GENERAL GEOLOGY OF SOUTH-CENTRAL NEW YORK

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PHYSICAL SETTING

South-central New York is part of the Appalachian Plateau geomorphic province (Fig. 1), and the Catskill Mountains comprise the more rugged eastern part of the region. The Susquehanna River and Delaware River (Fig. 2) are the master drainage systems. According to textbooks the Appalachian Plateau stereotype is supposed to be characterized by rocks that are essentially horizontal and structureless, are of Paleozoic age, and fall within a Davisonian cycle of being "maturely-dissected" with drainages systems that are largely of dendritic shape. On close examination, many of these ideas need modification.

In New York the Appalachian Plateau is bounded by lowlands of older and more complexly deformed rocks. The Hudson-Mohawk Lowland on the east is part of the Folded Appalachians and exhibit tighter folding and more faulting than the Erie-Ontario Lowland on the north. Summit elevations of the south-central New York region rise to the east and range from 1500'-1700' west of Binghamton, are 1800'-2000' from Binghamton to Windsor, and are 2000'-2300' in the Deposit area (Fig. 3). As the master drainages occur at 800'-1000' elevations, the local relief is generally about 1000'. The Catskills provide a more mountainous appearance owing to topographic slopes that are about twice as steep and flood plain widths that are narrower than those in the western part of the region. The valley gradient of the Delaware River is 2.5 times as steep as the Susquehanna River, as it declines from 1060' at Cannonsville to 960' at the State line a distance of 14 miles whereas the Susquehanna declines from 1000' at Unadilla to 900' at the Pennsylvania border, a 37-mile distance.

STRATIGRAPHY

The age of rocks in this region is Upper Devonian and the stratigraphy of the units in the central and western part of the region is thoroughly discussed in other articles of this volume. All strata were formed under Catskill deltaic-alluvial plain conditions, but rocks east of Windsor were mostly deposited on land while those to the west formed in the ocean part of the delta. (Fig. 4) A classic example of a regressing shoreline is depicted in Figure 5. The erosional products from the Acadian highlands expanded the terrigenous part of the delta covering to the west the older marine sediments.

The original thickness of the Catskill beds may have been more than 13,000', but thickness of remaining rocks in New York is interpreted to be about 5,000'. The direction of transport of sediments was westward from the Acadian highlands as inferred through study of "lateral grain size diminution, current direction criteria, i.e. cross-bedding, primary current lineation, and oriented plant fragments, and 'lensing-out' of the red beds" (Fletcher D-2 in Valentine, 1962).

The degraded materials of the highlands in this region produced clays, muds, silts and sands so that shale and siltstone are the common rocks of the marine facies whereas

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sandstone and some siltstone and shale comprise the non-marine facies. There is a significant absence of limestone with the exception of a few thin coquinite horizons. Conglomerates are rare in the part of the Catskills traversed on the field-trip route. Although some literature offers the impression that the Catskill beds are largely "red beds", less than 10 percent of the beds in this area are "red". The reader is referred to the Explanation in Figure 4 for current nomenclature of the various rock-time units.

The rocks that will be seen on the field trip are mostly fine to medium-grained subgraywackes that range in color from brown and red to gray and blue. The volume of sandstone-type units when compared to finer-grained clastics is about 9 to one for rocks east of Windsor, whereas the sandstones comprise only about 20 percent of the sedimentary volume west of the village.

The mineral composition and fabric of the non-marine sandstones make them particularly valuable in the quarrying and milling of dimension stone. The slightly angular sand grains are tightly bonded by an indurated matrix of materials that include sericite, chlorite, mica, and feldspars. This combination of features make the rock hard and of desirable color. Joints and "reed planes" facilitate commercial operations. The rock is sold under a variety of names as: Hudson River Stone, North River Stone, Railroad Stone, Catskill Stone, Bluestone, and Genesee Standard Dark. The thinner units, generally less than 2" are referred to as "flagstone" and are used for sidewalks, patio walls, floor treads etc. Thicker units have a wide range of uses in buildings, construction, and decoration in the architectural arts. Figure 6a and 6b illustrate the natural setting and commercial production of good quality "bluestone".

STRUCTURAL GEOLOGY

The primary or sedimentary structures of the Upper Devonian strata cover a wide range of small-scale features. Ripple marks, rill marks, and flute grooves and casts are common in most south-central New York rocks. Some sequences of the marine facies contain graded bedding, and the sandier horizons show cross lamination. The flow rolls are restricted to marine rocks. Cross bedding is the most important primary structure of the non-marine sandstones. It should be understood that the sedimentary rocks occur in layers with some variation in texture, composition and color. The angularity of bedding planes is so common as to make this a general feature of sediments that formed on a huge system of coalescing alluvial fans and deltaic distributaries. Other features of the non-marine rocks include rain-drop impressions, plant rootlet casts, mud cracks, and occasional fresh-water molluscs.

Certain aspects of the structural history of south-central New York and its relation to other regions in eastern North America are discussed in the Meyerhoff and Woodrow and Nugent articles in this volume. The main properties of the regional structure consist of a slightly flexured south to southwest dipping homocline. Wedel (1932) shows the wave length to be about 10 miles for the gentle east and northeast trending fold axes. More recent work by the University of Rochester group indicates that such structures might more accurately be interpreted as several series of aligned domes. The dip of the rocks is rarely more than 1-2 degrees, but the southern limbs are steeper than their northern counterparts. Wedel uses the following terms from west to east to describe the flexures: Watkins Anticline, Enfield Syncline, Alpine Anticline, Cayuta Syncline, Van Etten Anticline, Horseheads Syncline, Elmira Anticline, Nichols syncline, and Union Center Dome. Table 1 presents data for selected deep wells in south-central New York. An unsuccessful oil test hole was drilled on the Union Center Dome. The regional dip in Broome County is about 11 ft. per mi. in a direction S 30° W.

The main architecture of the Catskill Mountains is a large synclinorium with upturned nose to the east and plunging gently S 25° W. The eastern rim of this region as it rises majestically over the Hudson-Mohawk region is the classic example of a retreat-

TABLE 1

DATA FOR SELECTED DEEP WELLS IN SOUTH-CENTRAL NEW YORK

U.S.G.S. Quadrangle 1;24,000	Location		Elevation (feet)	Well Depth (feet) Bottom Formation	Elevation at Top of Tully Limestone (feet)	Depth to Top of Tully Limestone (feet)
	Longitude	Latitude				
Oneonta	3,300' N. of 42° 20'	400' E. of 75° 05'	1457	4,570 Clinton	-293	1750
Binghamton West	4,200' N. of 42° 05'	3,550' E. of 75° 55'	940	3,117 Tully	-1310	2250
Maine	100' S. of 42° 10'	2,000' E. of 76° 05'	968	3,850 Oriskany	-1038	2006
Maine	3,300' N. of 42° 10'	6,750' W. of 76° 00'	830	4,412 Oriskany	--	--
Whitney Point	10,000' N. of 42° 20'	2,150' E. of 76° 00'	1300	3,250 Oriskany	-205	1505

Kreidler, W. L., 1959, Selected deep wells and areas of gas production in eastern and central New York: N.Y.S. Museum and Science Service Bull. no. 373, p. 243.

ing escarpment in eastern North America, (see Fig. 1 and 5). The structural trends within the Catskills have greatly influenced the thinking of some geologists as they seek explanations of erosional history of the region. Although the dip of major time-rock units rarely exceeds a few degrees, limited localities do contain dips in excess of 10°.

Jointing is the predominant manner of rock fracturing. Small faults do occur but they are local and of small extent horizontally and vertically. The region contains a well-developed joint pattern (Parker, 1942) with two sets nearly at right angles, the best developed joints are approximately north-south and this set is intersected by joints that trend east-west. The joint walls contain several features, the most common are plumose markings. Joints are of local importance for wells in bedrock as they provide the only significant avenues of groud-water movement through otherwise very dense and mostly impermeable rocks. Joints also occasionally control the orientation of some post-glacial streams, and as mentioned earlier, can facilitate quarrying operations of commercial-grade stone.

