustulina pustulosa zone at 1253' to 1257' in sandy shales of the Windom and the "Lopholasma" zone at 1291' in a limy sandstone of the West Brook.	± 20
190	Shaly sandstone	Thin-bedded shale and sandstone	1120	Yes	Presence of fimbriata zone in sandstone and shale of the West Brook at 1193'.	± 20
194	Covered	Covered	1570	No	Presence of Pustulina pustulosa zone in sandy shale of the Windom at 1565'.	± 20
196	Covered	Covered	1620	No	Presence of Pustulina pustulosa at 1586' in sandy shale and shaly sandstone of the Windom.	± 20
205	Covered	Covered	1297	No	Presence of Pustulina pustulosa at 1295' in shaly sandstones of the Windom.	± 20

TABLE 9 (Continued)

Loc. No.	Character of the Contact		Elevation	Contact seen	Basis for Contact Location	Error
	Moscow	Tully				
209	Thin-bedded black shale and sandy shale	Medium- to thin-bedded sandstone and shaly sandstone	1130	Yes	Presence of *Leiorhynchus mesacostale* at 1144' in shaly sandstone of the New Lisbon with a lithologic change to shale at 1130'.	± 10
210	Covered	Covered	1120	No	Presence of *Lopholasma* zone in slightly shaly sandstone of the West Brook.	± 30
220	Covered	Covered	1330	No	Presence of *Leiorhynchus mesacostale* at 1382' to 1389' in shaly sandstone of the New Lisbon.	± 30
224	Covered	Medium- to thin-bedded platy fine sandstone	1275	No?	Presence of *Leiorhynchus mesacostale* at 1275' to 1322' in fine sandstone of the New Lisbon.	± 20
225	Covered	Covered	1383	No	Presence of *Leiorhynchus mesacostale* at 1385' to 1415' in fine sandstone of the New Lisbon.	± 30

TABLE 9 (Continued)

Loc. No.	Character of the Contact		Elevation	Contact seen	Basis for Contact Location	Error
	Moscow	Tully				
227	Thin-bedded sandy shale	Medium- to thin-bedded platy fine sandstone	1155	Yes	Presence of _Leiorhynchus mesacostale_ at 1190' to 1200' in platy sandstone of the New Lisbon.	± 30
228	Thin-bedded sandy shale	Covered	1120	No?	Presence of _Pustulina pustulosa_ zone at 1120' in sandy shale of the Windom.	± 10
229	Covered	Covered	1224	No	Presence of _Leiorhynchus mesacostale_ at 1248' in sandy shales of the New Lisbon.	± 30
237	Thin-bedded sandy shale	Thin-bedded sandy shale	1258	Yes	Presence of _Leiorhynchus mesacostale_ at 1258' in sandy shales of the New Lisbon.	± 20
238	Covered	Thin-bedded sandy shale and shaly sandstone	1625	No?	Presence of _Leiorhynchus mesacostale_ at 1628' in sandy shale of the New Lisbon and _Hypothyridina venustula_ at 1695 in shaly sandstone of the Laurens.	± 10

TABLE 9 (Continued)

Loc. No.	Character of the Contact		Eleva-tion	Contact seen	Basis for Contact Location	Error
	Moscow	Tully				
240	Covered	Covered	1145	No	Presence of Leiorhynchus mesacostale at 1156' in shaly sandstone of the New Lisbon.	± 30
245	Covered	Platy thin-bedded fine sandstone	1320	No	Presence of Leiorhynchus mesacostale at 1321' to 1376' in sandstone and sandy shales of the New Lisbon.	± 10
247	Covered	Covered	1615	No	Presence of Leiorhynchus mesacostale at 1620' to 1623' in slightly shaly sandstone of the New Lisbon.	± 30
248	Covered	Covered	1640	No	Presence of Leiorhynchus mesacostale at 1350' to 1363' in fine sandstone of the New Lisbon.	± 20
249	Fine-grained sandstone and sandy shale	Platy thin-bedded sandstone	1617	Yes	Presence of Leiorhynchus mesacostale at 1617' to 1631' in sandstone and storm-roller beds of the New Lisbon	± 10

TABLE 9 (Continued)

Loc. No.	Character of the Contact		Elevation	Contact seen	Basis for Contact Location	Error
	Moscow	Tully				
250	Covered	Massive storm-roller sandstone	1480	No	Presence of Leiorhynchus mesacostale at 1485' in massive storm-roller sandstone of the New Lisbon.	± 20
251	Covered	Covered	1474	No	Presence of Leiorhynchus at mesacostale at 1496' in fine sandstones of the New Lisbon and Hypothyridina venustula at 1525' in sandstone of Laurens.	± 20
252	Covered	Covered	1420	No	Presence of Hypothyridina venustula at 1460' in the sandstones of the Laurens.	± 30

