

MIDDLE AND UPPER DEVONIAN CLASTICS OF THE CATSKILL FRONT, NEW YORK

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STRATIGRAPHY

Introduction

The Middle and Upper Devonian of the Catskill Mountains region of southeastern New York consist of approximately 8000 feet of strata which commence with limestones at the base and grade upward through black shales, gray siltstones, gray sandstones, red beds, and, at the top, conglomerates (Fig. 3). The lowermost 2000 feet (Onondaga, Bakoven, and Ashokan Formations) are described by Chadwick (1944, p. 94-116). The purpose of this field trip is to examine the red bed-gray sandstone and conglomerate facies or depositional phases (Rickard, 1964) that have been referred to as "Catskill."*

Detailed Stratigraphy

PLATTEKILL FORMATION

The oldest red-bed formation in this area is the Plattekill, which is characterized by three tongues of grayish-red (10 R 4/2) claystone and shale interbedded with medium-dark-gray (N4) shale and cross-bedded sandstone. The base of the Plattekill Formation is drawn at the base of the lowest red bed, because the gray shales and sandstones are indistinguishable from those of the Ashokan Formation. The Plattekill Formation is named for exposures in Plattekill Creek at West Saugerties, New York (Kaaterskill quadrangle). The name was introduced to replace, in part, "Kiskatom" which was employed by Chadwick (1933, p. 482) for alleged Hamilton non-marine strata (Fletcher, 1962, p. D3).

The formation has a maximum thickness of 1000 feet at the Catskill Front, but thins rapidly westward because of the wedging-out of the two lowest tongues (Fig. 5). The lowest tongue is only 125 feet thick and is difficult to trace on the surface. The middle tongue is thicker and can be identified both on the surface and in the subsurface by the presence of two thin, light-gray sandstones which contrast markedly with the more common dark-gray sandstones. The upper tongue measures 250 feet at the Catskill Front, but thins to a feather-edge in the subsurface near Margaretville. The most complete exposures of this tongue are located in Plattekill Clove and Kaaterskill Clove.

The lowermost 690 feet of the Plattekill is composed of medium-dark-gray (N4) shales, siltstones and fine- and medium-grained subgraywackes. Interbedded fine-grained, grayish-red (5 R 4/2) sandstones, shales, and claystones are present in minor quantities and are concentrated in the three tongues described above. Red beds in this part of the Plattekill do not exceed 10 feet in thickness and average five feet. A distinctive medium- to coarse-grained, light-medium-bluish-gray (N7-5B7/1) subgraywacke sandstone and grayish-black (N2) to medium-dark-gray (N4) shale interval lies approximately 800 feet below the top of the formation and serves as a useful marker bed for the lower part of the unit at the Catskill Front (Lucier, 1966, p. 8). The upper 300 feet is composed almost entirely of grayish-red shales, siltstones, and claystones (the upper tongue). Sedimentary cycles (Fig. 6) are well-developed in the red-bed portions of the Plattekill and are composed of a fining-upward sequence of sandstone (gray or red), at the base, followed by red siltstone, red shale and claystone, and, at the top, a thin layer of greenish-gray claystone. The cycles are generally less than 20 feet in thickness.

*Rickard (1964) calls the conglomerate phase "Pocono."

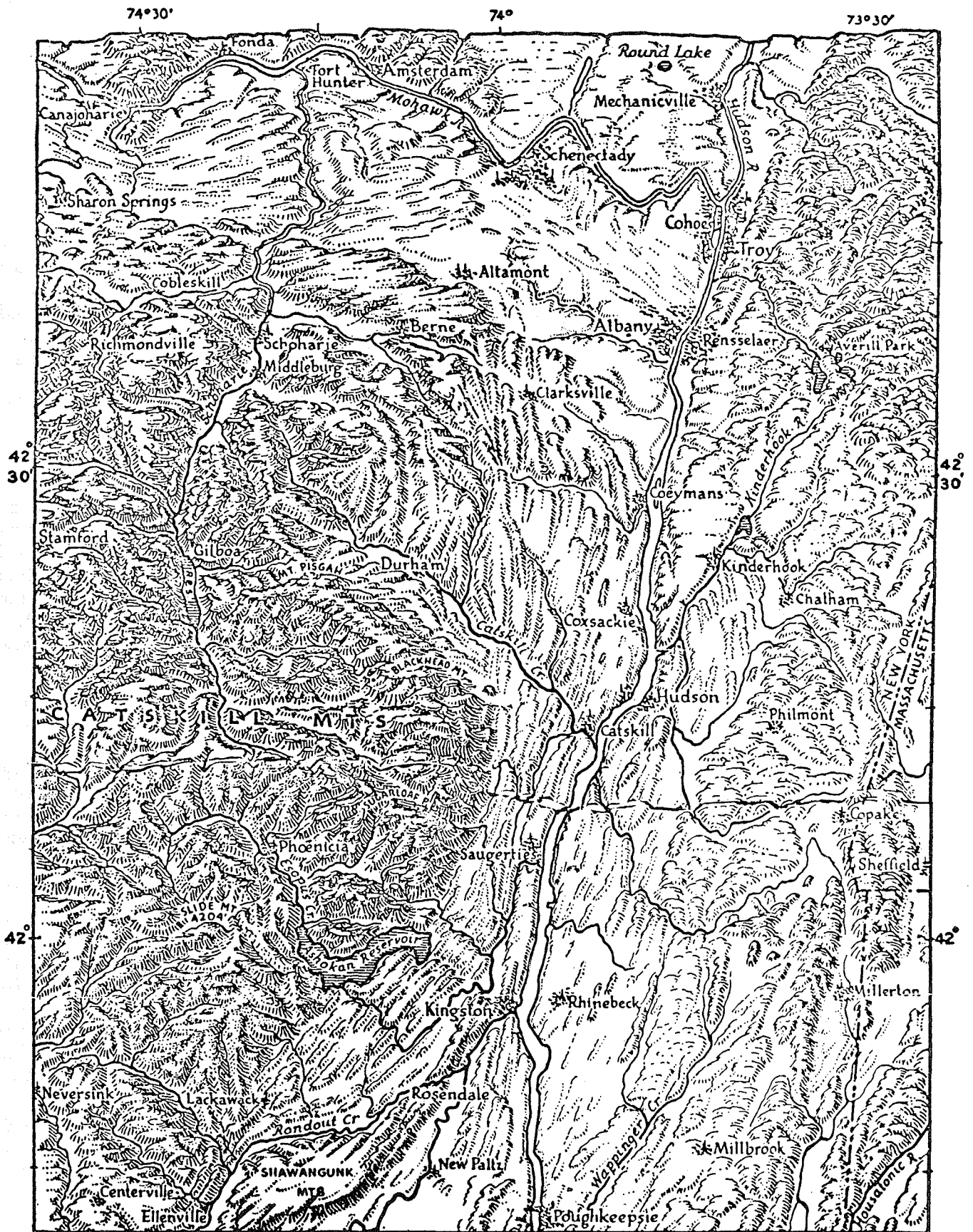


Figure 1. Physiography of the Catskill Front and the Hudson Valley (from Berkey, 1933).

POTTER HOLLOW FORMATION

The Plattekill is overlain by the Potter Hollow Formation which consists of medium-dark-gray (N4) shales and subgraywackes, and smaller amounts of very distinctive light-olive-gray (5 Y 5/2) sandstones. It is 250 feet thick in the subsurface at Phoenicia, New York and contains a substantial amount of shale. The Potter Hollow thins to 212 feet and becomes more sandy at the Catskill Front where it forms a continuous ridge between the 1390 and 1580 foot elevations. The upper and lower contacts of the unit are sharply delineated by the red-bed lithologies of the Manorkill and Plattekill Formations respectively.

The Potter Hollow Formation originally was believed to be an easterly extension of part of the Gilboa Formation (Fletcher, 1963, p. 32), but subsequent field tracing has established that it is an easterly tongue of the Cooperstown Formation (Fig. 5). The Portland Point Limestone of the upper Hamilton lies within the Potter Hollow. Extensive and detailed studies by McCave (1965, p. 103) have greatly increased our knowledge of this unit.

MANORKILL FORMATION

The Manorkill Formation, like the Plattekill, is distinguished by the presence of red beds although it is thinner than the Plattekill. The sandstones of the Manorkill also serve to characterize the formation. They are fine-grained, medium-dark gray (N4) in the lower half, but medium-grained and medium gray (N5) in the upper half. The Manorkill can be recognized, therefore, everywhere along the Catskill Front by the presence

Mather 1840	Chadwick 1933	Chadwick 1936	Fletcher 1963	Fletcher this report	
Catskill Mountain Series	Catskill	Slide Mt.	Wittenberg	Slide Mt.	
		Wittenberg			
		Katsberg	Walton	Walton	
	Stony Clove				
	Oneonta	Oneonta	Twilight Park	Oneonta	
		Onteora			
	Kiskatom	Kiskatom	Kaaterskill	Oneonta	Gilboa Manorkill Potter Hollow
			Kiskatom	Gilboa	
			Kiskatom	Plattekill	
		Lower Hamilton	Ashokan	Ashokan	Ashokan
			Mt. Marion	Mt. Marion	Mt. Marion
	Bakoven		Bakoven	Bakoven	

Figure 2. Comparative stratigraphic nomenclature for the Catskill Front.