DRAINAGE HISTORY

General Statement

The topographic flavor of most landscapes is produced by the interaction of degradational processes acting upon earth materials contained within certain structural forms. The amount of time involved without interruption of the status quo may also play a role in the ultimate appearance of the topography. Running water and its gravity friend have scuptured the great majority of land forms in south-central New York. The work of glacial ice is only of tertiary mention.

Descriptive terms that have usually been used to categorize this region include such phrases as "maturely-dissected plateau". This classification depends on the absence of flat uplands and the presence of floodplains in all the major streams. The prominence of the Catskill Mountains may be attributed to the superior erosion resistance of the hard sandstones as the weaker shales were being selectively removed. Uplift was also higher in the east contributing to elevation differences. Although there are no sizable upland areas, some observors claim that there is a rather uniform accordance of peak elevations and that this gradual eastward rise of elevations into the main Catskills can best be interpreted as a former erosional surface of low relief that has been uplifted one or more times.

Development of River Systems

Drainage evolution and erosional history of south-central New York is largely the story of the origin of the Susquehanna and Delaware drainage systems and their ancestors, if they were present. The dating and relative importance of the drainage initiation and its development in time is a hotly contested issue*. Two schools of thought have emerged, namely: 1) The present topography is an inheritance from a more or less continuous erosional history dating from post-Permian times. There is disagreement concerning the mechanics of the drainage development, the nature of uplift renewals, and the importance of drainage reversals and capture. Meyerhoff, Davis, Ashley and Thompson belong in this group. 2) The present landscape is largely post-Cretaceous and all or most of the earlier drainage systems have been obliterated. There is some disagreement concerning the priority of drainage systems. Johnson, Strahler, Mackin, and Ruedemann

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*As the author has in preparation a manuscript that includes a reevaluation of the drainage history of eastern New York, he believes this is not the time or place to attempt a final solution for the problem.

have supported this idea. Fairchild seems to occupy an intermediate view and in one area has support of Ruedemann.

Table 2 is a chronological presentation of ideas in the geological literature that seek to explain drainage evolution in northeastern United States.

TABLE 2

Theories of Drainage Evolution in the Appalachians

Name	Theory
1. Davis, 1909	Primitive drainage flowed north and west. Rivers gradually reversed flow to the east in same valleys.
2. Fairchild, 1925	Primitive drainage flowed southwest from rising Catskills. Susquehanna arced to the north and probably only flowed southeast after Pleistocene time.
3. Johnson, 1931	Consequent streams flowed southeast on a Cretaceous coastal plain cover. Evolution of superposed drainage of principal streams with subsequents developing in weak zones with some captures.
4. Ruedemann, 1932	"Ancestral Susquehanna System" flowed southwest as synclinal consequents of Permian age. The more recent subsequent Delaware River has captured important Susquehanna territory.
5. Ashley, 1933, 1935	Development of transverse southeast flowing streams on a peneplain surface, and many subsequent adjustments of drainage orientation as streams were extended and discovered a variety of weaknesses in underlying rocks and structures.
6. Mackin, 1933, 1938	Similar to Johnson. Differs from Ruedemann in western Catskills with the Susquehanna River capturing ancestral Delaware drainage.
7. Meyerhoff, 1936	Primitive drainage occurred in post-Permian tectonic elements. Present drainage patterns are largely inherited from stream migration and capture as structural forms were exhumed. Western Catskill drainage is subsequent.
8. Strahler, 1945	Similar to Johnson.
9. Thompson, 1949	Westward migration of drainage divide owing to asymmetry and structural and compostional weaknesses in rock units.

The question that should be answered is 'what has caused such a wide variety of views in 70 years to explain drainage evolution in eastern North America'? Behind the answer are the interpretations and their relative importance in accessing certain anomalies and facts. A partial listing of such items is presented below but it should be understood that this is only a small sampling of ideas that can be used to test the validity of any drainage theory.

1. The regional drainage fabric. It can be seen in Figure 2 that there are two dominant drainage lineations, the southeast-flowing streams are transverse to the regional structures whereas the southwest and northeast flowing streams strike parallel with the crustal architectural pattern.

2. Barbed tributaries. In the Appalachian Plateau many examples could be cited of stream junctions where the smaller stream joins the master with the V pointing opposite to the present direction of flow.

3. The double drainage divide of the Susquehanna in New York. Although the regional dip is south, hills increase in elevation to the south. Tributaries of the east-west trending Susquehanna are in the awkward position that northern streams are flowing opposite to the summit elevations whereas the southern streams flow opposite to the regional dip.

4. Through-valleys. The headwaters of many tributaries end in valleys that continue in lineation with valleys occupied by streams flowing in the opposite direction. Such rivers as the Chenango, Unadilla, West Branch Delaware River present the puzzling appearance of broader and more mature valleys at the source, instead of becoming more youthful as in the general case.

5. The right angle bend of the West Branch Delaware River. The strange behavior of this river in the Deposit area contributes to one important controversy. Ruedemann's theory holds that the Delaware captured a former tributary of the Susquehanna, whereas Mackin's theory insists the opposite is true (Fig. 7a, 7b, and 8). Stop 5 of the field trip is designed to explore this problem more fully.

6. The drainage reversal bend of the Susquehanna River. The unusual arc of this river as it flows into Pennsylvania and then loops back into New York only to again reverse direction and flow southeast at Elmira. This city is at the heart of a topographic sag.

It is possible to make a second listing of those ideas, many are debatable and conjectural, that may possibly play some part in attempting to derive a reasonable explanation for drainage evolution.

1. Entrenched appearance of East Branch Delaware River (Fig. 3).

2. Migration down the regional dip by the Susquehanna River east of Oneonta, by West Branch Delaware River, and by Ouleout Creek. For example Figure 9 clearly indicates the trellis pattern of the Ouleout drainage so that the master stream appears to be subsequent, the south-flowing longer tributaries might be resequent, and the north-flowing tributaries would be obsequent.

3. Although Figure 3 does not illustrate it very well, on larger scale topographic maps a series of saddles or possible wind gaps can be aligned north of the West Branch Delaware River with decreasing gap elevations to the west. Could this be what Meyerhoff (this volume) terms "relic topography"?

4. What determines the highest elevations? The author is of the opinion that it is not coincidence that high elevations are located where at least one and often all three of the following factors are involved, namely: (1) At or near drainage divides; (2) the cap rock is the most resistant unit in the area, and; (3) the underlying structure is synclinal. A consideration of such features leads to the discussion of "the peneplain problem".

The Peneplain Problem.

Although the concept of an area being degraded to a plain of low relief was not original with W. M. Davis, he named the concept "peneplain" and carefully enunciated with clarity of deductive reasoning what has served as a denudational model since his papers in the 1890's. The classic area for the study of peneplains and the geomorphic age cycle has been eastern North America, and the clearest expression of the logic is found in the numerous studies of the Folded Appalachians. Perhaps the Appalachian Plateau has not been so exciting a place for regional studies, because the literature is not as voluminous. Contributing to this relative lack of articles and argumentation describing "peneplain" features in the Plateau, is the general absence of such features as water gaps, wind gaps, accordant summits, trellis drainages, etc. that have often been used to count peneplains in the Folded region. Estimates on the number of peneplains in the Folded Appalachians range from 1 to 31. Of course many of these differences can be attributed to variations in interpretation as to what constitutes evidence for peneplains, and/or strath surfaces.

The agreement upon two, possibly three, peneplains by workers in southern New York is remarkable. (Table 3).

TABLE 3

Comparison of Nomenclature for Erosional Surfaces in southern New York. (Cole, 1938)

Campbell (1903)	Fridley (1929)	VerSteeg (1930)	Cole (1938)	Approximate Elevation of surface
Schooley	Kitatinny	Schooley (Kitatinny)	Upland	2300' - 2400'
Harrisburg	Schooley	Harrisburg	Allegheny	1700' - 1800'
	Mine Ridge Three erosion surfaces north of Ithaca		Niagara Floors of pre-glacial valleys	

The views of Rich (1915) could also be added to Table 3. He believed in two cycles of erosion with peneplain surfaces. During the second cycle streams in the northern Catskills were entrenched 1,000' and dissected the peneplain to late youth whereas in the central Catskills they excavated steep-sided valleys in the bottoms of the broad, late mature valleys of the previous cycle. This trenching has not yet reached the extreme upper courses of the streams.