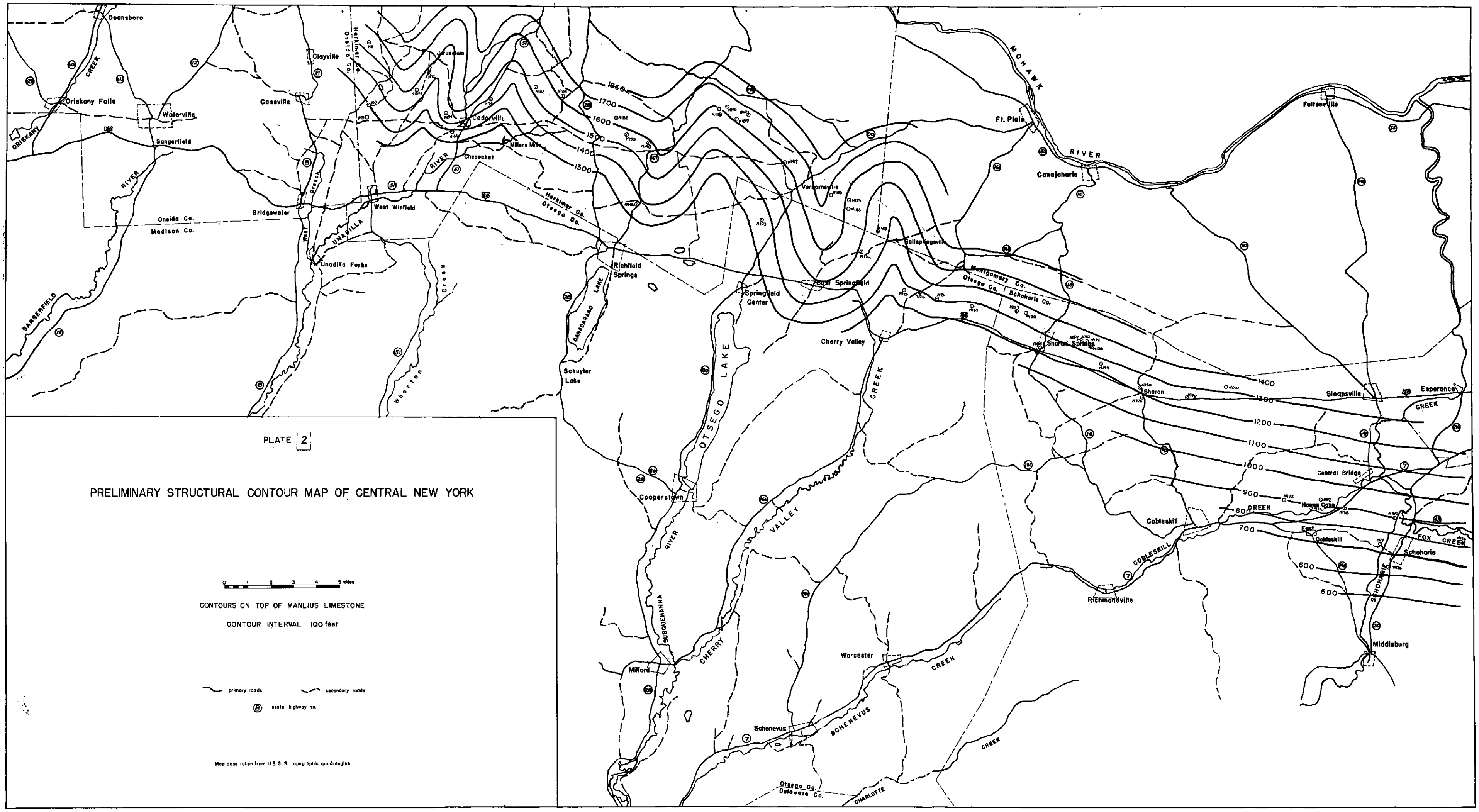
PLATE 2
PRELIMINARY STRUCTURAL CONTOUR MAP OF CENTRAL NEW YORK
0 1 2 3 4 5 miles
CONTOURS ON TOP OF MANLIUS LIMESTONE
CONTOUR INTERVAL 100 feet
primary roads
secondary roads
state highway no.
Map base taken from U.S.G.S. topographic quadrangles
Deansboro
Clayville
Jerusalem
Oriskany Falls
Waterville
Cassville
Cedarville
Sangerfield
Millers Mills
Chepachet
West Winfield
Bridgewater
Oneida Co.
Madison Co.
Herkimer Co.
Otsego Co.
Unadilla Forks
Richfield Springs
Springfield Center
East Springfield
Van Hornesville
Ft. Plain
Canajoharie
Fultonville
Montgomery Co.
Schoharie Co.
Cherry Valley
Sharon Springs
Sharon
Sloansville
Esperance
Central Bridge
Howes Cave
Cobleskill
East Cobleskill
Schoharie
Richmondville
Middleburg
Schuyler Lake
Cooperstown
Milford
Worcester
Schenevus
Otsego Co.
Delaware Co.
MOHAWK RIVER
ORISKANY CREEK
SANGERFIELD RIVER
UNADILLA RIVER
OTSEGO LAKE
CANADARAGO LAKE
SUSQUEHANNA RIVER
CHERRY VALLEY CREEK
SCHENEVUS CREEK
COBLESKILL CREEK
SCHOHARIE CREEK
FOX CREEK
CHARLOTTE CREEK
Wharton Creek
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500