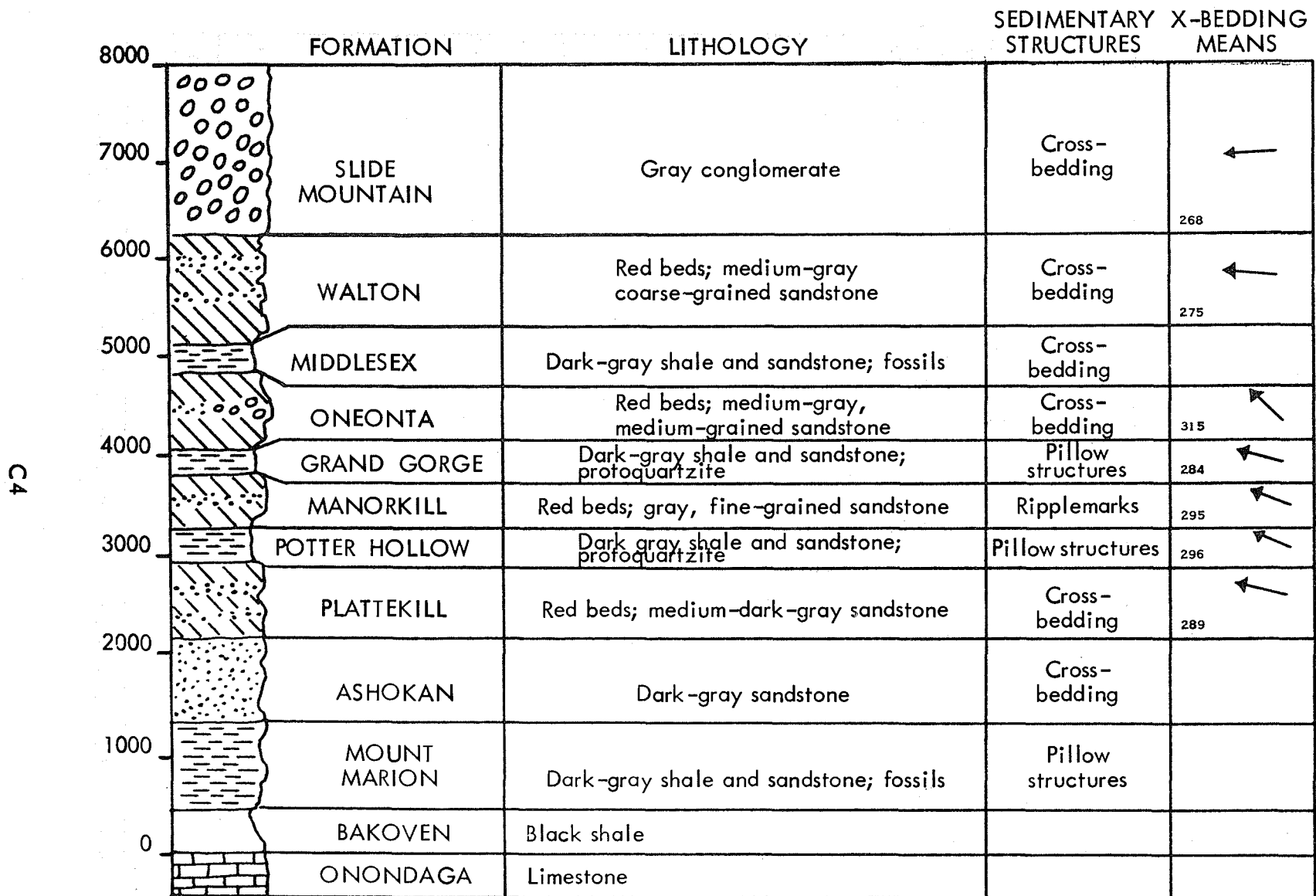


Figure 3 Idealized composite stratigraphic column of the Catskill Mountains region (slightly modified from Fletcher, 1964).

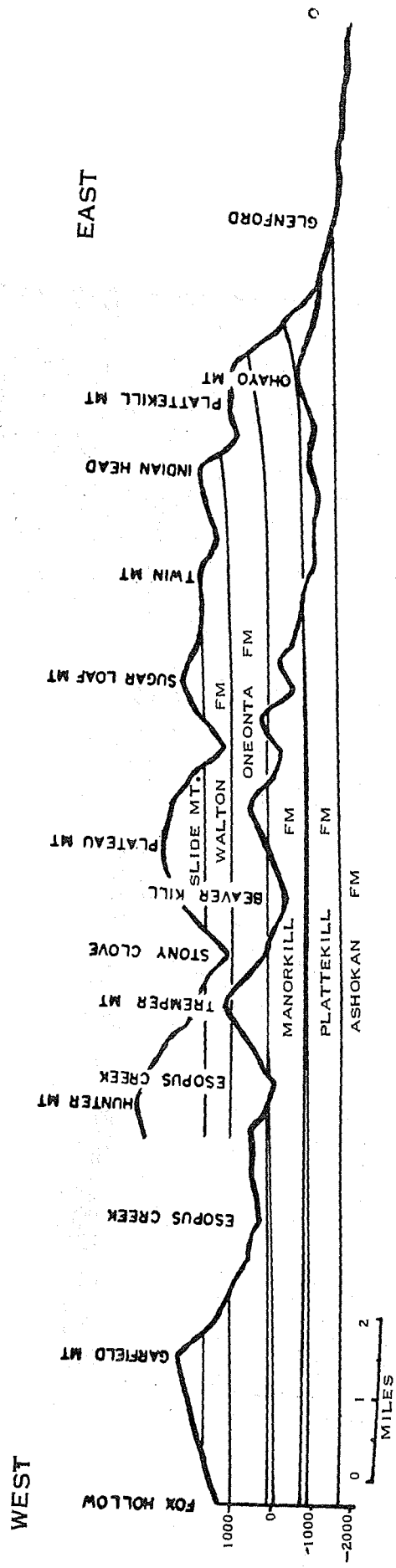


Figure 4 Geologic cross-section of the Catskill Front.

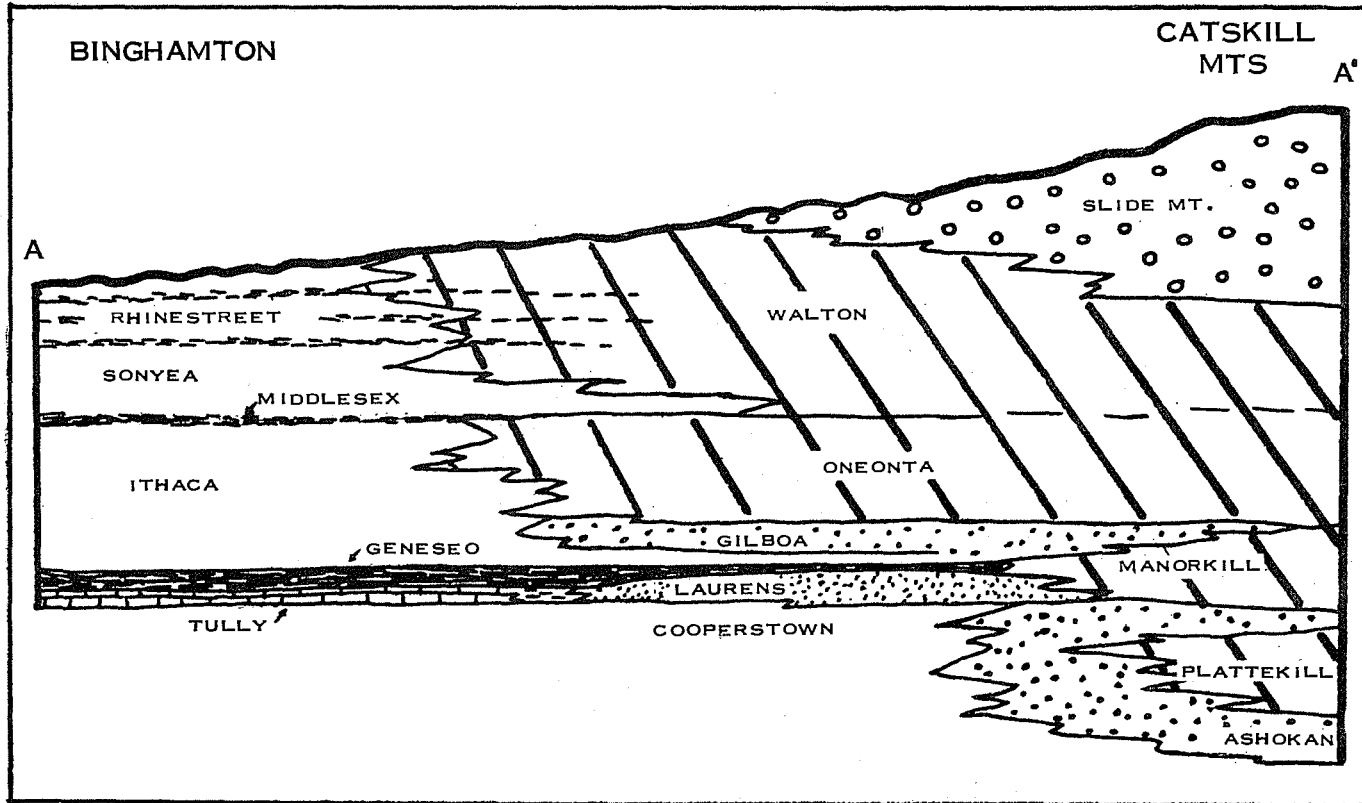


Figure 5 Diagram of marine and non-marine facies relationships. Major red-bed tongues are shown by diagonal lines (modified from Woodrow and Fletcher, 1967 after Fletcher, 1964).

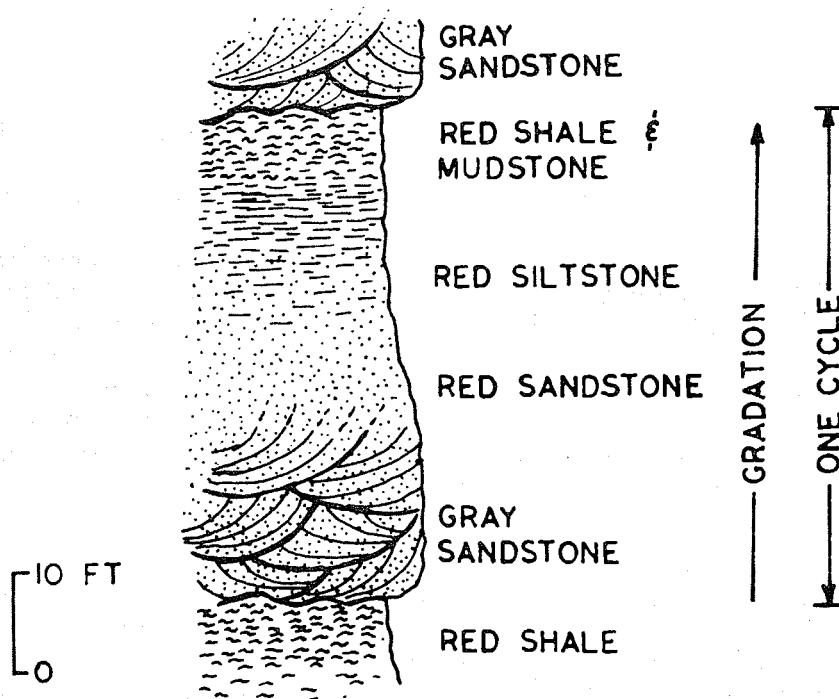


Figure 6 SEDIMENTARY CYCLE

of these two facies. Red beds are the dominant rock type in the formation and consist of brownish-gray (5 YR 4/1) to grayish-red (10 R 4/2) shales, claystones, siltstones and fine-grained sandstones. Sedimentary cycles commonly exceed 50 feet in thickness.

The Manorkill Formation is approximately 620 feet thick and forms much of the Catskill Front. The lower boundary of the unit is drawn at the base of 37 feet of red shale and siltstone that overlie the gray sandstones of the Potter Hollow Formation. The upper contact is marked by the termination of 80 feet of red shale, claystone and siltstone (Lucier, 1966, p. 9). Field tracing of the Laurens Sandstone of the Tully Formation into Schoharie Creek from the west has demonstrated that the Manorkill is the eastern equivalent of the Laurens (Fig. 5). The type section of the Manorkill is the creek of the same name adjacent to the Schoharie Reservoir (Fletcher, 1963, p. 32.)