The concept of physiographic aging of a land mass ending in a peneplain has dominated American geomorphic thinking from the time of Davis. Although it was periodically debated, only in recent years has this growing disenchantment reached major proportions that seriously challenge the fundamentals of such a teachable and beautiful system. The views of Hack (1960) and Strahler (1958) represent an alternative to the Davisonian aging concept of land-mass degradation. Such landscapes as the "maturely-dissected plateau" of south-central New York are explained by an equilibrium theory that operates in space and time. If summit levels exist they are explained on the basis of stream spacing and positions of drainage divides. The dynamics of the new approach firmly rooted in such ideas as fluid mechanics offers a clearer understanding of the degradation processes. Some of the new tools being developed to test such concepts are in the field of quantitative geomorphology.

TABLE 4

MORPHOMETRIC COMPARISON OF THIRD-ORDER BASINS IN SOUTH-CENTRAL NEW YORK

Locality		A 50 basins north of Binghamton (mean)	B 50 basins Windsor to Oneonta area (mean)	C 50 basins Deposit to Margaretville area (mean)
Basin area (sq. mi.)		0.57	0.99	1.11
Basin perimeter (mi.)		3.18	4.87	4.60
Stream length mean (mi.)	First order	0.17	0.18	0.21
	Second order	0.25	0.27	0.28
	Third order	0.72	0.90	0.89
	Mean all orders	0.29	0.32	0.35
Overland flow (mi.)		0.062	--	--
Stream gradient (percent)	First order	10.9	11.4	25.2
	Second order	8.4	7.3	19.7
	Third order	4.5	4.7	12.3
	Mean all orders	8.5	9.0	22.0
Topographic slope (percent)		13.0	15.3	27.0
Basin relief (ft.)		428	672	1265
Drainage density		8.38	6.30	5.32
Circularity index		.56	.59	.66
Lithology		shale and siltstone (marine)	shale, siltstone, sandstone (marine and non-marine)	90% sandstone (non-marine)

GEOHYDROLOGY

Geomorphometry Considerations

The most important element of any landscape is slope. The nature of the slopes, whether gentle or steep, long or short, convex, concave, or linear, and their arrangment in space constitutes one important aspect of geomorphometry. Table 4 presents the results of measurements taken within third-order drainage basins along a traverse from Binghamton into the western Catskills. The data were obtained from U.S. Geological Survey topographic maps of 1:24,000 scale. The reader is referred to the many articles by A. N. Strahler and his Columbia University students for a full understanding of procedural methods and nomenclature. For purposes of comparison three different areas were investigated. The areas are disimilar in appearance and in lithology.

Group C, the Catskill drainages, have basins that are twice as large, the relief is three times as great, and topographic slopes are twice as steep when compared with Group A, the non-Catskill drainages. Furthermore in Group C the streams are longer, gradients are steeper, and there are fewer channels per unit area (drainage density). Group B, the transitional section, occupies a somewhat intermediate step between the measurement extremes. Because the rocks throughout the region are of similar age and structure, their degradational history must have been of similar length. The cause of the differences, therefore, are attributed to lithologic characteristics. Sandstone is a coarser-grained and more permeable rock than the shales and thus is capable of supporting larger channels and longer slopes.

Hydrologic Considerations

In regions as south-central New York that have been largely sculptured by the many phases of running-water processes, it is necessary to catalog some facets of the hydrologic regime and to offer some accessment of this activity. Table 5 itemizes the amount of streamflow for the principal drainage systems in the region.

TABLE 5

STREAMFLOW DATA FOR MAJOR RIVERS IN SOUTH-CENTRAL NEW YORK

Name of River	Gaging Station Location	Drainage Area (sq.mi.)	Average Discharge (cfs.)	cfs. per sq. mi.
Susquehanna River	Unadilla, N.Y.	984	1,626	1.65
"	Conklin, N.Y.	2,240	3,654	1.63
"	Vestal, N.Y.	3,960	6,451	1.62
Chenango River	Greene, N.Y.	598	932	1.55
"	Chenango Forks, N.Y.	1,492	2,452	1.64
Unadilla River	Rockdale, N.Y.	518	842	1.62
East Branch Delaware River	Fishs Eddy, N.Y.	783	1,673	2.13
West Branch Delaware River	Near Cannonsville, N.Y.	456	844	1.85
Tioughnioga River	Itaska (south of Whitney Point), N.Y.	735	1,250	1.70
Chenango River	Chemung, N.Y.	2,530	2,530	1.00

Data from U. S. Geological Survey Water Supply Papers.

In this short generalized article, it is not possible to offer a balanced treatment of geohydrology or to explore the many important and difficult interlocking relations that exist between topographic development and the various hydrologic cycle components as the character of the storms, nature of water flow, amount and compositional quality of the water etc. Some topographic and hydrologic parameters, however, are indicated in Table 6.

TABLE 6

GEOMORPHIC AND HYDROLOGIC CHARACTERISTICS OF THREE RIVERS IN THE CATSKILL MOUNTAINS

	Trout Creek	Oquaga Creek	Ouleout Creek
Drainage area (sq. mi.)	49.5	66.0	102.0
Drainage perimeter (mi.)	33.3	45.2	55.1
Maximum relief (ft.)	1280	1040	1370
Circularity	56	41	42
Topographic slope (percent)	20.5	19.2	15.0
Stream gradient (percent)	10.1	9.2	7.8
Areal extent of valley fill (percent)	7.6	5.2	8.0
Annual discharge (cfs.)	90.6	117	171
Annual discharge (ins.)	24.8	24.2	22.8
Annual discharge (cfs. per sq. mi.)	1.83	1.77	1.67
Annual precipitation (in.)	43.4	43.0	42.0
Water loss (in.)	18.6	18.8	19.2

Geomorphic data from U.S.G.S. 1:62, 500 scale topographic maps
Discharge data from U.S.G.S. Water Supply Papers
Precipitation data from Coates manuscript in press.

Precipitation in south-central New York ranges from about 33 inches in the western part of the region to more than 55 inches in the east. The increase of precipitation can be closely correlated with topographic and altitudinal changes. About 50 percent of the precipitation is carried out of a drainage basin as streamflow; it is more than 60 percent in the higher Catskills and less than 50 percent in Chemung drainages. Although such factors as the amount of slope, nature of earth materials, and temperature affect the amount of streamflow, it is water loss through transpiration and evaporation that is the most important determining criterion for the amount of water available to degrade the land mass. The water loss throughout the region has a narrow range of 18-20 inches, and after this requirement has been fulfilled the remainder of the precipitation eventually emerges as streamflow. This is the reason why the Chenango River has only 50 percent the square mile flow of the East Branch Delaware River yet has 70 percent the precipitation. The three rivers that are characterized in Table 6 will be seen on the field trip.

Ground Water Considerations

For a discussion of ground water in south-central New York the reader should study Brown and Ferris (1946) and Wetterhall (1959). Ground water occurs in the interstices of unconsolidated materials and in the joints and fractures of the bedrock. The best water is obtained from outwash sands and gravels. The wells are shallower, the water has smaller amounts of dissolved solids, and yields of 100's of gallons per minute are common with range up to 2,000 gpm. Other wells in the valley fill many encounter clay beds and morainic materials that deteriorate ground-water properties. Bedrock wells commonly are more than 100 feet deep. Such depths are necessary in order to incise sufficient numbers of rock fractures that slowly permit recharge in the well bore. The yield of bedrock wells average 5-10 gpm and rarely exceed 30 gpm. The quality of water has a wide range, but would average about 200 parts per million as $CaCO_3$ hardness, about 180 ppm alkalinity, 15 ppm chlorine, and 0.1 ppm iron.