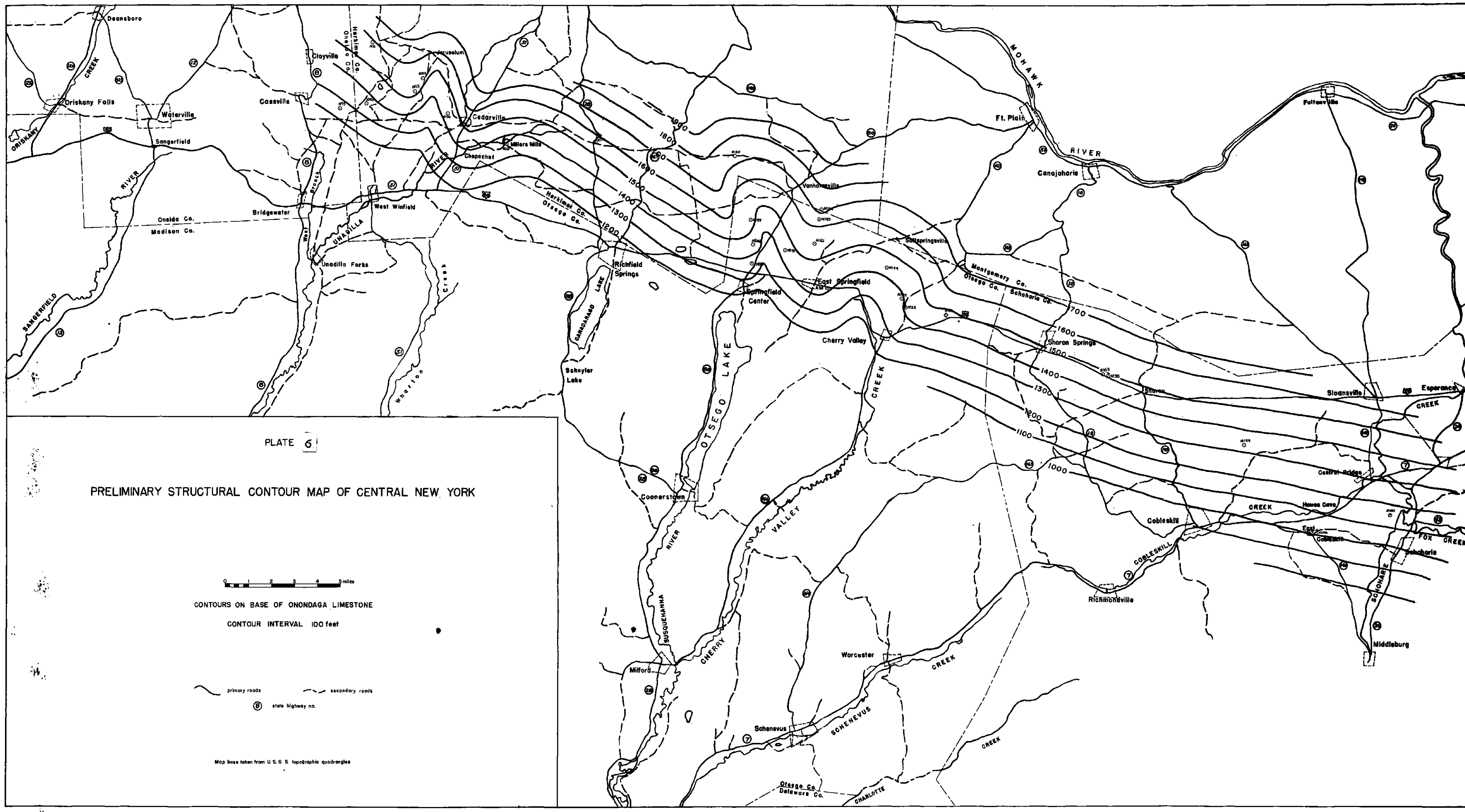

PLATE 6
PRELIMINARY STRUCTURAL CONTOUR MAP OF CENTRAL NEW YORK
CONTOURS ON BASE OF ONONDAGA LIMESTONE
CONTOUR INTERVAL 100 feet
primary roads
secondary roads
state highway no.
Map base taken from U.S.G.S. topographic quadrangles
Deansboro
Oriskany Falls
Waterville
Sangerfield
Cassville
Clayville
Bridgewater
West Winfield
Unadilla Forks
Cedarville
Millers Mills
Richfield Springs
Schuyler Lake
Cooperstown
Milford
Vanhornsville
East Springfield
Springfield Center
Cherry Valley
Ft. Plain
Canajoharie
Fultonville
Sharon Springs
Sloansville
Esperance
Central Bridge
Howes Cave
Cobleskill
Richmondville
Schoharie
Middleburg
Worcester
Schenevus
Oneida Co.
Madison Co.
Herkimer Co.
Otsego Co.
Montgomery Co.
Schoharie Co.
Delaware Co.
MOHAWK RIVER
OTSEGO LAKE
CHERRY VALLEY
SUSQUEHANNA RIVER
COBLESKILL
FOX CREEK
SCHENEVUS CREEK
CHARLOTTE CREEK
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000