GILBOA FORMATION

The Gilboa Formation in the region of the Catskill Front consists of interbedded medium-gray (N5), cross-bedded subgraywackes and medium-dark-gray (N4) shales and siltstones. Although it measures only 44 feet in Kaaterskill Clove, it is readily recognized by the presence of a 15-foot dark-gray siltstone bed that contains pillow structures ("flow rolls"). This bed is the only one of its kind above the Ashokan Formation and thus serves as a useful marker in the thick red-bed sequence at the Catskill Front. The Gilboa can be recognized along the old cog-hill railway up to the site of the famous Catskill Mountain House (now North Lake State Park) by 1.5 feet of distinctive, whitish-weathering siltstone.

The siltstone unit was called the Grand Gorge Member of the Gilboa Formation by Fletcher (1963, p. 34) before correlation between Schoharie and Kaaterskill Creeks had been definitely established. It seems best, now, simply to recognize it as an easterly-extending tongue of the Gilboa Formation (Fig. 5).

ONEONTA FORMATION

Overlying the Gilboa and forming the rimrock of the Catskill Front is the lowest 280 feet of the Oneonta Formation. These rocks, to the base of the Twilight Park conglomerate formed the Kaaterskill Sandstone of Willard (in Chadwick, 1936, p. 74). The entire thickness of the Oneonta is approximately 900 feet and the base of the unit is

drawn at the red beds that directly overlie the Gilboa Formation.

The Oneonta is a sequence of grayish-red (5 R 4/2) sandstones, siltstones, shales, and claystones and of coarse-grained, medium-gray (N5), cross-bedded sandstones with scattered quartz pebbles. Red beds comprise 44 percent of the formation and fining-upward cycles may exceed 80 feet in thickness (Lucier, 1966, p. 11). The Oneonta may be distinguished from the older red-bed units because its sandstones are lighter colored and coarser grained. Approximately 100 to 200 feet of massively - and cross-bedded conglomerate form a prominent topographic bench along the top of the Catskill Front and form the caprock of South Mountain. This is the Twilight Park conglomerate of Prosser (1899). It is one of the most diagnostic features of the Oneonta and marks the lowest major zone of pebbles in the section. Recent work by Buttner (personal communication) has brought to light the complex geologic history of this conglomerate and casts doubt on the validity of assigning formal stratigraphic rank to it.

WALTON FORMATION

Chadwick (1933, p. 483) proposed the name "Onteora" for the strata between the Twilight Park conglomerate and his Stony Clove Sandstone in the vicinity of High Peak. The Stony Clove, which Chadwick (1944, p. 130) described as "gray sandstones coarsely flaggy and without a noticeable trace of red color throughout a thickness of eight or nine hundred feet" actually contains three thick zones of red shale and claystone at the type locality. Since it is impossible to distinguish the rocks Chadwick included in the Stony Clove Formation from the zone of red beds that he reported in the basal part of his Katsberg Formation, these two series of strata were combined with Chadwick's Onteora by Fletcher (1963, p. 38) to form a distinctive mappable unit — the Walton Formation. The type locality of the Walton is Bear Spring Mountain, approximately one mile south-east of Walton, New York.

The Walton consists of 1000 feet of red beds, gray sandstones and small amounts of gray shale. Its lowest 100 feet are composed of fine-grained sandstones which represent a marked lithologic change from the coarser-grained, conglomeratic sandstones of the underlying Oneonta Formation. The uppermost sandstones are medium-gray (N5) and greenish-gray (10 GY 5/2) and coarse-grained. These beds are conglomeratic and contain pebbles of dark-gray (N3) and white quartz and light-gray (N7) chert. The conglomeratic sandstones grade upward into the overlying Slide Mountain Formation. The transition can be observed readily on the flanks of Wittenberg and Hunter Mountains.

SLIDE MOUNTAIN FORMATION

The youngest formation in the area is the Slide Mountain. The name was proposed by Chadwick (1933, p. 480) and was restricted originally to the uppermost 400 feet of strata on Slide Mountain. Chadwick believed these to be correlative with "Chemung." Because there is no difference between the top 400 feet of conglomerate and any of the underlying 1600 feet of rock, Fletcher (1964a) redefined the unit to include all the strata above the Walton. The name "Wittenberg" had been employed earlier by Fletcher (1963, p. 39) for these same conglomerates because of the excellent exposures on the flanks and top of Wittenberg Mountain. Although the boundary between the Slide Mountain and the underlying Walton Formation is gradational through approximately 300 feet, the Slide Mountain can be identified by the predominance of conglomerate and the paucity of red claystone.

Lithologically the Slide Mountain consists of cross-bedded, yellowish-gray (5 Y 7/2) conglomerate. Its pebbles are of milky quartz and red and yellowish-gray sandstone. Maximum diameter is 100 mm. This unit caps all the highest peaks of the Catskill Mountains.

PALEOGEOGRAPHY
Environments of Deposition

Twelve major rock-types can be recognized in the Catskill Mountains region and they form three distinct facies: 1) marine, 2) transition, and 3) continental (Table 1). Each facies is the record of a specific environment that has been determined by comparison with analogous modern environments on the basis of compositional, textural, and structural criteria. These criteria are discussed by: Dunbar and Rodgers (1957), Fisk, McFarlan, Kolb, and Wilbert (1954), Fischer (1961), and Allen (1965), and are summarized in Table 1.

Sedimentation Patterns

Figures 3 and 5 show that no simple vertical and lateral change from marine to non-marine conditions occurred in the basin of deposition during the Middle and Late Devonian, but that the complex intertonguing of facies is a record of rhythmic transgressive and regressive sedimentation. Three orders of cyclic sedimentation can be distinguished within the facies patterns.

FIRST-ORDER CYCLE

The first-order cycle is the thinnest, commonly 50 to 100 feet, and consists of the fining-upward cycle described in Figure 6. Comparison of cyclothemic sedimentation in other parts of the geologic record suggests that a common causal control exists and that lithologic differences reflect differences in depositional environment.

<u>Cyclic Deposit</u>	<u>Environment</u>	<u>Reference</u>
S.E. New York (Dev.)	Alluvial plain	Fletcher (1964a)
Dunkard (Perm.)	Transition	Beerbower (1961)
Illinois (Penna.)	Transition	Weller (1956)
Kansas (Penna.)	Marine	Moore (1936)

The absence of limestone, coal and other typical cyclothem members in these Devonian cycles indicates that the cycles were formed on an alluvial plain and not in the transition zone where swamps, lagoons and barrier bars are present. It is inferred from the similarity between the Catskill cycles and those described by Allen (1962 and 1964) that the cycles originated from fluvial deposition on an alluvial plain. The rock-types, the common cross-bedding and the poor to moderate sorting of the sandstones are similar to features of modern braided stream deposits (Doeglas, 1962, p. 188-190). The distributary system of the Catskill cycles was composed, apparently, of short high-gradient streams. The relatively small variability of cross-bedding directions suggests also high-gradient stream deposition, for meandering would tend to increase cross-stratification variability as a function of local point-bar accumulation (Lucier, 1966, p. 84).

A possible sedimentologic interpretation for the cycles can be proposed in light of two studies in modern sediments: Fischer (1961) in the New Jersey Coastal Plain, and Fisk and McFarlan (1955) in the Quaternary Mississippi delta. The stages of development of the alluvial plain cycles are summarized as follows:

- (1) Base level at minimum. Gradient and competence of streams at maximum. Erosion of alluvial plain and deposition on slope. Slope builds out into basin.
- (2) Base level rising. Gradient and competence of streams reduced progressively. Coarse, poorly-sorted sands with quartz and shale pebbles at base deposited on alluvial plain. Gradation upward to finer-grained silts and clays as base level rises.

TABLE 1

LITHOLOGY	SEDIMENTARY STRUCTURES	TYPICAL FOSSILS	ENVIRONMENT
Dark gray shale	---	Pelecypods	MARINE
Dark gray siltstone	Pillow structures	---	
Dark gray sandstone	Flaggy-bedding	Brachiopods	Infralittoral
Arenaceous coquinite	---	Brachiopods	
Protoquartzite	Cross-bedding	Plants	TRANSITION
Mottled siltstone	Ripple-marks	---	Littoral
Gray sandstones	Cross-bedding	Plants	Tidal Flat
Red sandstone	Cross-bedding	---	
Red siltstone & shale	---	---	CONTINENTAL
Red mudstone	Disturbed bedding	---	
Greenish-gray, conglomeratic sandstone	Cross-bedding	---	
Gray & red conglomerate	Cross-bedding	---	

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- (3) Base level at maximum. Gradient and competence of streams at minimum. Oxidation of muds exposed to atmosphere to red soil. Layering in uppermost muds destroyed by burrowing worms and other organisms, dessication cracks, and plant roots; swamps formed locally.
- (4) Base level lowering. Streams rejuvenated. Alluvial plain eroded by entrenched streams that are located in restricted channels. Entrenchment of streams lowers water-table enabling oxidation to occur to depths of 30 to 40 feet below surface of plain.

The ultimate cause of the change in base level could have been eustatic change in sea level or tectonic (i.e., differential uplift in the source and/or subsidence in the basin of deposition). In light of the nature of the second- and third-order cycles described below, tectonic control seems most probable.

SECOND-ORDER CYCLE

The second-order cycle is represented by the alternation between marine and non-marine facies in vertical section.

Walton Fm.	REGRESSION
Middlesex Fm.	TRANSGRESSION
Oneonta Fm.	REGRESSION
Gilboa Fm.	TRANSGRESSION
Manorkill Fm.	REGRESSION
Potter Hollow Fm.	TRANSGRESSION
Plattekill Fm.	REGRESSION

The regressive phase of the cycle is typically the thickest (600 to 1500 feet). Deposition of cross-bedded, gray sands preceded deposition of the red beds and the older red beds of any red-bed formation do not extend into the basin as far as the younger ones (e.g. Plattekill Formation). The lower boundary of any regressive tongue "rises" stratigraphically toward the basin interior, whereas the upper boundary is abrupt. This suggests that the regressive stages were long-lived in contrast to the short-lived, thin (100 to 300 feet) transgressive stages. The stages of development of the second-order cycle are:

- (1) Sands, derived from up-lifted source area, deposited on alluvial plain, which builds out gradually into the basin.
- (2) Red beds developed above gray sands; they also migrate toward basin interior. Sediment supply reduced and subsidence exceeds deposition.
- (3) Sea transgresses and dark gray shales deposited.

These cycles reflect intermittent uplift in the source area and relatively continuous subsidence in the basin. The amount of sedimentary detritus from the source area is determined by the changes in the rate of uplift. Variability in the rate of uplift was chiefly responsible for the alternate episodes of regression and transgression. Figure 7 shows the paleogeography of the region during the late Middle and early Late Devonian.

