FACIES AND THE RHINESTREET FORMATION IN SOUTH CENTRAL NEW YORK

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INTRODUCTION

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

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

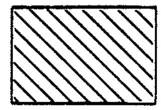
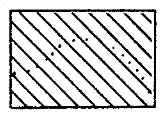
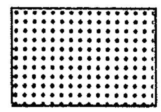
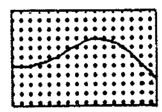
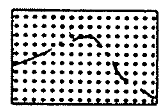
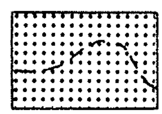
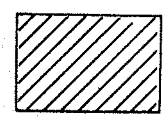
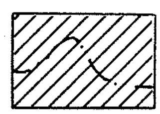
This report may serve as an introduction to the problems involved when working in the North American Upper Devonian standard section. For historical perspective, those interested should read Hall's "Report of the Fourth Geological District" and then proceed, preferably in chronologic order, through the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

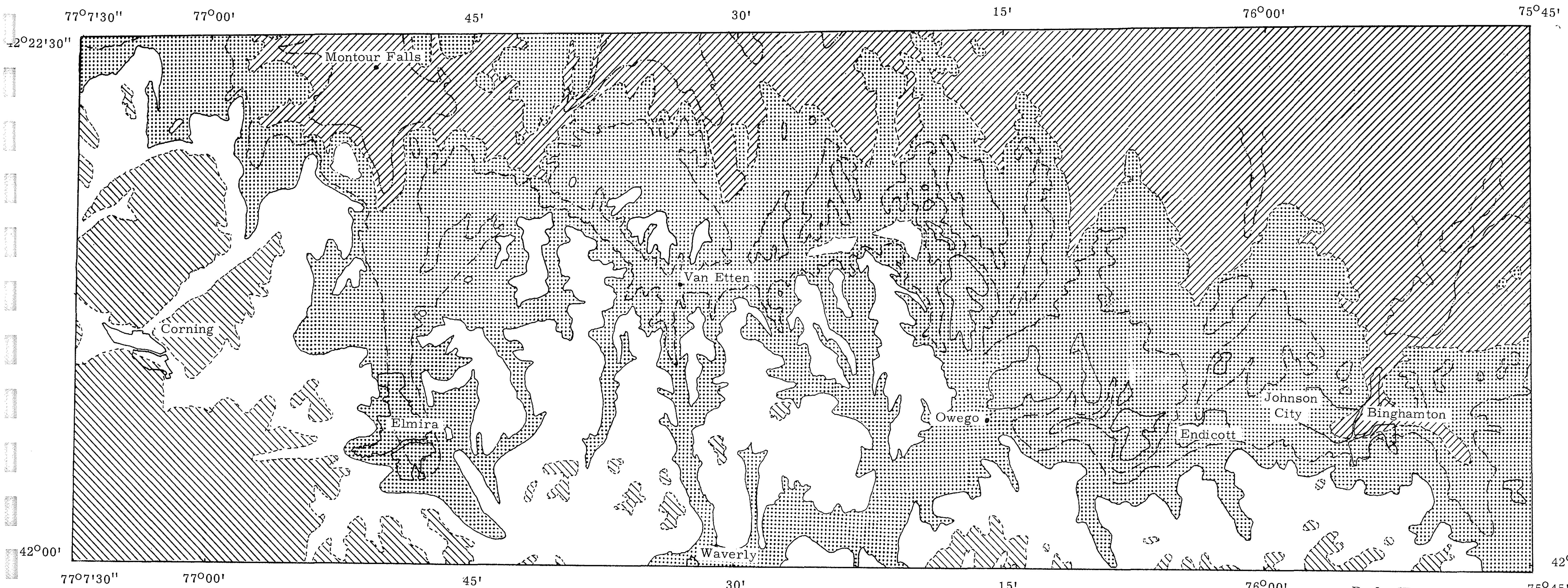
THE RHINESTREET FORMATION IN THE FIELD TRIP AREA

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

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

Figure 1. Index to Map Symbols

Formations and Members Shown	Map Symbols
Post - Rhinestreet Strata (undifferentiated)	
Corning Member of the Gardeau Formation	
Rhinestreet Formation	
Roricks Glen Member	
Dunn Hill Member	
Moreland Member	
Pre - Rhinestreet Units (Including the Sonyea, Middlesex, and Ithaca Formations; See: Figure 2.)	
Sawmill Creek Member of the Middlesex Formation (Shown near Montour Falls, West Danby, and Binghamton.)	