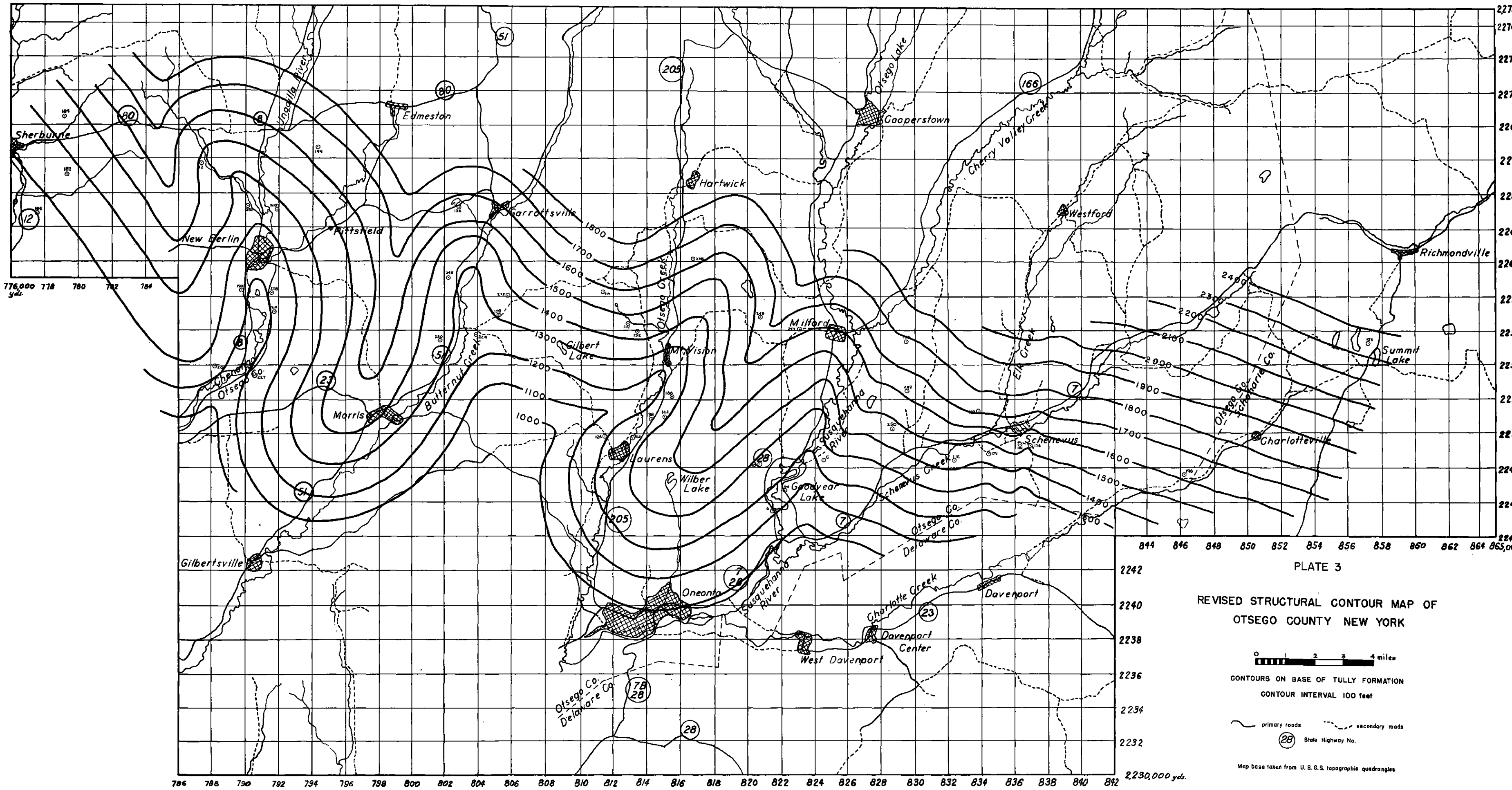

PLATE 3

REVISED STRUCTURAL CONTOUR MAP OF OTSEGO COUNTY NEW YORK

0 1 2 3 4 miles

CONTOURS ON BASE OF TULLY FORMATION

CONTOUR INTERVAL 100 feet

primary roads — secondary roads

(28) State Highway No.