GLACIAL GEOLOGY

Although Illinoian and Wisconsin ice sheets are known to have travelled at least 40 miles south of the region under discussion in this report, all glacial features and deposits in south-central New York have been given a Wisconsin date in the literature. The youngest ice sheet of Wisconsin time stopped north of the south-central New York region and has been given the name "Valley Heads". This glacier was responsible for many of the features in the Finger Lakes district. The important and debatable question is, however, were there one or two ice sheets that covered southern New York during the Wisconsin prior to Valley Heads time? Although some work has been done on the problem, the writer is unaware of glacial mapping studies that have been done in the area traversed by the field route.

Rich (1935) using topographic and weathering criteria states the case for two separate ice advances in the region of the central Catskills.

> "....an outer belt of moraines...seems to separate two unlike areas - one to the north and east, in which moraine loops are abundant, sharp and fresh; and the other to the south and west where few moraines are found, where smooth, thick drift is the prevailing form of glacial deposit, where evidences of the erosive action of the ice are few, and where the topography and the weathering of boulders suggest noticeably greater age of the drift" (Rich, 1935, p. 130).

MacClintock and Apfel (1944) by the use of pebble counts,outwash, and moraine relations in the area west of Binghamton also state there were two ice sheets. The older one is called "Olean" and the younger is termed the "Binghamton".

Flint (1953, p. 904-5) correlated New York and New England till sheets and concluded that Olean drift is of the Tazewell Substage and that Binghamton drift is the same as Rich's younger moraine and is of the Cary Substage.

Denny (1956) working in the Elmira area doubted the presence of the "Binghamton" for that locality and believed it must occur north of the Valley Heads border. Moss and Ritter (1962) using heavy-mineral-suite characteristics and sand-silt-clay ratios deny a separate advance of the "Binghamton". On the basis of previous studies and work done by the author in the preparation of this report, Table 7 is presented as a summation of till characteristics for this region.

Thus, the author believes that a single ice sheet created the morainic materials in this region, and recommends retention of the names "Olean" and "Binghamton" as lithologic facies. The Olean is the upland facies and the Binghamton is the valley facies. In deep excavations the Binghamton grades vertically into the overlying Olean without an intervening soil profile. Along valley walls the Binghamton also grades laterally into the higher Olean lithology. The circumstances that caused facies development is discussed below.

TABLE 7

Till Facies Characteristics in South-Central New York

		Olean Facies	Binghamton Facies
General appearance		drab and dull	variegated more heterogeneous
Associated land forms		ground moraine, few topographic forms	knobby, irregular
Outwash materials		practically none	some outwash
Lithology of materials larger than gravel size	Local rocks	major constituents	important but rarely more than 80 percent.
	Limestone & chert	generally less than 5 percent	May be as high as 35 percent
	Igneous-metamorphic crystallines		Limestone & chert more than 10 percent
	Degree of round of materials larger than gravel size	poorly-rounded	Bi-Modal, moderately rounded for local rocks, crystallines well rounded.
Heavy Mineral % .149-.317 mm	Coated	Generally more than 65 percent	Generally less than 50 percent
	Opaque	Less than 25 percent	More than 25 percent
Texture Percent	Sand	variable	variable
	Silt	variable	variable
	Clay	variable	variable

Non-Catskill Till

Stream erosion prior to Pleistocene time was vigorous and of long duration. Through-valleys were developed at the points of piracy along the north and east-facing escarpments as obsequent streams with superior kinetics captured south and west-flowing streams with gentle gradients. The drainage divide was continually pushed farther into central New York and the col-like areas are vestages of the relic topography. Along the northern escarpment that delineates the Appalachian Plateau from the Erie-Ontario Lowlands a series of more than 10 through-valleys were developed. Although the present valley floors at the divides range from 1150' to more than 1400', it is certain that bedrock elevations were considerably lower during the ice ages. In this area Fairchild (1925, p. 51) shows post-glacial uplift of about 300'. The thickness of valley fill in some of these saddles is more than 75'. The relative importance of fluviatile erosion in the through-valleys when compared to amount of sculpturing by ice abrasion is an unanswered question. It is clear, however, that by Olean time through-valleys were well developed. Older ice sheets gouging southward traversed the limestone belts incorporating limestone with the erratic-rich igneous-metamorphics from farther north. These lithologies selectively enriched outwash materials owing to their superior cohesiveness and dense fabric. The lower part of the Olean ice in the through-valleys contained these non-digenous rocks in the basal load. With ice wastage the morainic materials kept their residence in the valleys, and such deposits are not found above 950' elevation in the Binghamton area. Thus the Binghamton facies is restricted to the through-valley areas whereas the Olean facies is commonly found in the uplands.

Catskill Moraines

The glacial history of morainic deposits in the western Catskills is different than in the region to the north and west. The topographic orientation of the principal valleys is athwart the major direction of ice transport. As a result ice abrasion was weaker in the valleys than in the upland areas. Other differences are discussed in the Description for Field Trip D. The Binghamton facies is absent from the western Catskills. A brief reconnaissance of the region failed to produce positive proof of more than one till sheet. Thus the till is believed to be the Catskill phase of the Olean facies. The topographic development of the till is well developed, and this is illustrated by the field trip route that traverses many of the morainic loops ("choker moraines") and lobate hilly forms of the till. Apparently the history of ice wastage was different than at Binghamton, because ice retreat was periodic with the development of recessional moraines as individual units in many of the valleys.

Alluvial Plains

A great variety of planar and fan features occur in stream valleys of south-central New York. Many specifics are contained in the report Geomorphology of the Binghamton Area and in the Description for Field Trips B and D. The largest and best-developed plains are found in the Susquehanna River and its major tributaries as the Unadilla and Chenango Rivers. Alluvial features are more subdued in the Delaware drainages and cannot compare in perfection of development.

The planar features range from those that are original surfaces of deposition with little erosional modification, to those erosional forms beveled by lateral stream degration. All are composed of valley-fill materials as bedrock terraces are unknown in this region. The depth of fill often exceeds 200' in the Susquehanna, Unadilla, and Chenango rivers. In the Delaware drainage system thickness of fill is rarely more than 100'feet. The origin of the materials is largely glacial outwash that ranges from clean sand and gravel to lacustrine clays that are known to be as thick as 150' in the Binghamton area. Although Peltier (1949) studied terraces along the Susquehanna River south of Elmira, very little work has been done on similar features in the southern New York region.

Included in the array of planar features are alluvial fans, deltas, kame terraces, valley trains, erosional plains, flood plains, lake plains etc. Many cities and villages have utilized these features as the following tabulation indicates: (See Table 8).

TABLE 8

Alluvial Plains in South-Central New York

Name of community	Principal elevation (elevation in feet)	Type of planar feature
Unadilla	1010	Floodplain of Susquehanna River and alluvial fan of Martin Brook
Sidney	980	Floodplain of Susquehanna at junction with Unadilla River
Bainbridge	990	Extension of terrace from Yaleville Brook junction with Susquehanna
Afton	1000+	Kelsey Brook alluvial fan in Susquehanna
Windsor	980	Occanum Creek alluvial fan in Susquehanna
Damascus	970	Tuscarora Creek alluvial fan in Susquehanna
Binghamton area	840	Floodplain of Susquehanna

From such a tabulation it is apparent that when tributaries joined the Susquehanna, plains of alluviation have developed. Other localities that support this generalization can be found in the Binghamton area, such as the terrace in the Willow Point area of Vestal, and the terrace at Hillcrest near Port Dickinson.

The best developed terrace levels along the Susquehanna River between Unadilla and Binghamton are at elevations of 950'-970' and 1050'-1060'. The terrace history is probably similar to that of other glaciated regions. Lands marginal to the glacier were aggraded during the ice ages, and are currently being degraded by entrenchment of river systems.

SYNTHESIS

South-central New York is the gift of the Devonian Acadian Highlands and the Pleistocene Laurentide glaciers. Clastic, fine-grained, marine units constitute bedrock in the west, and in the east the sediments are coarser grained and terrigenous. Surficial deposits of glacial materials, alluvium, colluvium, and soil show a wide range of composition and texture.