D. L. Woodrow, 1963

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

SCALE : MILES

4 0 4

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

Figure 1

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

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

OLDER STRATIGRAPHIC TERMINOLOGY

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

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

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

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

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

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

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

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

MAGNAFACIES

The Concept, Its Applications and Limitations

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

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

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

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

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

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

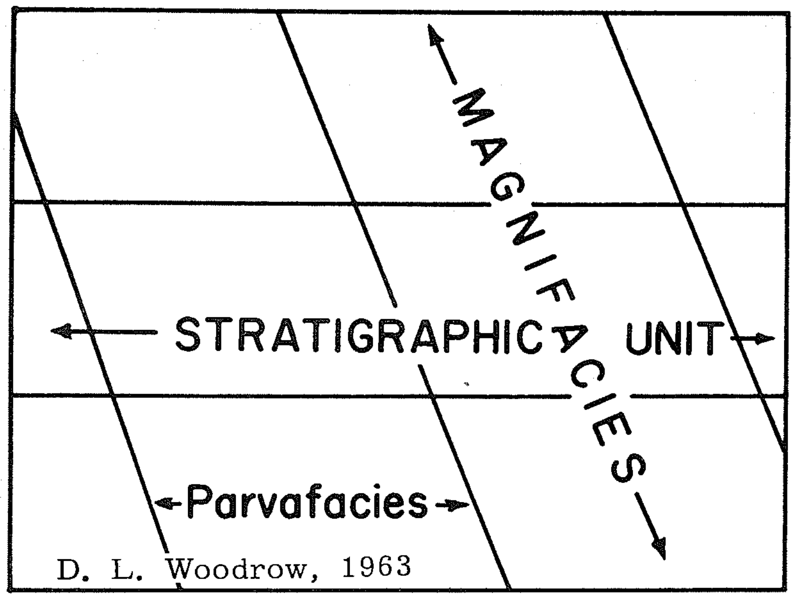
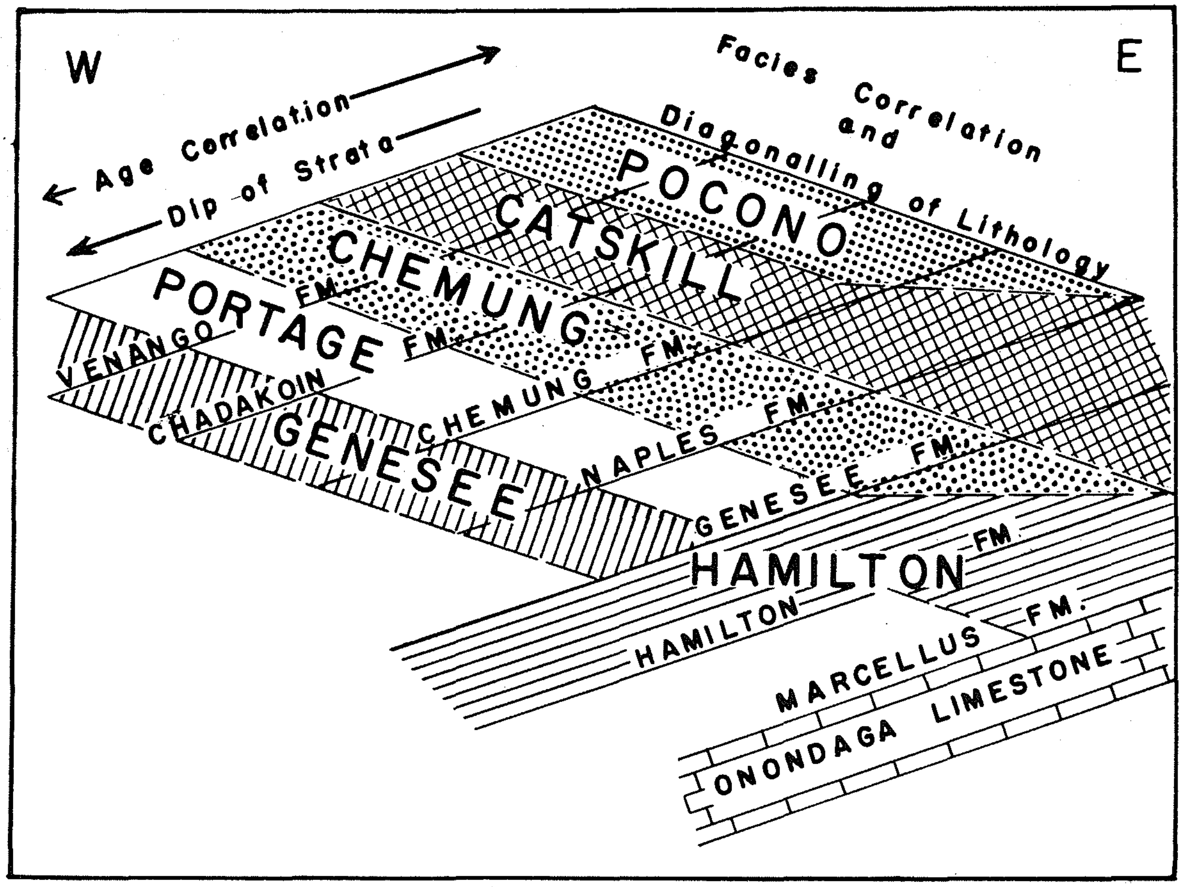