THIRD-ORDER CYCLE

The thickest cycle, 8000 feet at its maximum along the Catskill Front, is a composite of a number of second-order cycles and represents the combined effect of the smaller scale uplifts. It is an example of the geosynclinal cycle of Pettijohn (1958, p. 637).

<u>Lithology</u>	<u>Principle Facies</u>	<u>Example</u>
Coal	Molasse	Not present in New York
Conglomerate	Molasse	Slide Mt. Fm.
Red beds	Molasse	Plattekill through Oneonta Fm.
Gray sandstone and shale	Flysch	Mount Marion Fm.
Black shale	Euxinic	Bakoven Fm.
Limestone	Pre-orogenic	Onondaga Fm.

This cycle shows two major patterns: (1) general increase in grain size upward, and (2) change from marine to non-marine conditions upward. It represents over-all general uplift in the source area and subsidence in the basin, but subsidence was generally slower than uplift, which caused the westward shift of the facies with time (Fig. 7).

Source Area

The three most intensive studies of the provenance of the Catskill sediments have produced divergent hypotheses. The earliest study led to the postulation of a source area located east and southeast of the Catskill Front at a distance greater than 100 miles and in an area of Precambrian crystalline rocks. This source area, called Appalachia, was inferred to be a great mountain system occupying parts of eastern Connecticut and the region now overlain by the Coastal Plain and portions of the continental shelf sediments (Barrell, 1914, p. 246-247; and Fig. 8). The second study placed the source to the north and east of the Catskill Front at a distance of approximately 50 to 75 miles and in the general region of the Taconic-Berkshire-Green Mountain belt (Mencher, 1939, p. 1779-1782). The third study, based on paleocurrent and petrographic criteria of the Catskill facies, postulates a source area composed of Silurian and Lower Ordovician limestone and argillaceous rocks which presently crop out within 25 miles of the eastern limits of the Catskill Front sediments (Burtner, 1964, p. 189).

The detailed study of Lucier (1966) indicates that supracrustal rocks were the dominant suppliers of sediment throughout the time of deposition of the Catskill facies. There is no petrographic evidence to support the contention that plutonic crystalline rocks or eruptive igneous rocks served as either the dominant or accessory source terrane for the sediments. The evidence for this conclusion is the lack of plutonic or eruptive igneous rock fragments in the sandstones, the general absence of igneous and high-rank metamorphic index minerals in the heavy mineral suite, and the scarcity of feldspar (Lucier, 1966, p. 68).

Within the supracrustal suite two distinct lithologic associations were dominant at different times. Analysis of all mineralogic data indicates that a sequence of interbedded shales and sandstones, perhaps slightly metamorphosed, was the dominant source lithology of the pre-Oneonta sediments. The evidence that supports this contention is dominance of foliated aphanites, the abundance of graywacke sandstone and siltstone fragments and the presence of lesser amounts of chert throughout the section, and the occurrence of rounded zircon, tourmaline and rutile in the heavy mineral suite. The presence of detrital chlorite and muscovite and the persistent inclusion of chlorite within many of the rock fragments indicates that the source terrane was subjected to a very low grade regional metamorphism (Lucier, 1966, p. 70).

The base of the Oneonta Formation, however, is marked by intersecting trends of the foliated aphanites (decreasing) and polycrystalline quartz (increasing) and it is inferred from this that a more quartz-rich source area was being eroded. Metamorphic quartzite containing chlorite and, more rarely, muscovite inclusions was a common rock type in the source terrane. Whereas most of the quartzite pebbles are white, some of those found in the lower Oneonta Formation have a pinkish and greenish tinge. The trace minerals and rock

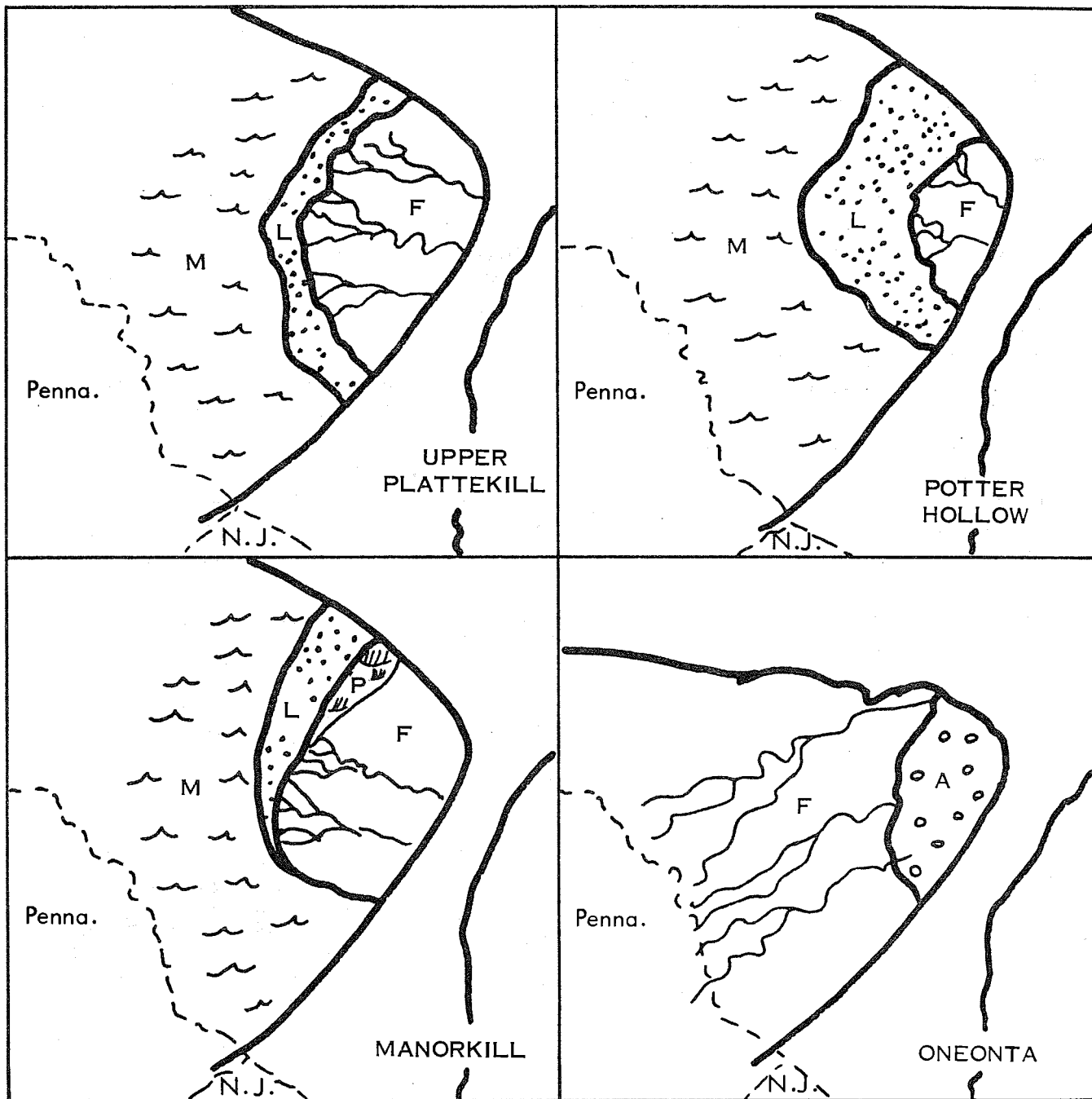


Figure 7 Paleogeographic maps of the Catskill Mountains region, late Middle Devonian and early Late Devonian. Symbols: M: marine, L - littoral, P: paludal, F: fluvial, and A: alluvial plain.

fragments that are more abundant in the Oneonta also suggest a quartzitic source. These include the angular pink-to-green tourmaline, the angular orange rutile, the chlorite-veined quartz, and the red argillite fragments (Lucier, 1966, p. 71). At this time, no detailed petrographic data are available from the Walton and Slide Mountain Formations.

Figure 10 summarizes the stratigraphic section of the source area as inferred from all the field and petrographic information. The section is based on the assumption that the source rocks shed quantities of detritus in proportion to their concentrations in the Catskill facies and in an inverted stratigraphic order. The location of the source is placed east-southeast of the Catskill Front based on the cross-bedding and particle orientation data (Fletcher, 1964b; Lucier, 1966).

The poor to moderate rounding of the detrital minerals and the abundance of labile rock fragments suggest a source in close proximity to the present Catskill Front. Figure 9 shows an area in eastern New York that lies between plus and minus one standard deviation of the cross-bedding mean and includes portions of the Kinderhook and Copake 15-minute quadrangles (Lucier, 1966, p. 74). Figure 11 is an idealized section of the sequence of rocks in this area based primarily on the correlations proposed by Craddock (1957, p. 697-699). Comparison of Figures 10 and 11 indicates that almost all the stratigraphic, lithologic and mineralogic requirements of the source area, as suggested by Lucier's petrographic analysis, are fulfilled by that sequence in eastern New York (Fig. 9).

Lucier (1966, p. 80) concludes that the provenance was that sequence of Lower Cambrian to Middle Ordovician clastics now exposed within 25 miles of the eastern limits of the Catskill Front sediments (Fig. 9). The vertical mineralogic variation evident throughout the Catskill facies' sandstones dominantly reflects the stratigraphic inversion of the Normanskill, Deepkill, and Nassau-Rensselaer sediments and low-rank metamorphics