Although the architectural pattern of the Appalachian Plateau is structurally less complicated than surrounding geomorphic provinces, the region has suffered through a long, vigorous, and complex erosional history. Important controversies have arisen not only concerning the details of the denudational life of the Plateau, but over the fundamental principles as well. Problems that must be listed, therefore, as unsolved include: Direction of flow and erosion intensity of primitive drainage systems; presence of a coastal plain cover through which rivers could become superimposed; the nature of stream captures and drainage reversals, and; the verity and/or perfection of peneplain development. Susquehanna drainage is largely limited to the marine bedrock area and Delaware drainage is restricted to sandstone lithologies of land derivation. These factors help account for steeper and longer slopes in the Catskill Mountains.

The ice age was instrumental in causing important topographic alterations. The deposits assume a variety of small morainic knolls and loops, and larger outwash and lacustrine terraces and plains. Numerous drainage diversions have resulted from deposition of till, and choker moraines. This caused abandonment of some channels necessitating their relocation. The variety of new channels includes syn-glacial, pene-glacial and post-glacial phenomena such as high level notches and overflow areas, and youthful bedrock gorges superimposed in valleys. It seems probable that the region of this study was profoundly affected by only one major Wisconsin ice sheet - the Olean Substage.

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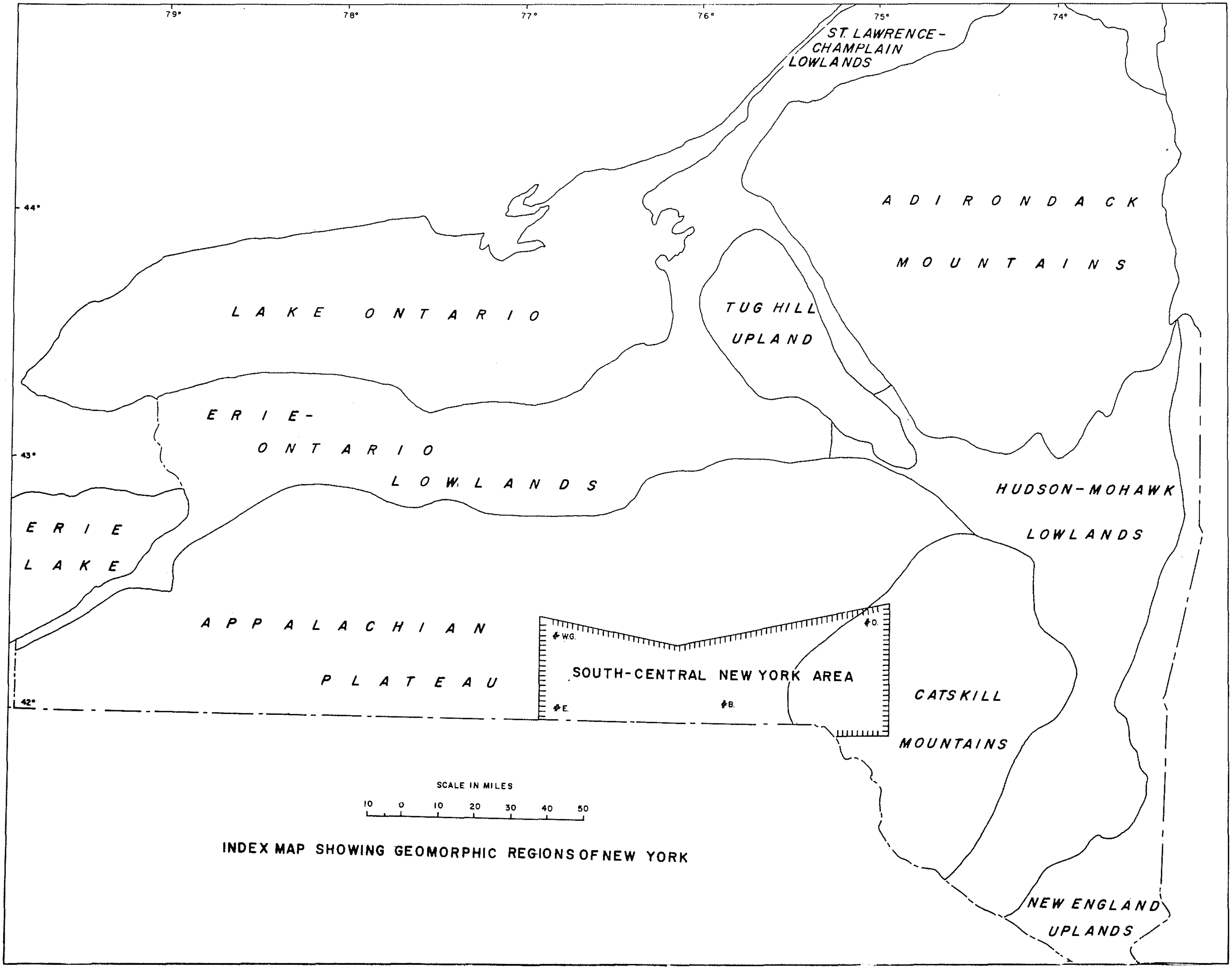

79°
78°
77°
76°
75°
74°
44°
43°
42°
ST. LAWRENCE-CHAMPLAIN LOWLANDS
ADIRONDACK MOUNTAINS
LAKE ONTARIO
TUG HILL UPLAND
ERIE-ONTARIO LOWLANDS
ERIE LAKE
HUDSON-MOHAWK LOWLANDS
APPALACHIAN PLATEAU
SOUTH-CENTRAL NEW YORK AREA
WG.
E.
B.
O.
CATSKILL MOUNTAINS
NEW ENGLAND UPLANDS
SCALE IN MILES
10 0 10 20 30 40 50
INDEX MAP SHOWING GEOMORPHIC REGIONS OF NEW YORK

Figure 1.