Map base taken from U. S. G. S. topographic quadrangles

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VITA

Robert E. Stevenson born May 5, 1916, in Des Moines, Iowa. Parents were Caleb B. and Edythe A. Stevenson. Attended grade schools in Visalia, California, and Honolulu, T. H., and graduated in 1934 from Roosevelt High School, Honolulu, T.H. Entered University of Hawaii in 1934 and graduated in February, 1939, with a B.S. in Chemistry. After a semester of graduate work at University of Hawaii, attended the State College of Washington for graduate work in geology and received M.S. in Geology in June, 1942. In the period 1939 to 1942 was a laboratory assistant and teaching fellow in Geology at State College of Washington. In 1942, entered the employ of the Division of Geology, Department of Conservation and Development, State of Washington as a geologist. In the fall of 1944 went to Venezuela as a surface geologist for the Venezuelan Atlantic Refining Company. In 1947, returned to the United States to begin graduate work at Lehigh University. Entered the employ of Lehigh University as an Instructor in Geology. During the summers of 1947 and 1948 worked for the New York State Science Service. In September of 1948, married Thelma Morrison of Eureka, Montana. Returned to Venezuela for the summer of 1949 for the Venezuelan Atlantic Refining Company. Member Sigma Xi, Sigma Gamma Epsilon, American Association of Petroleum Geologists, American Association for the

Advancement of Science, American Geophysical Union, and Pennsylvania Academy of Science.

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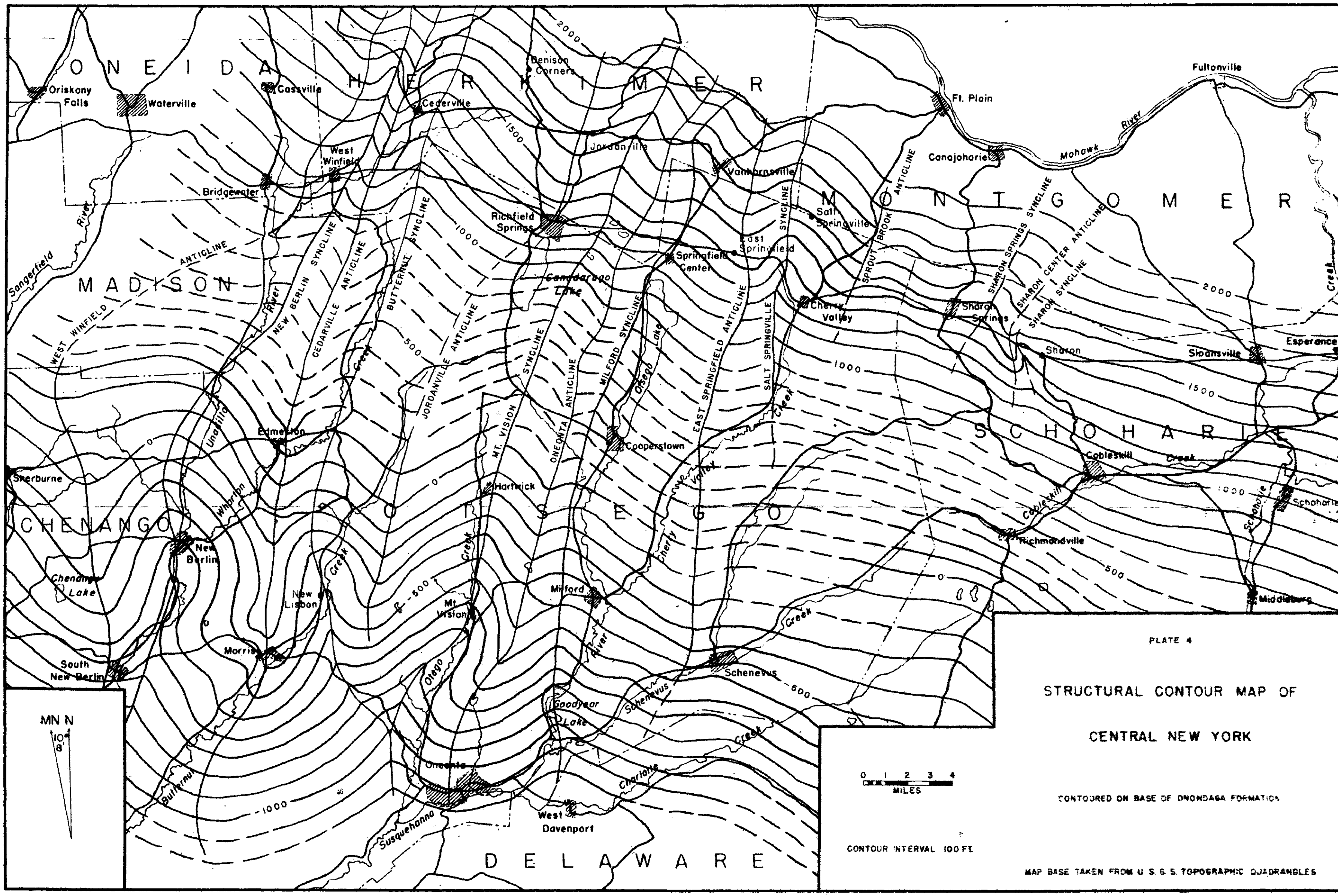