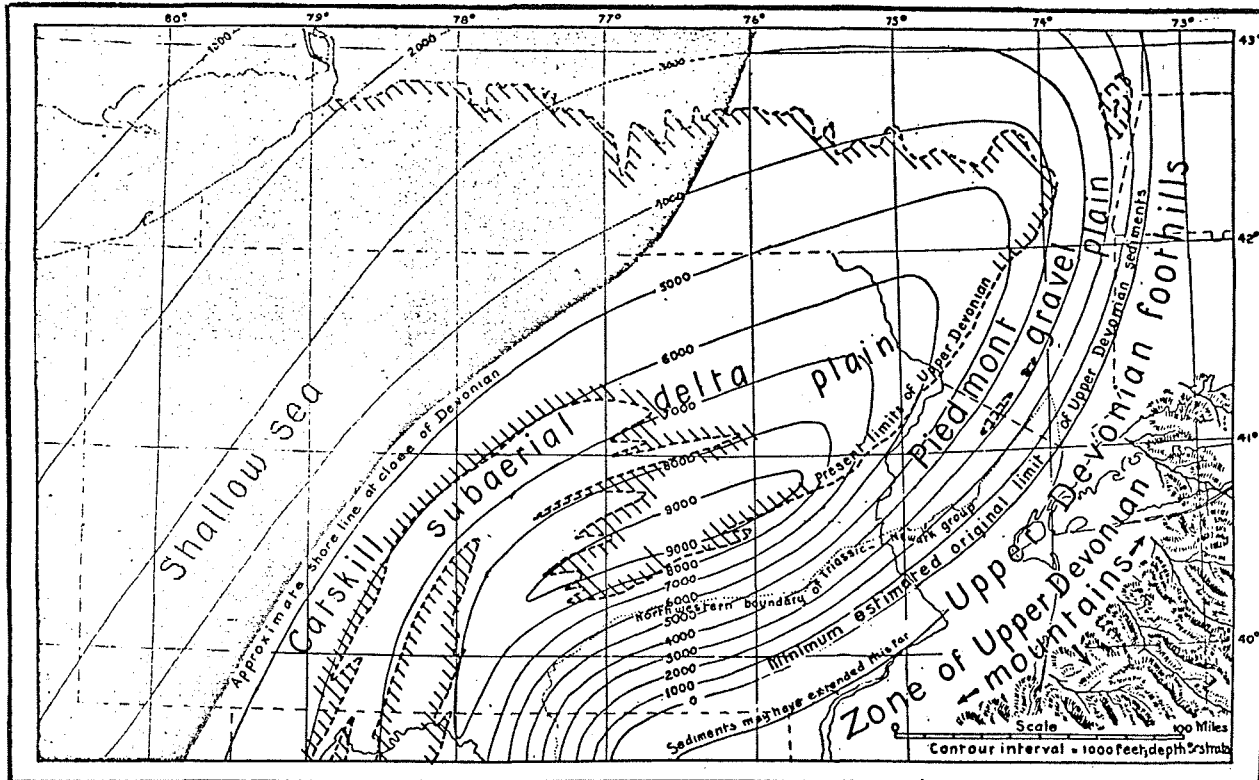


Figure 8. Barrell's interpretation of the Appalachian geosyncline at the close of the Devonian (from Barrell, 1913, Fig. 1, p. 430).

FIGURE 9 POSITION OF SOURCE AREA BASED ON CROSS-BEDDING AND METAMORPHIC ASSEMBLAGES (from Lucier, 1966, Fig. 25)

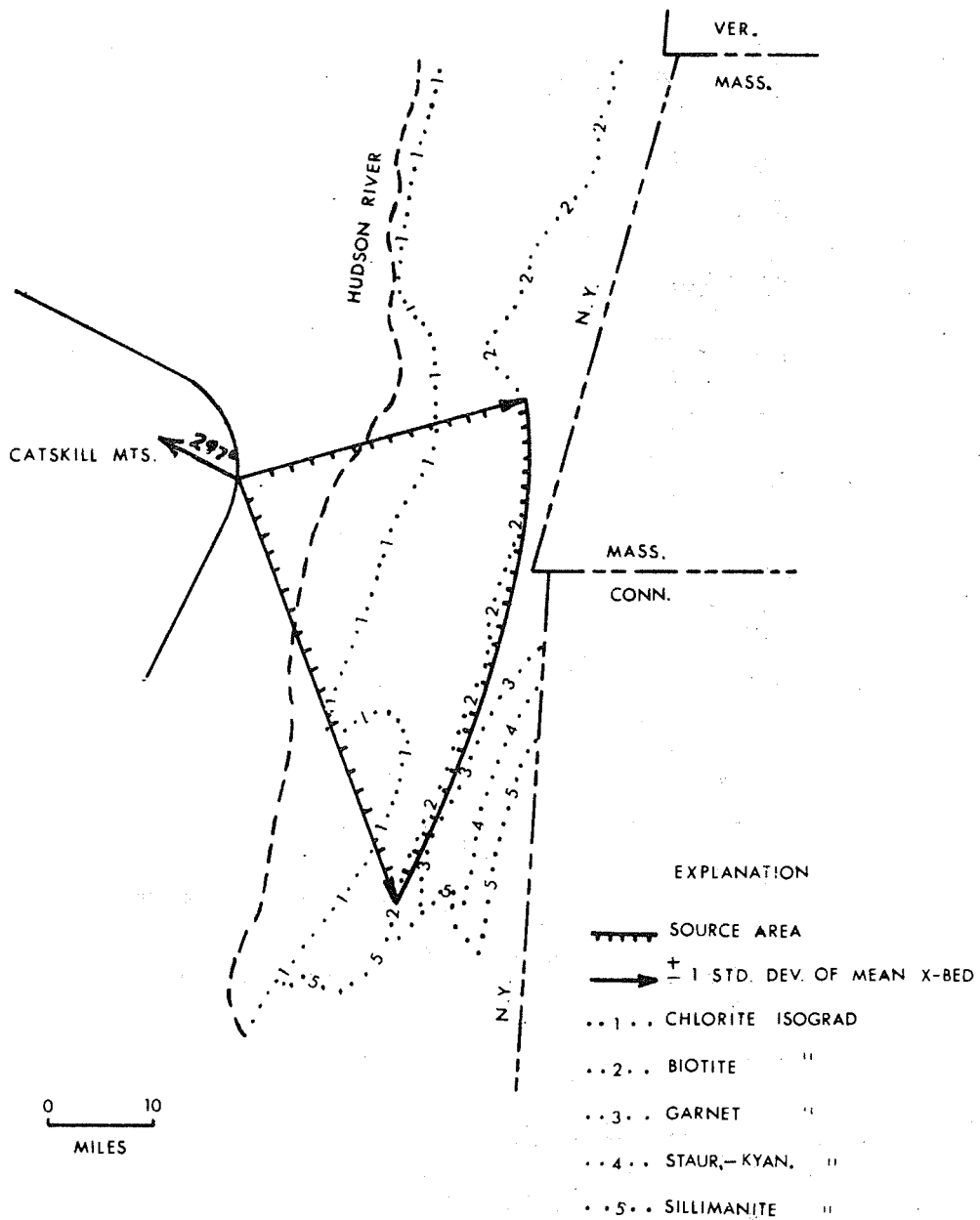


FIGURE 10 GENERALIZED STRATIGRAPHIC SECTION OF SOURCE AREA AS INFERRED FROM PETROGRAPHIC DATA
 (from Lucier, 1966, Fig. 23)

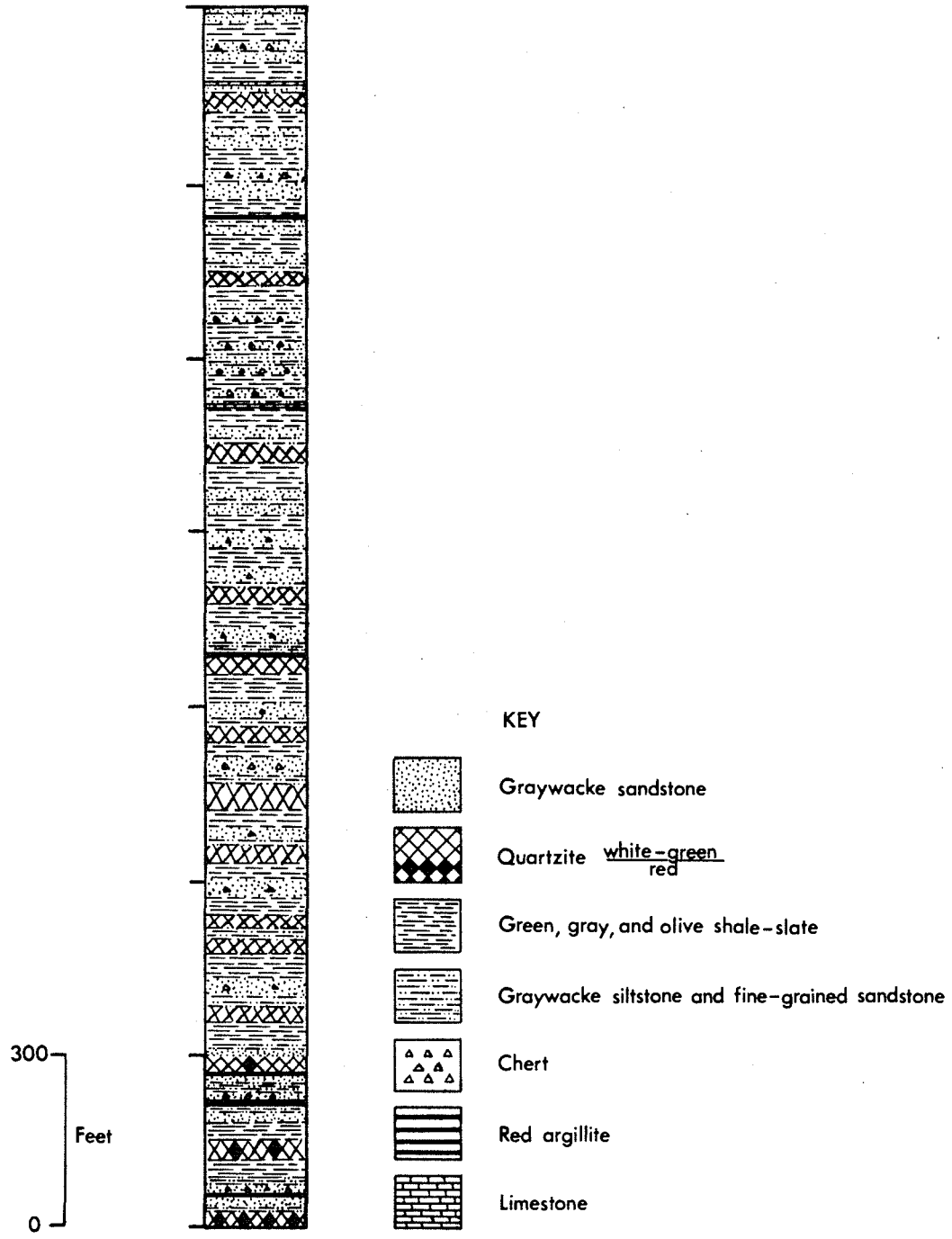
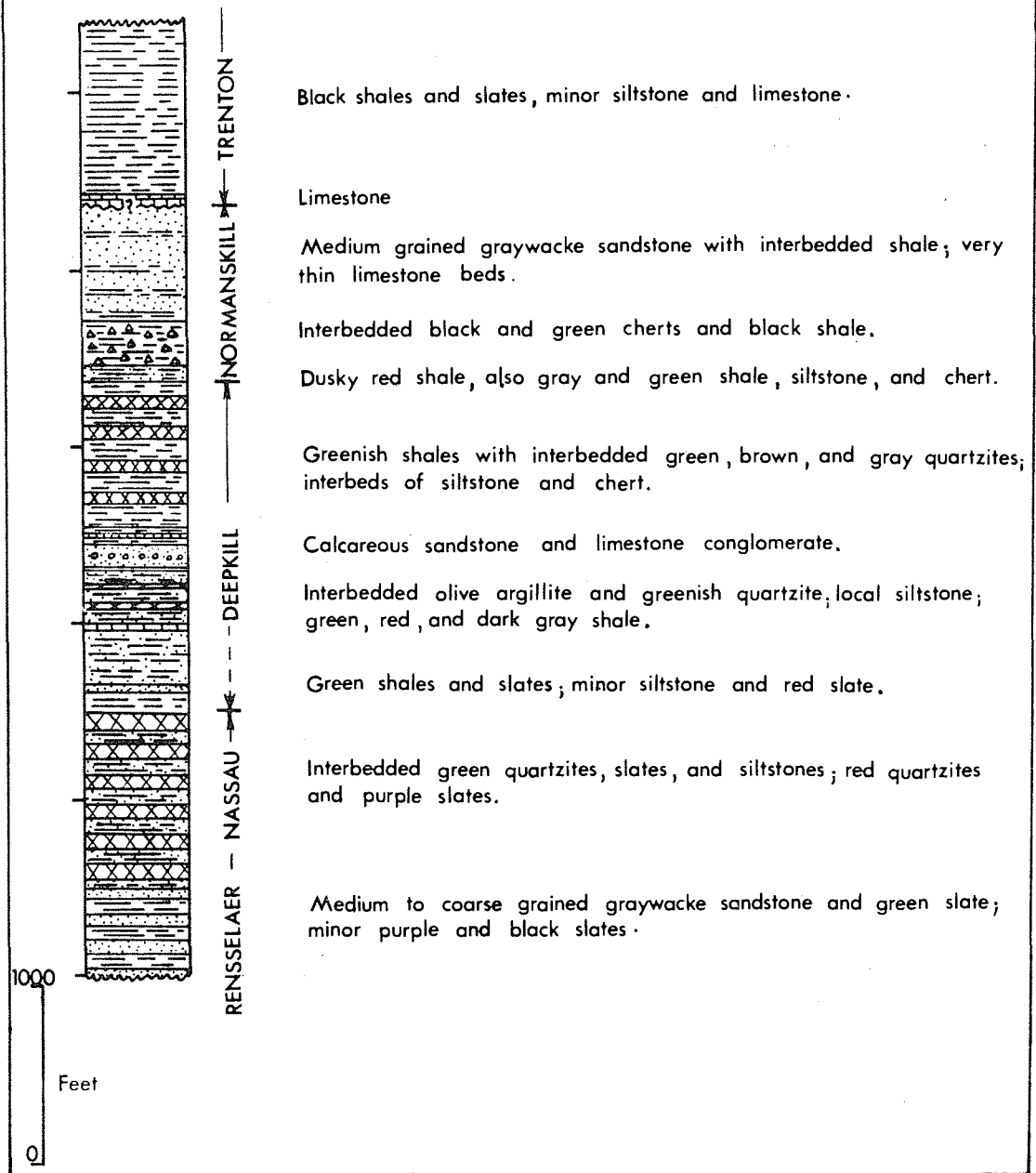