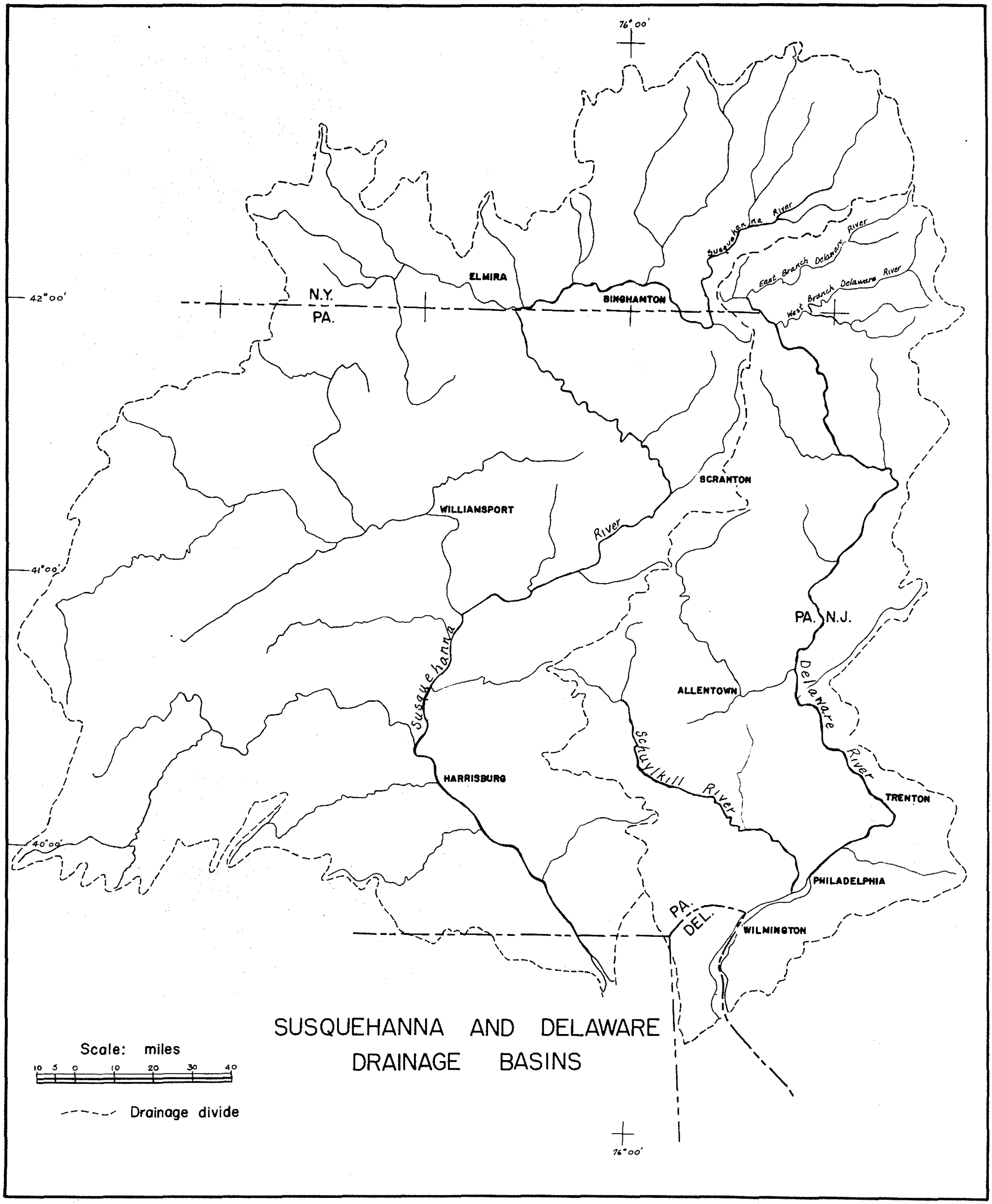

76° 00'
42° 00'
41° 00'
40° 00'
N.Y.
PA.
ELMIRA
BINGHAMTON
Susquehanna River
East Branch Delaware River
West Branch Delaware River
SCRANTON
WILLIAMSPORT
River
Susquehanna
PA.
N.J.
ALLENTOWN
Delaware River
Schuylkill River
HARRISBURG
TRENTON
PHILADELPHIA
PA.
DEL.
WILMINGTON
SUSQUEHANNA AND DELAWARE DRAINAGE BASINS
Scale: miles
10 5 0 10 20 30 40
Drainage divide
76° 00'

Figure 2.

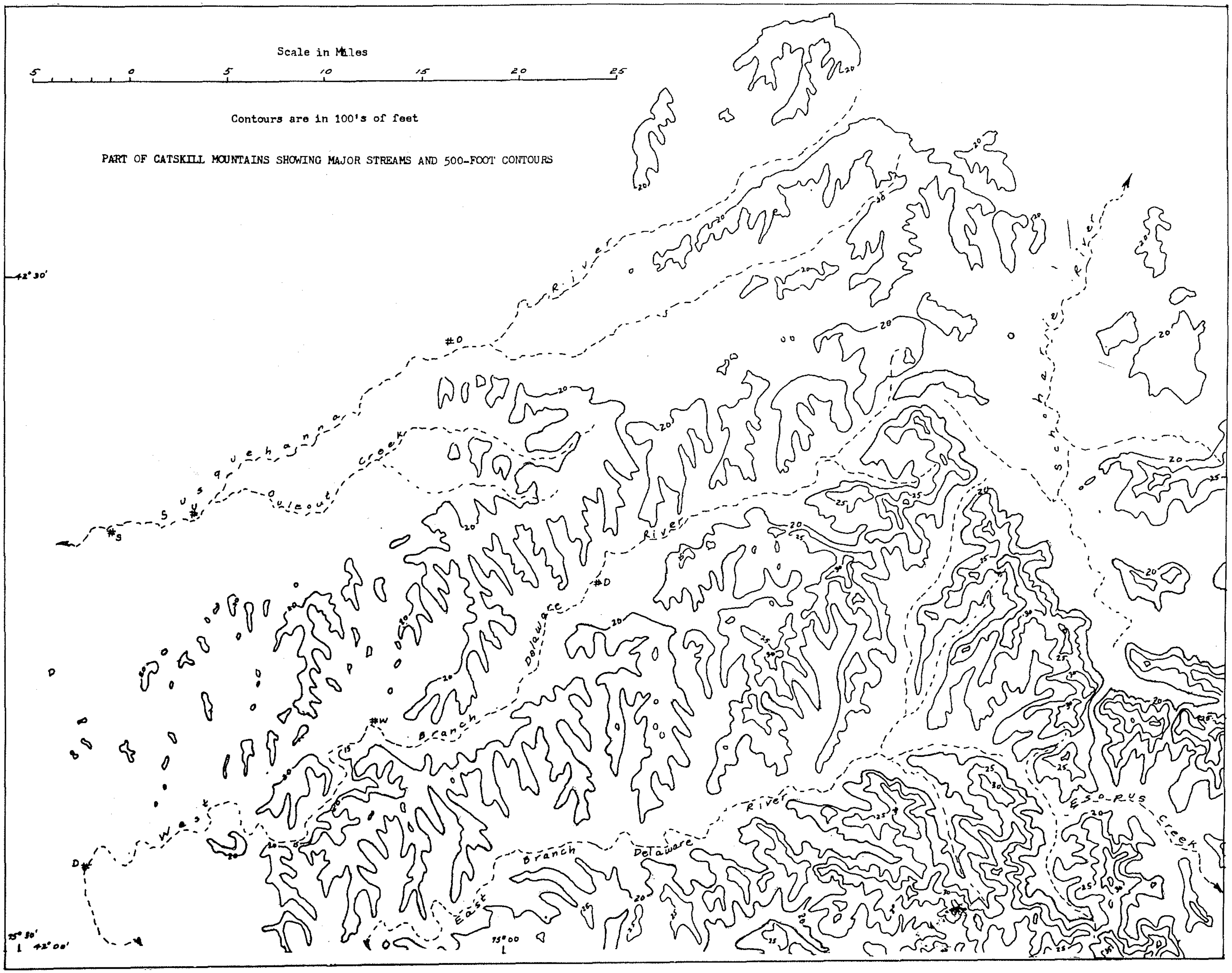

Scale in Miles
5
0
5
10
15
20
25
Contours are in 100's of feet
PART OF CATSKILL MOUNTAINS SHOWING MAJOR STREAMS AND 500-FOOT CONTOURS
42°30'
Susquehanna River
Ouleout Creek
Delaware River
West Branch
East Branch Delaware River
Schoharie River
Esopus Creek
#S
#U
#O
#D
#W
D
75°30'
42°00'
75°00
20
25
30

Figure 3.