PLATE 4

STRUCTURAL CONTOUR MAP OF

CENTRAL NEW YORK

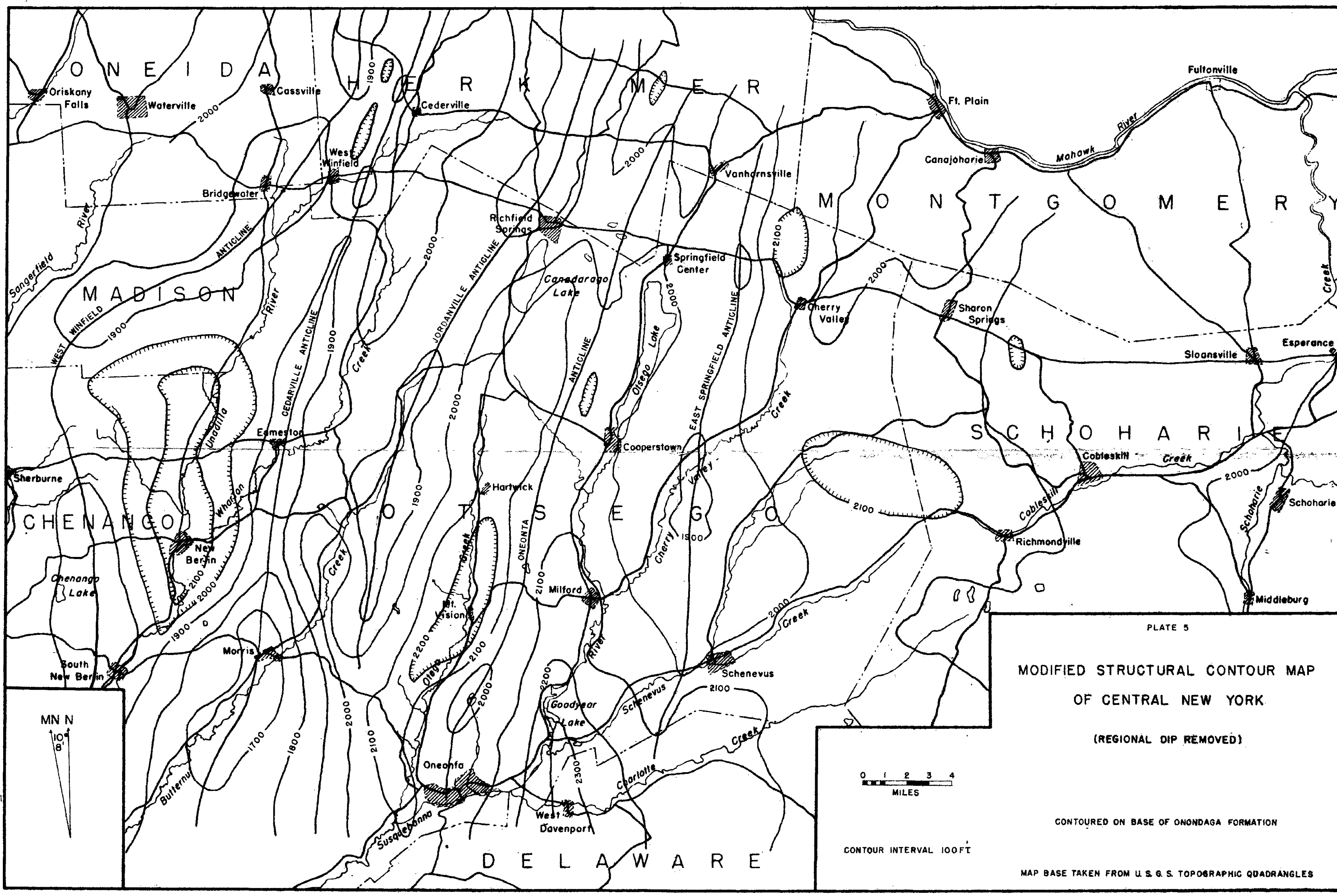


PLATE 5

MODIFIED STRUCTURAL CONTOUR MAP OF CENTRAL NEW YORK

(REGIONAL DIP REMOVED)