FIGURE 11 COMPOSITE STRATIGRAPHIC COLUMN OF ROCKS EAST OF STUDY AREA AND WEST OF TACONIC MOUNTAINS (from Lucier, 1966, Fig. 26)



as a function of progressive uplift and denudation of the source terrane (Fig. 11). The total minimum thickness of sediments (Normanskill-Nassau) eroded from the source area during this time was in excess of 4000 feet (Lucier, 1966, p. 81).

Preliminary study of the pebbles in the Slide Mountain Formation suggests previously deposited Catskill red beds (Plattekill?) served as a source for the detritus that later formed the younger conglomerates. Large pebbles of red sandstone identical with the red sandstones of the Plattekill Formation are a common constituent of the Slide Mountain. Apparently "cannibalism" of strata along the margin of the depositional basin occurred.

Summary

The sediments of the Catskill region reflects rhythmic braided stream and alluvial plain deposits. Periodic uplift of the Cambrian-Ordovician source during the Middle and Late Devonian produced highlands from which short torrential streams debouched (Fletcher, 1964a; Lucier, 1966). Coarse, immature detritus was deposited by coalescing streams on the upland part of the alluvial plain. The finer sediment fraction that was transported with the coarser had three alternatives: 1) being trapped in the interstices afforded by the pebbles and sand grains, 2) being swept beyond the alluvial plain into the marine part of the basin, or 3) being stranded on the lowland part of the alluvial plain as flood-plain and interfluvial deposits where oxidation and plant growth would proceed (Lucier, 1966, p. 86). The calcareous, shale-pebble breccia lenses commonly found in the sandstones possibly result from overbank steepening of the interfluvial material. As erosion continued in the highlands stream flow would diminish and progressively finer detritus would be spread out over the previously deposited channel sands.

The classic picture of the so-called Catskill delta, in which a high range of mountains of Precambrian crystallines far to the east shed sediments into a constantly subsiding basin, becomes obsolete. Alternate periods of regression and transgression dominated sedimentary patterns during the Middle and Late Devonian. These alternations are concluded to be the result of tectonic activity in the faulted and folded flank-zone of the geosyncline (Fig. 12; Fletcher, 1964a, p. 63) which occupied the present position of the Taconic Mountains. Increased tectonic activity, primarily in the form of folding and high-angle reverse faulting in the flank zone, brought to the surface rocks previously deposited in the marginal trough (Fig. 12). Thus, while Ordovician rocks were the dominant source for the lowermost Catskill sediments, "cannibalized" Devonian rocks from the rim of the marginal trough served as the source for the upper Catskill sediments.

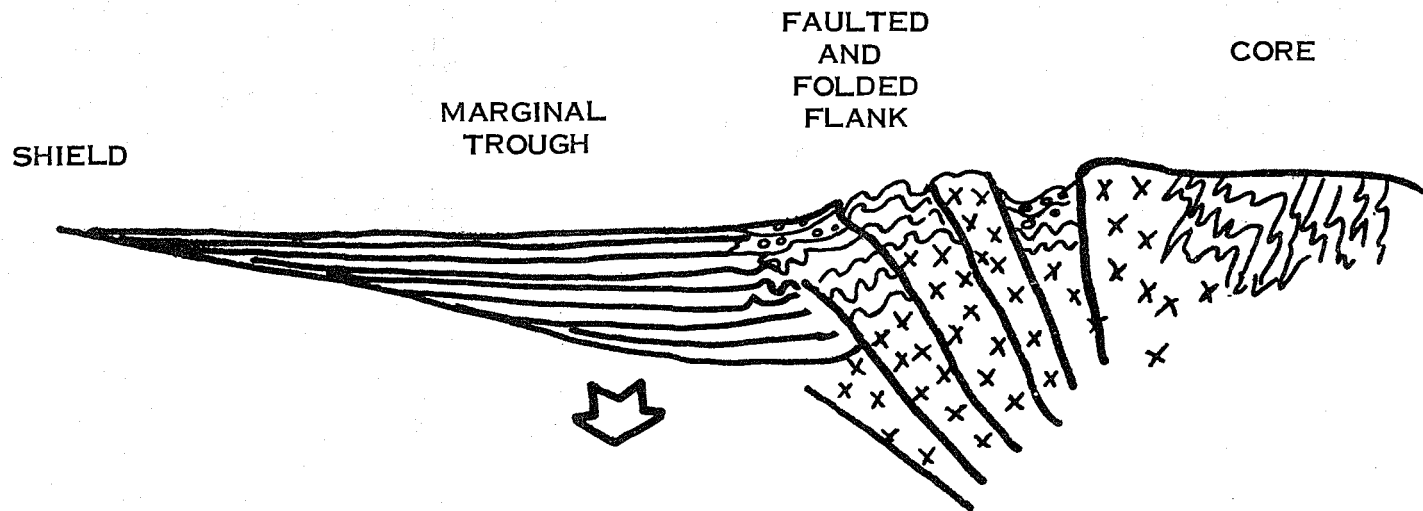


Figure 12 Interpretative reconstruction of tectonic framework of eastern New York in the Late Devonian.

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ROAD LOG TRIP C

Leader: Frank W. Fletcher — Guest Lecturer (Stop 3): Peter J. Buttner

MILEAGE

- 0.0 Holiday Inn, Newburgh (Field trip headquarters). Travel north on N.Y. Thruway.
- 42.0 Intersection of N.Y. Thruway exit and Rtes. N.Y.32 and 212. Turn left (west).
- 42.3 Turn right (north) on Rte. N.Y. 32.
- 43.9 STOP 1 (15 minutes) Onondaga Limestone (Middle Devonian). This is primarily a stop for introduction to the basic Middle and Upper Devonian stratigraphic sequence of the Catskill Mountains region (see p. C1-C8). The Onondaga at this locality consists of very cherty, fossiliferous limestone. It dips toward 258° at 13° and forms a low escarpment.

An excellent panorama of the chief physiographic elements of the region can be observed from this location. The topographic depression directly west of the Onondaga escarpment is Bakoven Valley, which is underlain by the relatively soft black shales of the Bakoven Formation. The low Hooberge range west of Bakoven Valley is composed primarily of resistant siltstones of the Mount Marion Formation and is capped by the Ashokan Sandstone. The plain beyond the Hoobergs is underlain at its most easterly part by the upper Ashokan Formation and at its westerly edge by red beds of the Plattekill Formation. Towering above all of these elements is the Catskill Front; and, beyond, the high peaks of the Catskills including Slide Mountain, Wittenberg Mountain, and Cornell Mountain, whose summits are composed of the Slide Mountain conglomerate (Fig. 4).

Continue north on Rte. N.Y. 32

- 48.0 Bear left on to Rte. N.Y. 32-A.
- 49.6 Cross Kaaterskill Creek.
- 50.0 Turn left on to Rte. N.Y. 23-A at traffic light in Palenville.
- 50.9 Cross Kaaterskill Creek again and begin climb up Catskill Front in Kaaterskill Clove.
- 53.8 STOP 2 (60 minutes) Manorkill and Gilboa Formations. Buses will allow field trip participants to disembark and then will drive to top of section. Participants will walk along right (north) side of highway to top of section. CAUTION: Road is narrow, so "cling" to side.

The upper part of Kaaterskill Creek can be seen approximately 0.2 miles northeast of this locality. This is the location of Prosser's classic example of stream piracy, where the headwaters of Schoharie Creek were captured by the much-steeper gradient Kaaterskill Creek.

Figure 13 describes the stratigraphic section of this stop. Many of the typical rock types and sedimentary structures of the lower Catskill facies can be observed here. Especially note-worthy are the fining-upward cycles discussed on page C1.

- 54.7 Top of section. Re-enter buses and continue west on Rte. N.Y. 23-A.
- 55.2 Turn right (north) in Haines Falls on to road to North Lake State Campsite.
- 55.3 Bear right.