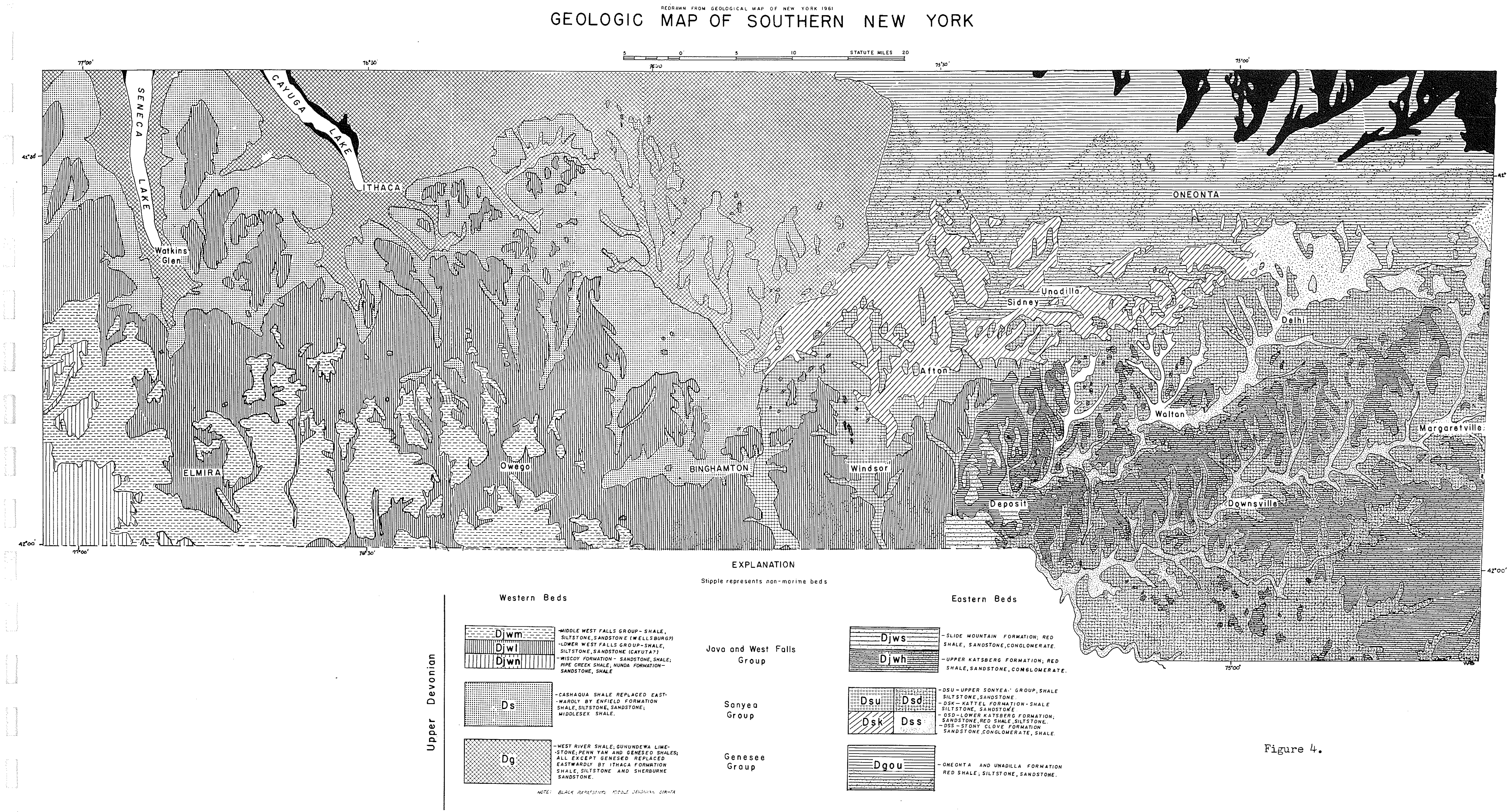
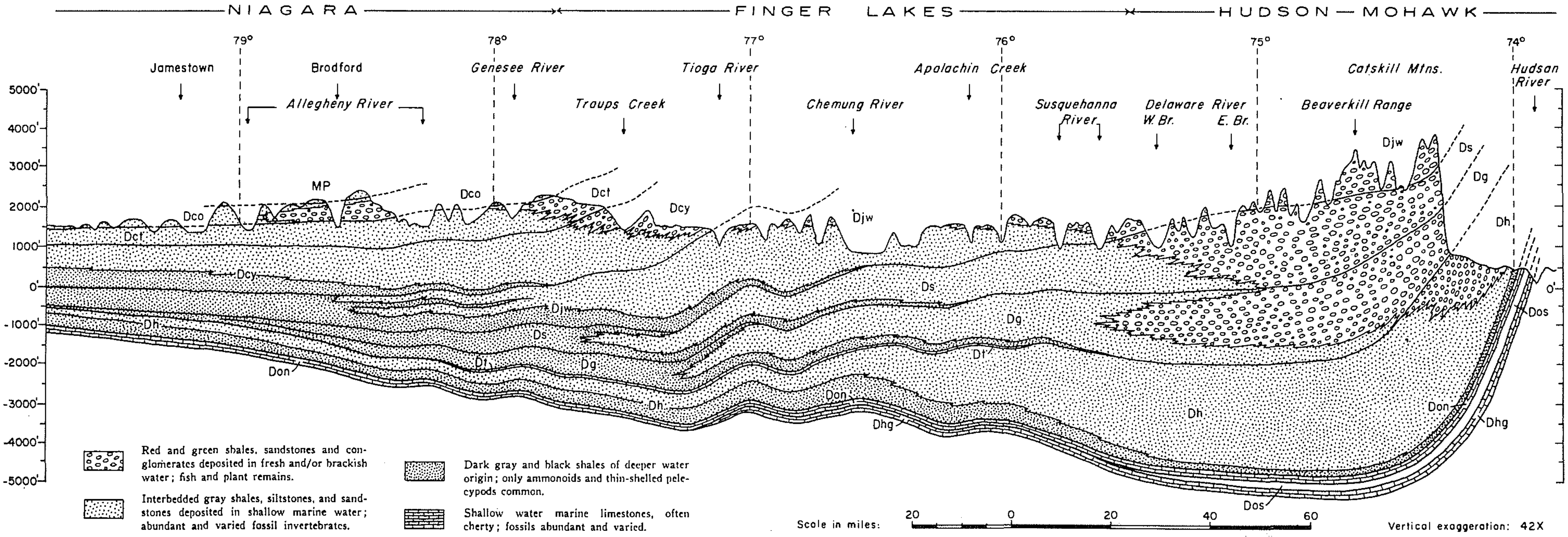

REDRAWN FROM GEOLOGICAL MAP OF NEW YORK 1961
GEOLOGIC MAP OF SOUTHERN NEW YORK
5 0 5 10 STATUTE MILES 20
77°00'
76°30'
76°00'
75°30'
75°00'
42°30'
42°00'
SENECA LAKE
CAYUGA LAKE
ITHACA
Watkins Glen
ONEONTA
Unadilla
Sidney
Delhi
Afton
Walton
Margaretville
ELMIRA
Owego
BINGHAMTON
Windsor
Deposit
Downsville
WB
EXPLANATION
Stipple represents non-marine beds
Western Beds
Upper Devonian
Djwm -MIDDLE WEST FALLS GROUP- SHALE, SILTSTONE, SANDSTONE (WELLSBURG?)
Djwl -LOWER WEST FALLS GROUP-SHALE, SILTSTONE, SANDSTONE (CAYUTA?)
Djwn -WISCOY FORMATION - SANDSTONE, SHALE; PIPE CREEK SHALE; NUNDA FORMATION- SANDSTONE, SHALE
Java and West Falls Group
Ds -CASHAQUA SHALE REPLACED EASTWARDLY BY ENFIELD FORMATION SHALE, SILTSTONE, SANDSTONE; MIDDLESEX SHALE.
Sanyea Group
Dg -WEST RIVER SHALE; GUNUNDEWA LIMESTONE; PENN YAN AND GENESED SHALES; ALL EXCEPT GENESED REPLACED EASTWARDLY BY ITHACA FORMATION SHALE, SILTSTONE AND SHERBURNE SANDSTONE.
Genesee Group
NOTE: BLACK REPRESENTS MIDDLE DEVONIAN STRATA
Eastern Beds
Djws -SLIDE MOUNTAIN FORMATION; RED SHALE, SANDSTONE, CONGLOMERATE.
Djwh -UPPER KATSBERG FORMATION; RED SHALE, SANDSTONE, CONGLOMERATE.
Dsu Dsd Dsk Dss
-DSU-UPPER SONYEA GROUP; SHALE SILTSTONE, SANDSTONE.
-DSK-KATTEL FORMATION-SHALE SILTSTONE, SANDSTONE
-OSD-LOWER KATSBERG FORMATION; SANDSTONE, RED SHALE, SILTSTONE.
-DSS-STONY CLOVE FORMATION SANDSTONE, CONGLOMERATE, SHALE.
Dgou -ONEONTA AND UNADILLA FORMATION RED SHALE; SILTSTONE, SANDSTONE.

Figure 4.