Figure 3. Relation of Formal Stratigraphic Units and Magnafacies (Modified from Caster, 1934, p. 20).



D. L. Woodrow, 1963

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

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

Chemung Lithofacies

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

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

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

Sandstone and Siltstone

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

Mudstone

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

Shale

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

Coquinite

Composed of size-sorted shells or shell fragments
Matrix of fine sand or shell fragments
Thickness variable: One or two inches to two or three feet; very lenticular
Massive, stylolites well developed; enclosed quartz grains often partially or totally replaced by carbonate.

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

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

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

Chemung Biofacies

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

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

THE STRATIGRAPHIC PROBLEM

Preliminary Statement

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

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

Techniques Applied by Previous Workers

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

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

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

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

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

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

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

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

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

Techniques Employed By The Writers

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

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

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

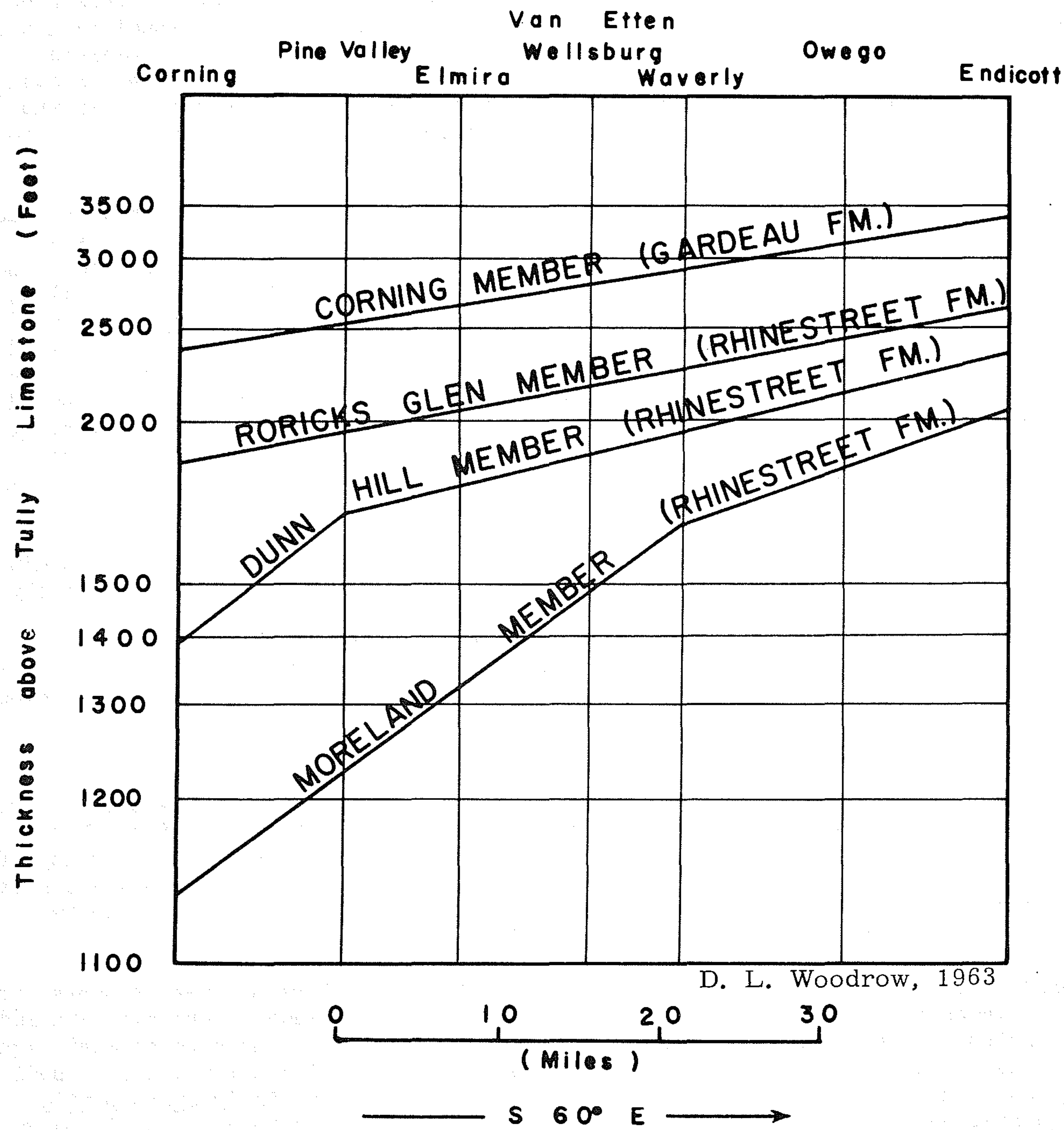


Figure 5. Post—Tully Thickening Rates

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

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

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

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

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

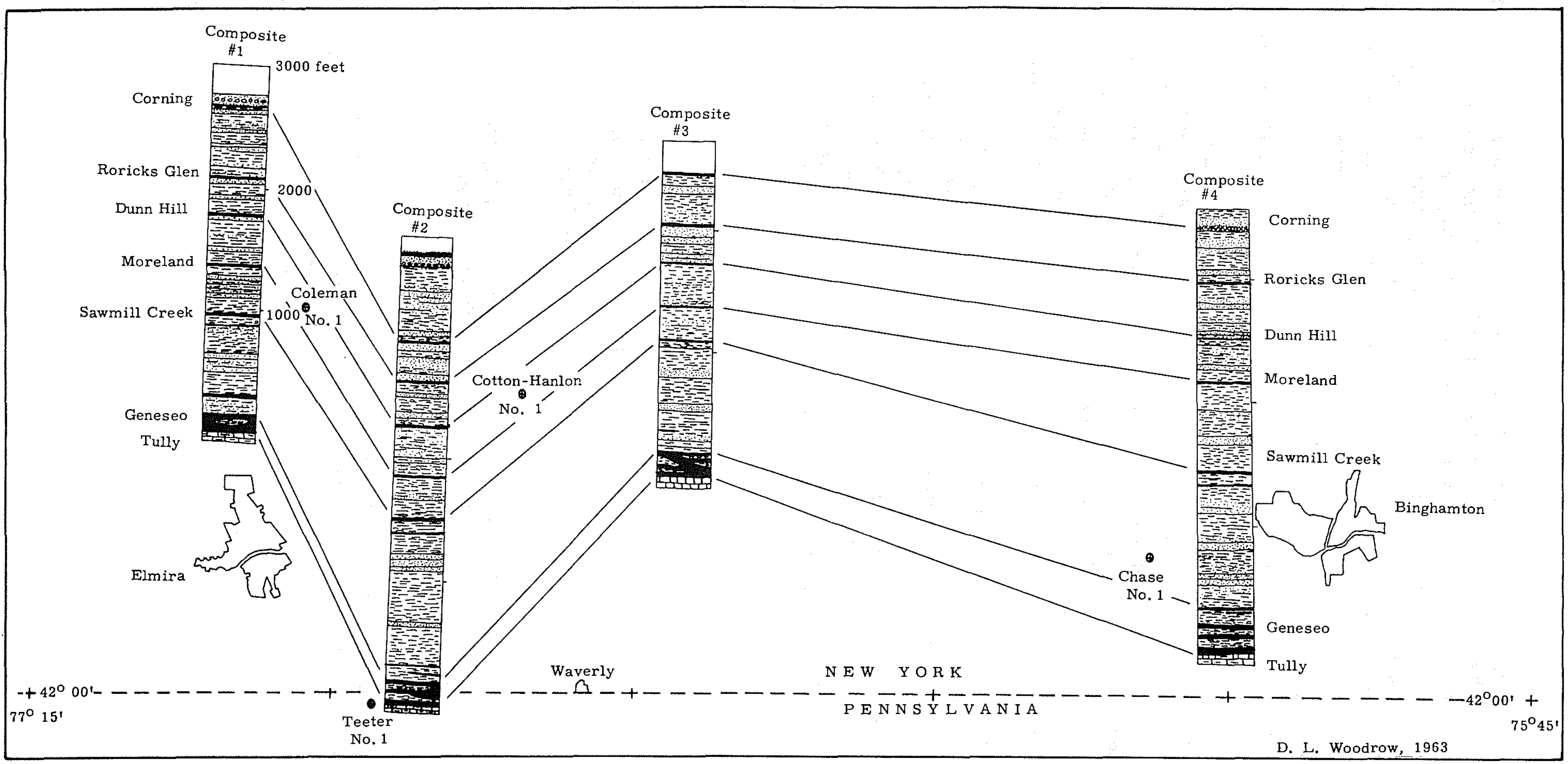


FIGURE 6. COMPOSITE SECTIONS COMPILED FROM SURFACE AND SUBSURFACE DATA

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

Map Scale: FEET 4 0 4

Sections are marked at intervals of one thousand feet.

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

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

Figure 6.

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APPENDIX A

STRATIGRAPHY IN THE APALACHIN AND BINGHAMTON QUADRANGLES

Robert G. Sutton[1]

Reconnaissance studies provide the following generalized stratigraphic section:

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

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

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

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

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

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

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

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

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

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

APPENDIX B

WELL DATA

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

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

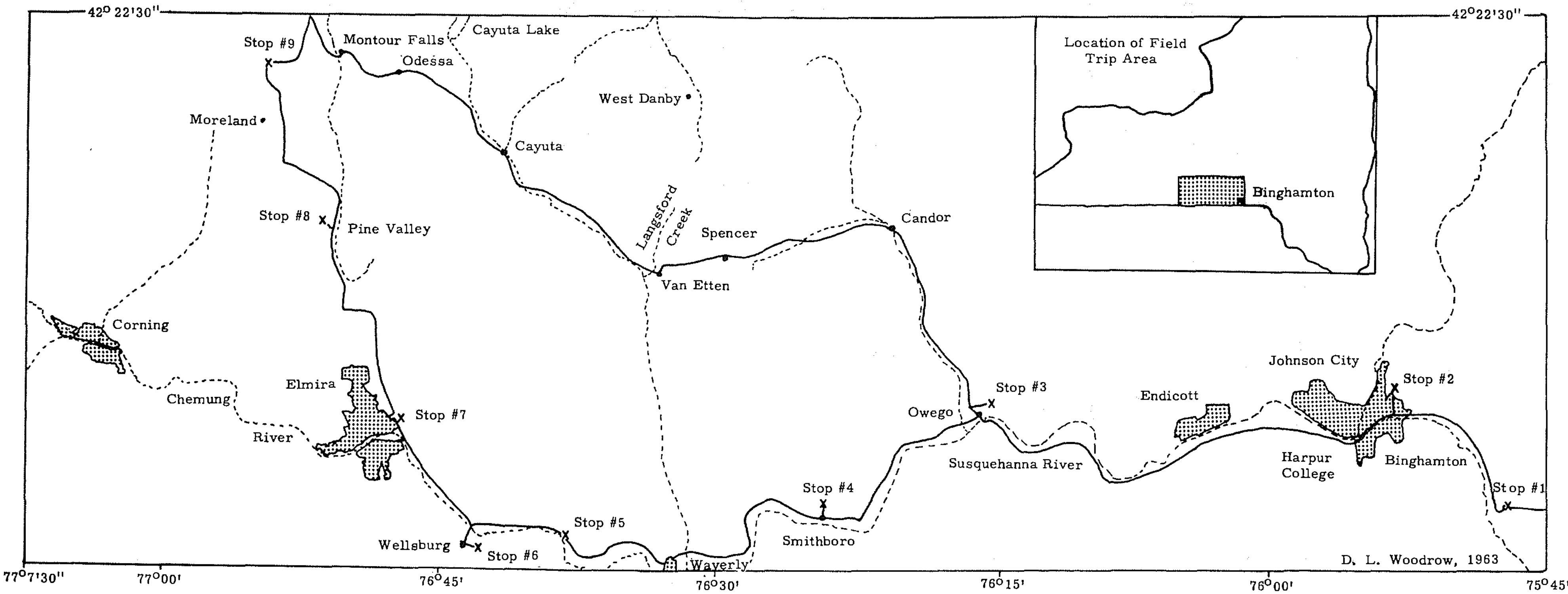

FIGURE 7. INDEX MAP SHOWING ROUTE OF FIELD TRIP AND LOCATION OF STOPS

SCALE : MILES

4 0 4

Figure 7.

APPENDIX C

ROAD LOG

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

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

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

Mileage	Description
97.3	Turn right (north) to Sullivan Street.
97.17	Turn right (east) to Watercure Hill Road.
98.0	Cross bridge over 17.
98.1	Leave busses at first dirt road to right after crossing bridge. Walk to quarries.

Stop 7. East Church Street Quarries.

Exposure of the Millport and Dunn Hill Members of the Rhinestreet. Elevation 910'.

A comparison of the lithologies displayed here with the lithologies seen in the Millport of the Binghamton region illustrates the facies changes that have occurred. At the top of this quarry may be seen the heavier-bedded siltstones and fine-grained sandstones of the upper Millport. The quarry floor and lower faces are cut into the black and very dark gray shales of the Dunn Hill Member.

Return to the busses and drive back through Elmira to route 17.

99.3	Proceed north on 17.
103.1	Intersection with New York 13; proceed west on 17.
105.0	Intersection with New York 14; turn right (north) to 14.
106.8	Stop light; turn left (north) on 14.
107.4	"Bluestone" quarry on left side (west) of road.
110.0	Village of Pine Valley; turn left (west) at paved road.
110.6	Leave busses at first dirt road to the right (north); walk to stream exposure.
111.0	Stop 8. Type Section of Dunn Hill Member.

Elevation: 1070'.

In this stream, the Dunn Hill Member is 22 feet thick and is composed of gray, silty shales and mudstones with nearly eight feet of black and very dark gray shales of which the majority is concentrated in the basal ten feet of the member. A tributary of this stream draining the hill to the south is the type section of the overlying Beers Hill Member of the Rhinestreet.

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

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

End of Trip