58.3 Entrance to North Lake Campsite. Continue to North Lake beach parking area.

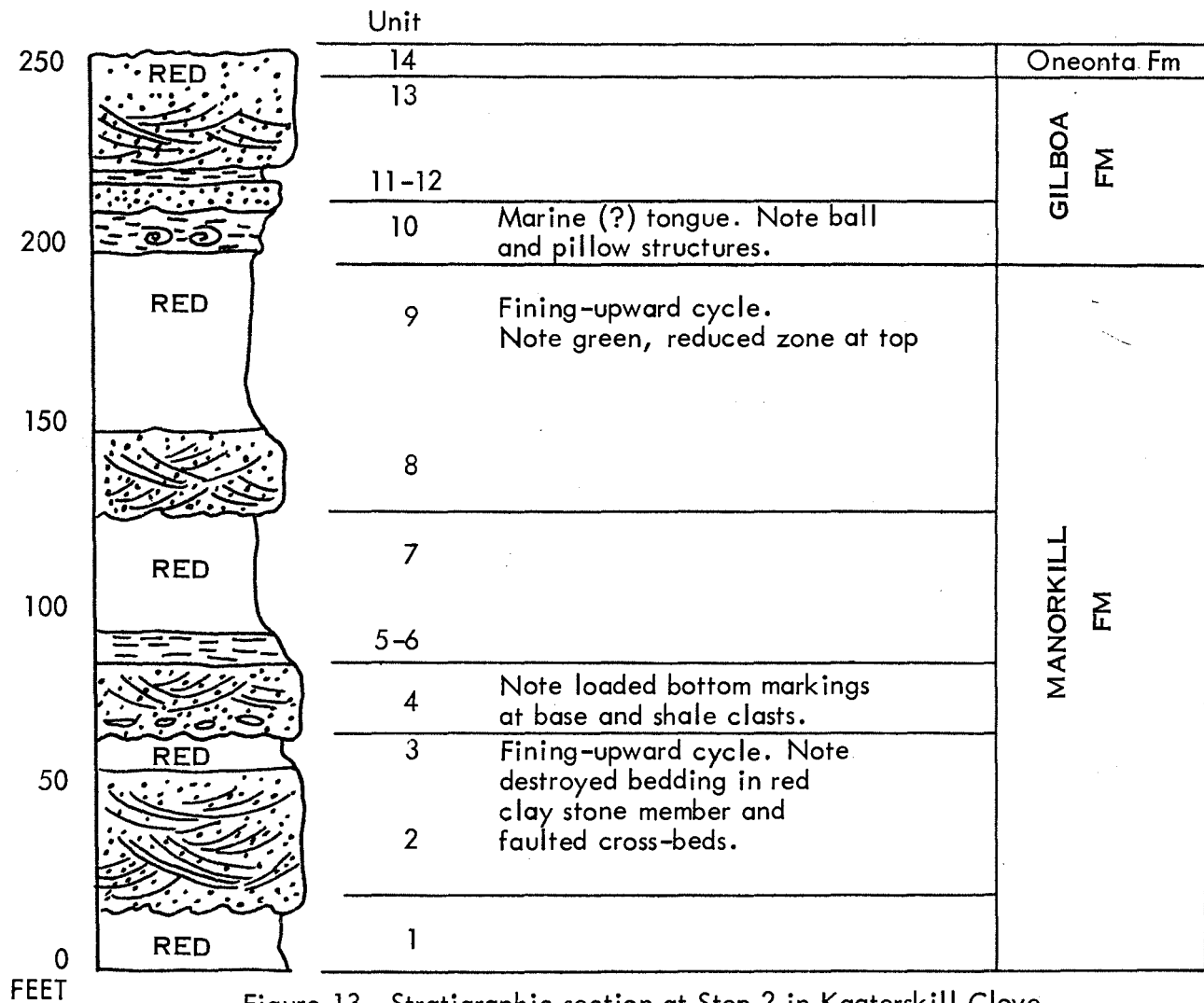
LUNCH (40 minutes)

*STOP 3 (90 minutes) Follow NYSGA trail markers along rim of Catskill Front to outcrop of the "Twilight Park Conglomerate." CAUTION: Watch your footing along the Front. Please remain at least five feet back from the edge of the cliff. NO SPECIMENS MAY BE TAKEN FROM WITHIN THE PARK BOUNDARIES.

Trail lies on strata of the lower Oneonta Formation. Note cross-bedding, excellent jointing and joint-controlled face of the Catskill Front. An excellent view of the Hudson Valley, the low Taconics, and, on very clear days, the Berkshires is available from the Front.

Return along trail to buses and return to field meeting headquarters.

*Guest Lecturer



CONTINENTAL SEQUENCES IN THE PROXIMAL GENESEE GROUP (STOP 3, FIELD TRIP C)

PETER J.R. BUTTNER
Computing Center, University of Rochester

Introduction

Wedge-like in form and generally thinning to the south-west, the Devonian accumulation in New York displays a wide variety of sedimentary types and stratigraphic patterns. Proximally, in southeastern New York, about 10,000 feet of Devonian section has been preserved. The upper 6,000 feet of this sequence contains elements of the remnant sedimentary units of a set of Middle and Upper Devonian fluvial events. This collection of continental terranes has been discussed in some detail by Barrell (1913, 1914 a, b) and Chadwick (1933 a, b; 1936; 1944). It has become known as the Catskill Delta (Chadwick 1933 b). Included in this proximal continental sequence are rock units presently thought to be part of the Middle Devonian Hamilton Group, and the Genesee, Sonyea and the West Falls Groups of the Upper Devonian (Cooper and others, 1942; Rickard, 1964; Wolff, 1965, 1967).

Location

On the North Point Trail to North Mountain from North Lake in the SW1/4 of the NE1/4 of the Kaaterskill 7 1/2 minute quadrangle, Catskill State Park, Greene County, New York.

STRATIGRAPHIC SETTING AT STOP 3 (page C23)

The rock units encountered along the trail to Stop 3 are thought to be part of the proximal Genesee Group in southeastern New York. Several hundred feet below the elevation of the trail at Stop 3 the basal units of this rock body demonstrate a significant regressive overlap of dominantly near-shore and coastal plain sedimentary domains over the subjacent tidal estuary and lagoonal sedimentary domains observed in Kaaterskill Clove. The Genesee Group in this area is a domain of homogeneously rhythmic character (abcdeabcdeabcabcddabebcdabcde) and includes all the rock units to the top of the near mountains. It should be noted that this stratigraphic reckoning is founded on the physical character of this block of rock; the single characteristic of rhythmic patterning predominant. A succession of rock units have been assembled into an informal rock-stratigraphic unit in answer to a single terminal question: Do the units display some aspect of rhythmic fluvial sedimentation?

The stratigraphic plan followed is based on the recent summaries and modifications proposed by Rickard (1964), Wolff (1965, 1967) and, Friedman and Johnson (1966). Rickard has presented a bed rock map of the Devonian of New York together with a detailed chart of the stratigraphic design of the Devonian System in New York. Working within this scheme, Wolff, with the support of detailed field work in several key areas, has demonstrated a high-order rhythmic pattern of regressive and transgressive phases of deltaic sedimentation. At Stop 3 are some of the rock types which characterize the fluvial aspects of a regressive phase. The regional character and setting of the Middle and Upper Devonian of New York has been presented by Krumbein and Sloss (1963, p. 525, 535), Potter and Pettijohn (1963, p. 230) and, Friedman and Johnson (1966, p. 185-186).

THE NORTH POINT DOMAIN

The name North Point has been informally used to delimit the rock body thought to be the proximal Genesee Group in southeastern New York. Rhythmic
C24

continental sequences characterize this rock body (Buttner, 1965). Interpreted as the remnant elements of a sequence of coastal plain and upland fluvial deposits, a rhythmic sequence consists of a braided pattern of coarse conglomeratic channel-fill; a composite of point-bar, channel-fill, and overbank sandstones; and, overbank, mudflat, and general floodplain accumulations represented by siltstones and mudrocks (Buttner, 1966). Widespread lateral variability, rapid change in vertical sequence, steep-banked channels (some more than 30 feet in depth), and low to moderate thalweg sinuosity together with textural mapping support speculations about a coastal plain - upland sedimentary domain for the North Point.

Detailed mapping together with the analysis of data using various operations research methods and a computer have shown that rhythmic patterns may be found in: sediment color, texture, and petrology; transport directions; sedimentary structures and flow patterns; and lithosome geometries. Figure one shows the composite structure of a rhythmic sequence; the North Point contains at least 23 major rhythms of this type.

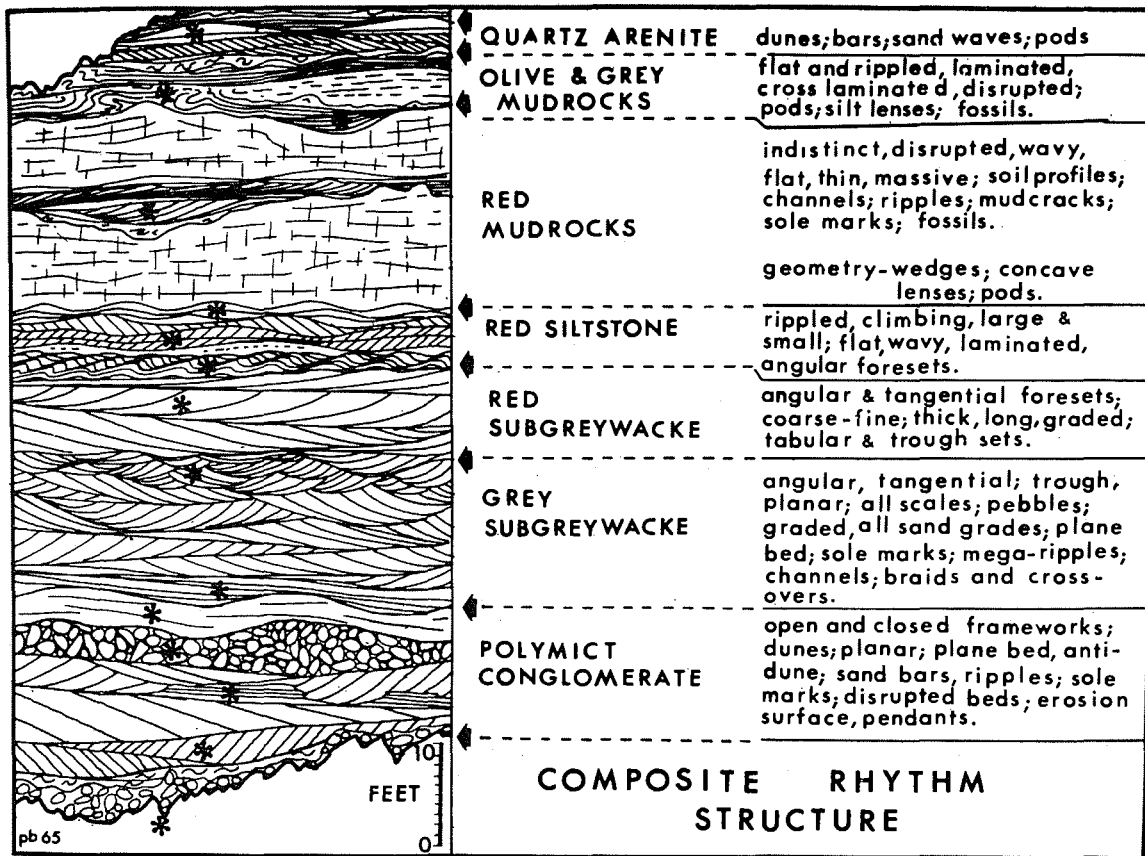


Figure 1. Composite Rhythm Structure in the North Point

As shown in Figure one, the rhythmic sequence is enclosed at base and top by erosion surfaces. A first impression of this structure is that there is a waxing and logarithmic waning of some fluvial event; what has been figured by several authors recently as a fining-upward cycle. Observation of more than one section and establishment of some geometric control reveals a much more complex arrangement of sedimentary associations. Adjacent sections, often as close as 5 meters, regularly

display wide variation in rock types at the same interval. Figure two is an attempt to summarize some of the characteristics of a rhythmic sequence in the area of Stop 3. Here is represented a rhythmic sequence in the form of a symbolic analogue model in order to study some of its geometric aspects.