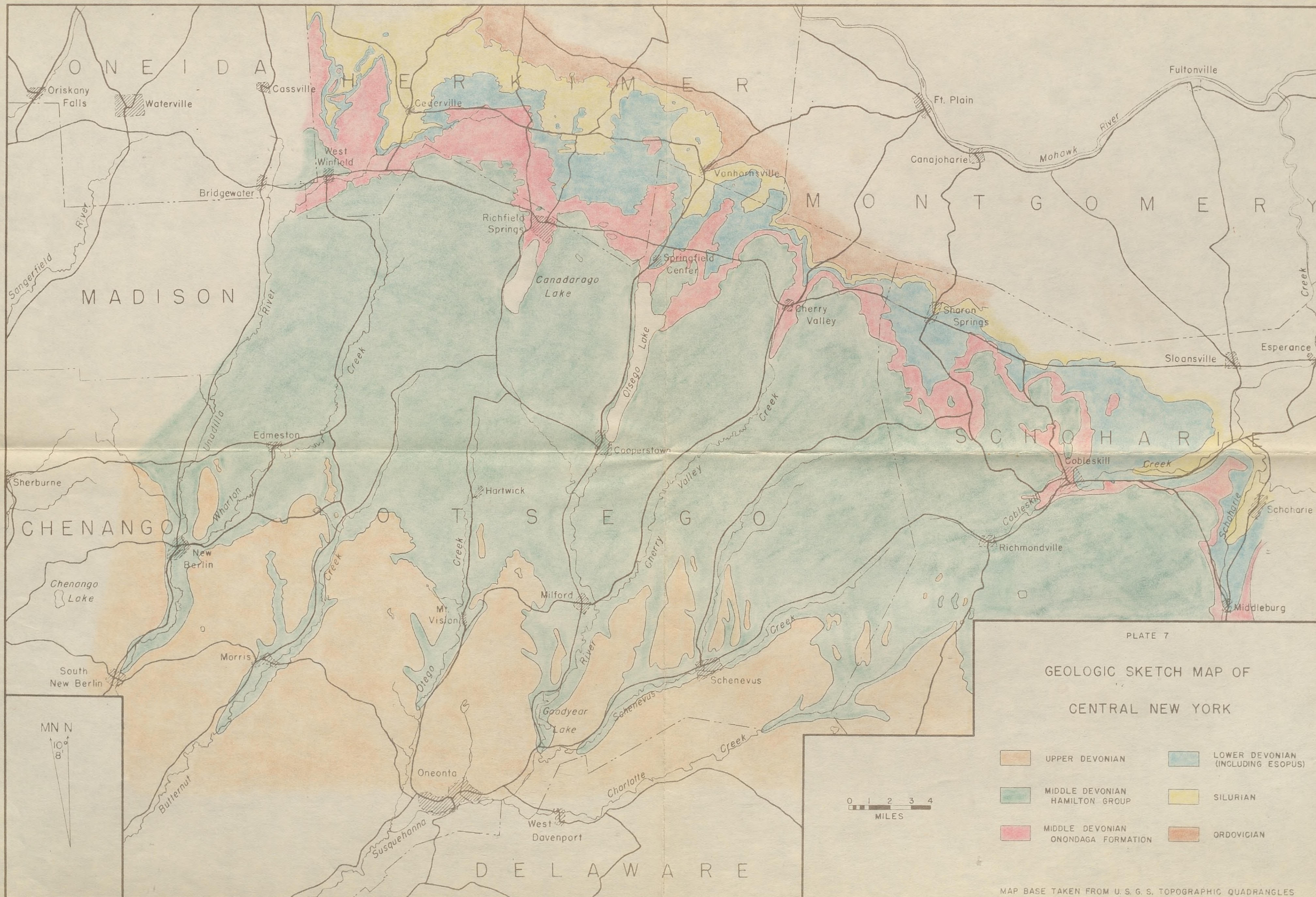
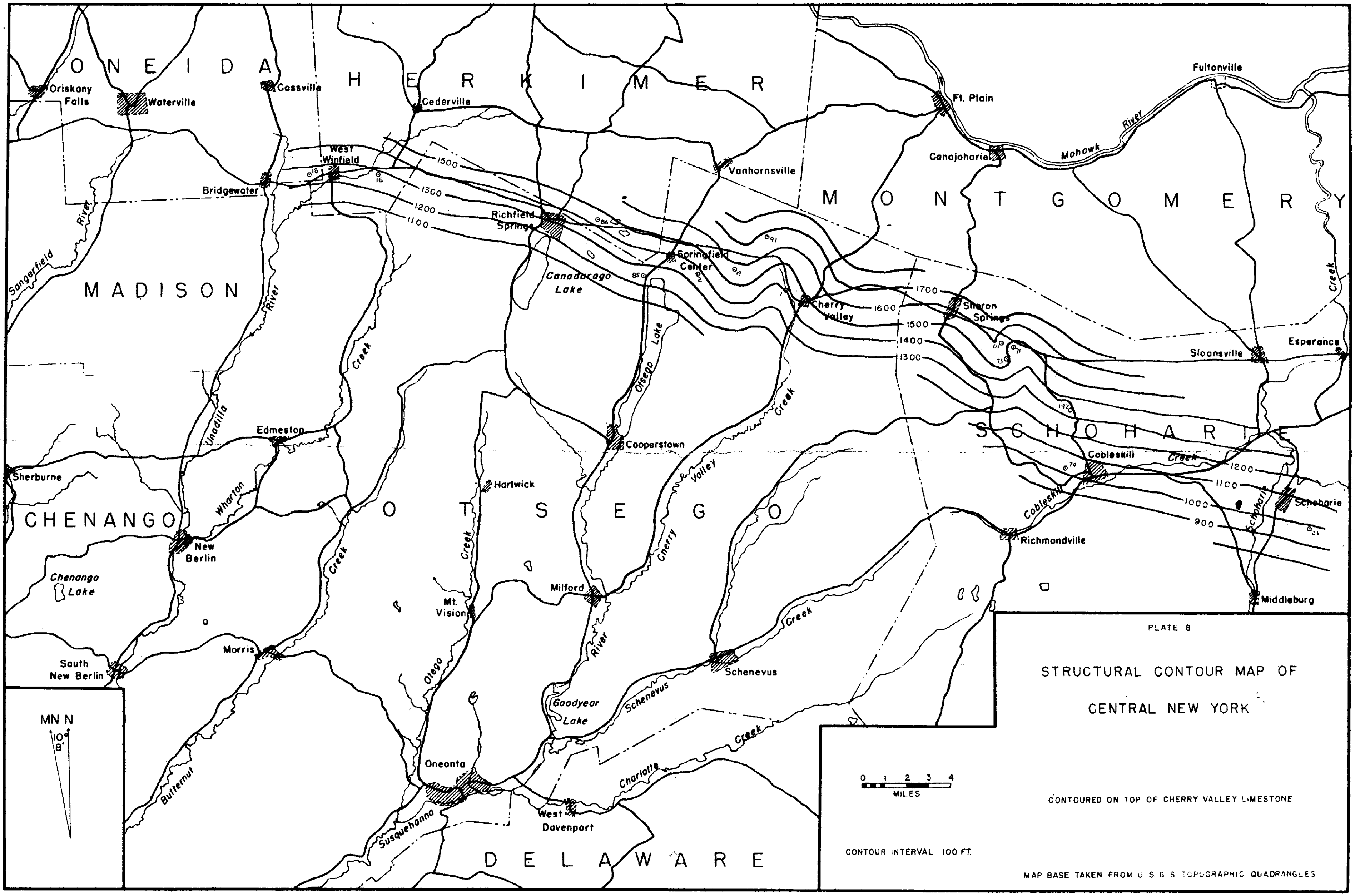