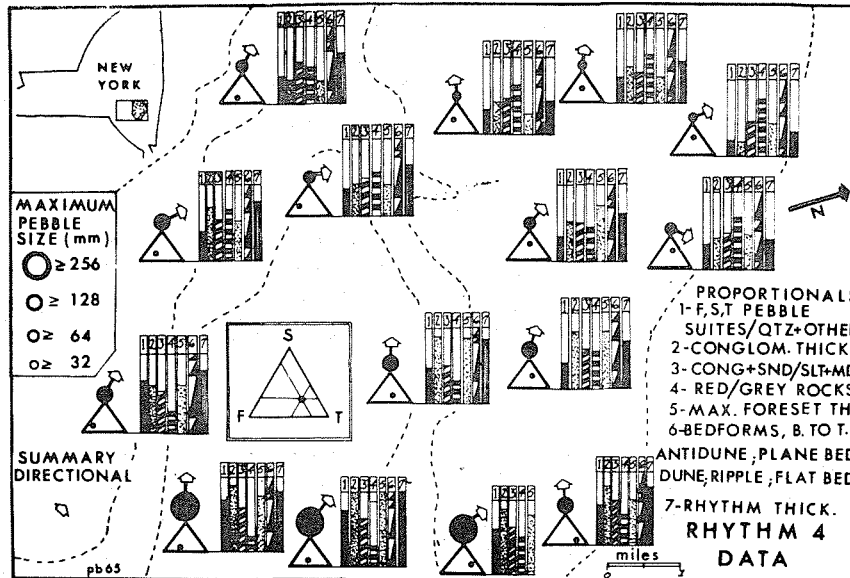


Figure 2. Symbolic Analogue Model of a Rhythmic Sequence

It is worthwhile to consider some of the types of formal models we might use to structure a rhythmic sequence. Figure three is presented to orient those unfamiliar with the concepts involved in model building and manipulation.

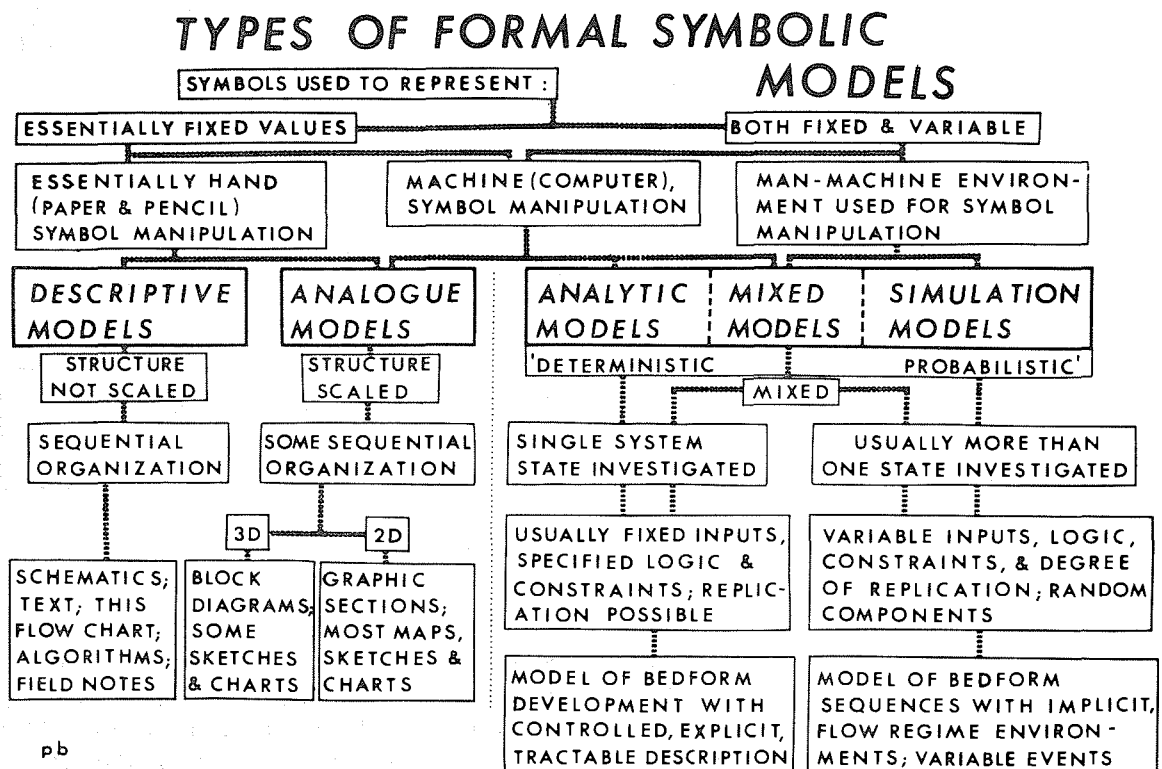
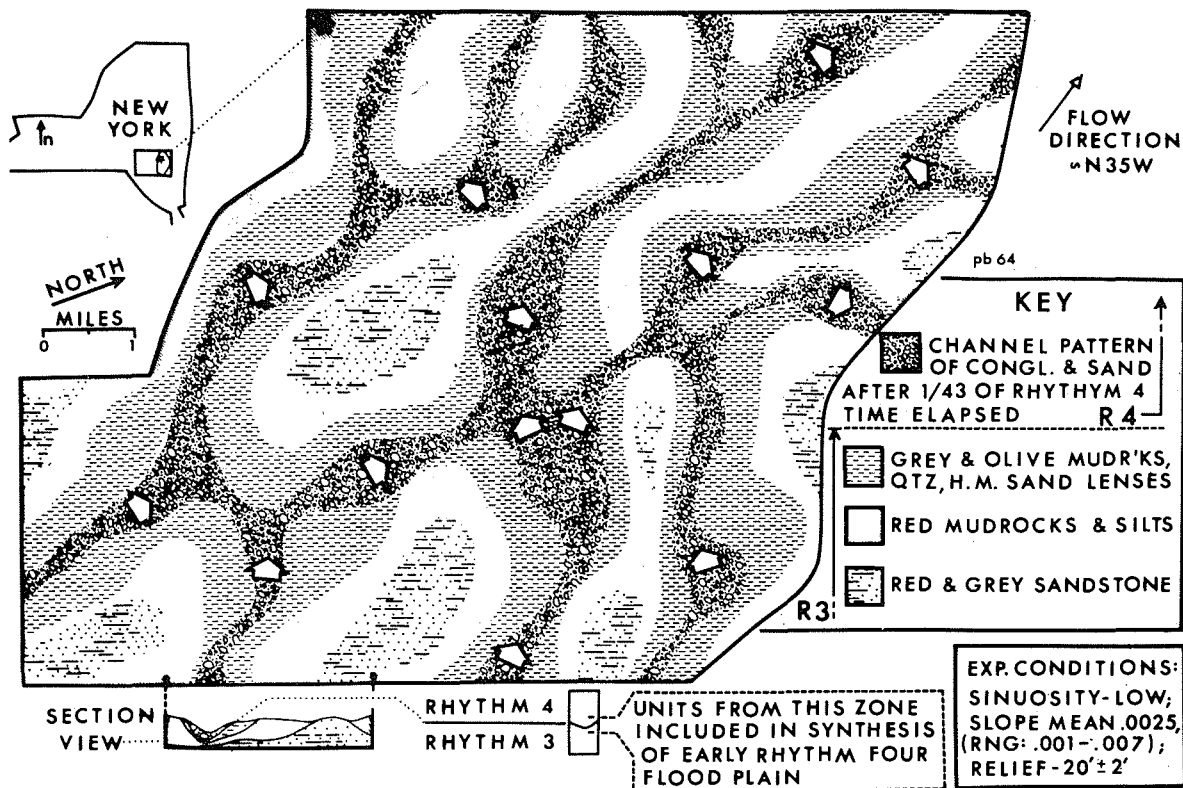


Figure Three. Types of Formal Symbolic Models

With the aid of a simulation model of the North Point domain I was able to experiment with various stratigraphic formats and sedimentologic designs and finally produced a configuration that not only showed close agreement with the field but also helped to explain the complex patterns in the field sections. This simulated rhythmic sequence is shown in Figure four. Represented is a paleogeographic surface of the coastal plain (in part of Kaaterskill Quadrangle) during an interval of time in the early stage of the development of a rhythmic sequence. As time progressed and the rhythm developed, the pattern changed. This is how a sequence of some 57 rhythms in the Catskill Complex was examined; looking in detail at their development over small increments of time. The picture figured here represents the graphic display of the synthesis of both the analogue and symbolic output from the computer. It is not possible to produce a single picture of this detail and complexity with even the most powerful computing system currently available.

It now becomes quite clear that the rhythmic sequences of the North Point were produced by the activities of a complex, braided fluvial system that was not far from a significant mountain source. A report on the sedimentology, dispersal, and petrology of the polymictic conglomerates in the North Point demonstrates the proximity and gross character of the source terranes (Buttner, manuscript in preparation). The main channels migrated laterally across the flood plain, while the main transport action was normal to the migration and downbasin (in the direction of least facies change). Migrations of the system produced the nested and imbricated patterns which contributed to the difficulties encountered in the correlation of adjacent sections.



SYNTHETIC FLOOD PLAIN & BRAIDED SYSTEM OF RHYTHM FOUR BY COMPUTER SIMULATION

Figure Four. Synthetic flood plain of the North Point at an early stage in the development of a rhythmic sequence.

SUMMARY REMARKS

The results of this six year study indicate that the lower Upper Devonian of southeastern New York was produced by a series of fluvial events. Moreover, the study has demonstrated that various computer techniques can be applied to help the field-oriented physical stratigrapher resolve complex stratigraphic problems where paleontological control is difficult to achieve. The use of these methods has been outlined by the author (Buttner, lecture notes in Briggs and Pollack, 1966), and the field geologist will soon be able to find consulting help at most computing installations.

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