PLATE 7
GEOLOGIC SKETCH MAP OF
CENTRAL NEW YORK
UPPER DEVONIAN
MIDDLE DEVONIAN HAMILTON GROUP
MIDDLE DEVONIAN ONONDAGA FORMATION
LOWER DEVONIAN (INCLUDING ESOPUS)
SILURIAN
ORDOVICIAN
0 1 2 3 4
MILES
MAP BASE TAKEN FROM U. S. G. S. TOPOGRAPHIC QUADRANGLES
MN N
10°
8'
ONEIDA
HERKIMER
MONTGOMERY
MADISON
CHENANGO
OTSEGO
SCHOHARIE
DELAWARE
Oriskany Falls
Waterville
Cassville
Cedarville
West Winfield
Bridgewater
Richfield Springs
Canadarago Lake
Springfield Center
Vanhornsville
Ft. Plain
Fultonville
Canajoharie
Mohawk River
Cherry Valley
Sharon Springs
Sloansville
Esperance
Cobleskill
Schoharie
Richmondville
Middleburg
Cooperstown
Otsego Lake
Hartwick
Milford
Edmeston
Sherburne
New Berlin
Chenango Lake
Morris
South New Berlin
Mt. Vision
Oneonta
West Davenport
Schenevus
Goodyear Lake
Sangerfield River
Unadilla River
Wharton Creek
Butternut Creek
Otego Creek
Susquehanna River
Charlotte Creek
Schenevus Creek
Cherry Valley Creek
Cobleskill Creek
Schoharie Creek


ONEIDA
HERKIMER
MONTGOMERY
MADISON
CHENANGO
OTSEGO
SCHOHARIE
DELAWARE
Oriskany Falls
Waterville
Cassville
Cederville
Ft. Plain
Fultonville
Canajoharie
Mohawk River
Vanhornsville
West Winfield
Bridgewater
Richfield Springs
Springfield Center
Cherry Valley
Sharon Springs
Sloansville
Esperance
Canadarago Lake
Cooperstown
Otsego Lake
Edmeston
Sherburne
Hartwick
Cobleskill
Schoharie
Richmondville
Middleburg
New Berlin
Chenango Lake
Milford
Mt. Vision
Morris
South New Berlin
Schenevus
Goodyear Lake
Oneonta
West Davenport
Susquehanna
Butternut
Charlotte Creek
Schenevus Creek
Otego Creek
Cherry Valley Creek
Unadilla River
Wharton Creek
Sangerfield River
Cobleskill Creek
Schoharie Creek
1700
1600
1500
1400
1300
1200
1100
1000
900
MN N
10°
8'
0 1 2 3 4
MILES
PLATE 8
STRUCTURAL CONTOUR MAP OF
CENTRAL NEW YORK
CONTOURED ON TOP OF CHERRY VALLEY LIMESTONE
CONTOUR INTERVAL 100 FT.
MAP BASE TAKEN FROM U. S. G. S. TOPOGRAPHIC QUADRANGLES