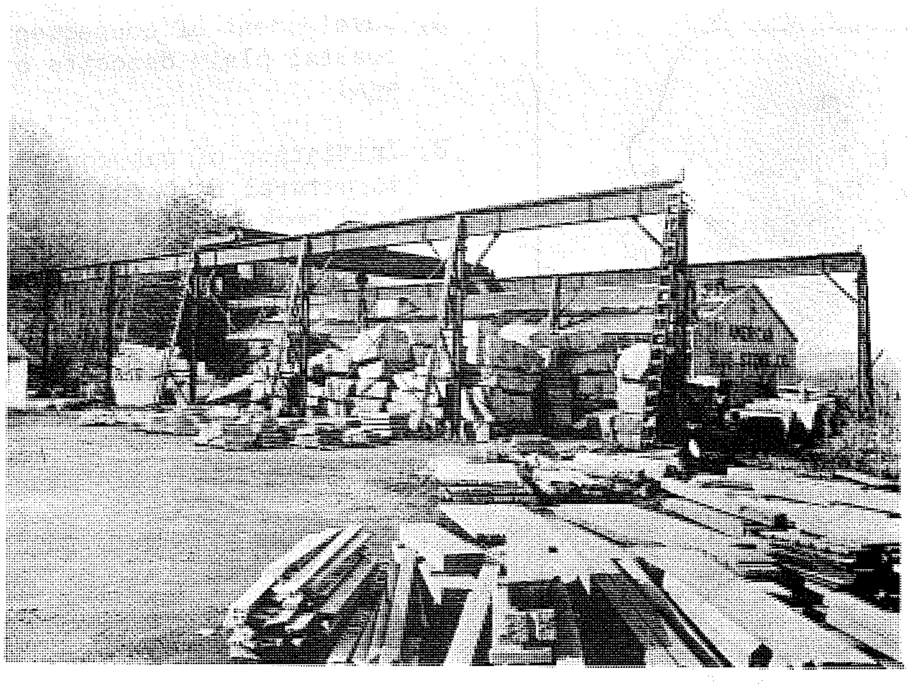


Reproduced from THE GEOLOGY OF NEW YORK STATE (1962) by permission of N.Y. State Museum and Science Service and Geological Survey

CROSS SECTION OF DEVONIAN ALONG NEW YORK-PENNSYLVANIA BORDER

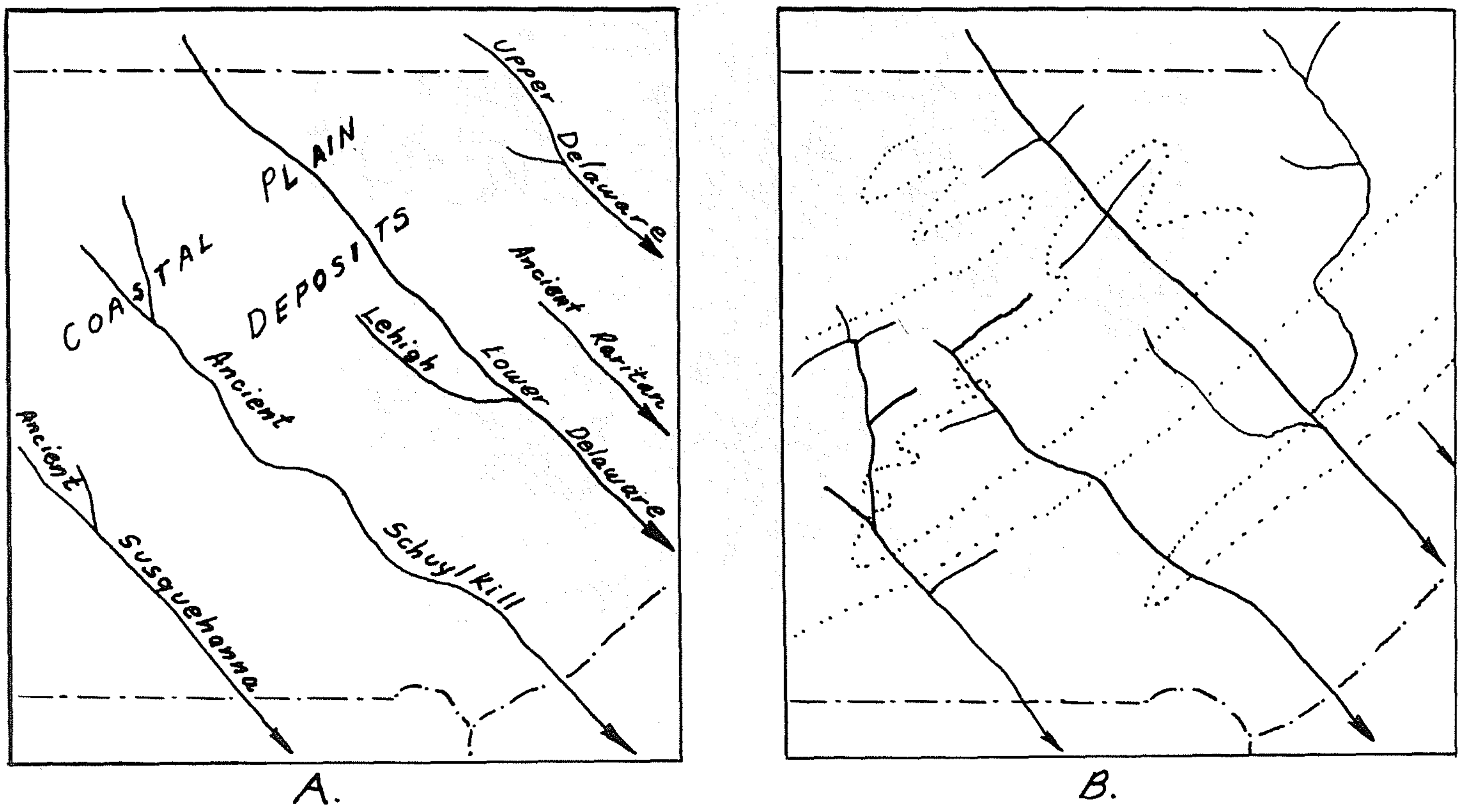
Figure 5.

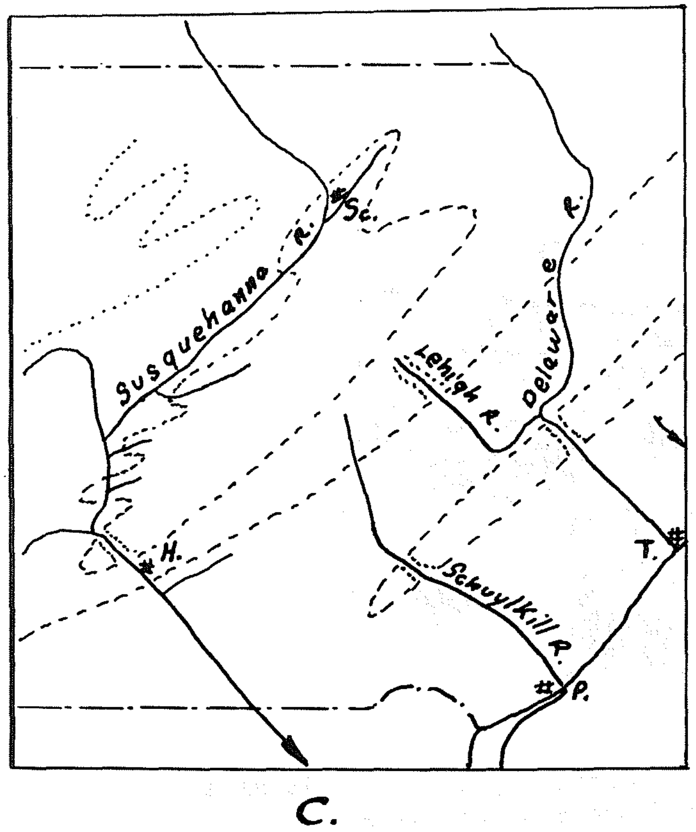
A. Catskill "Bluestone" Quarry South of Sidney, N.Y. These massive non-marine sandstone units yield dimension stone of excellent quality. Photographs taken on the property of American Bluestone Company by courtesy of J. J. Newbery



B. Mill Operation of "Bluestone" at South Unadilla, N.Y. At this site rock from the Sidney quarry is cut and prepared for sale.

Figure 6.





A. Development of consequent stream on coastal plain deposits of Cretaceous age.

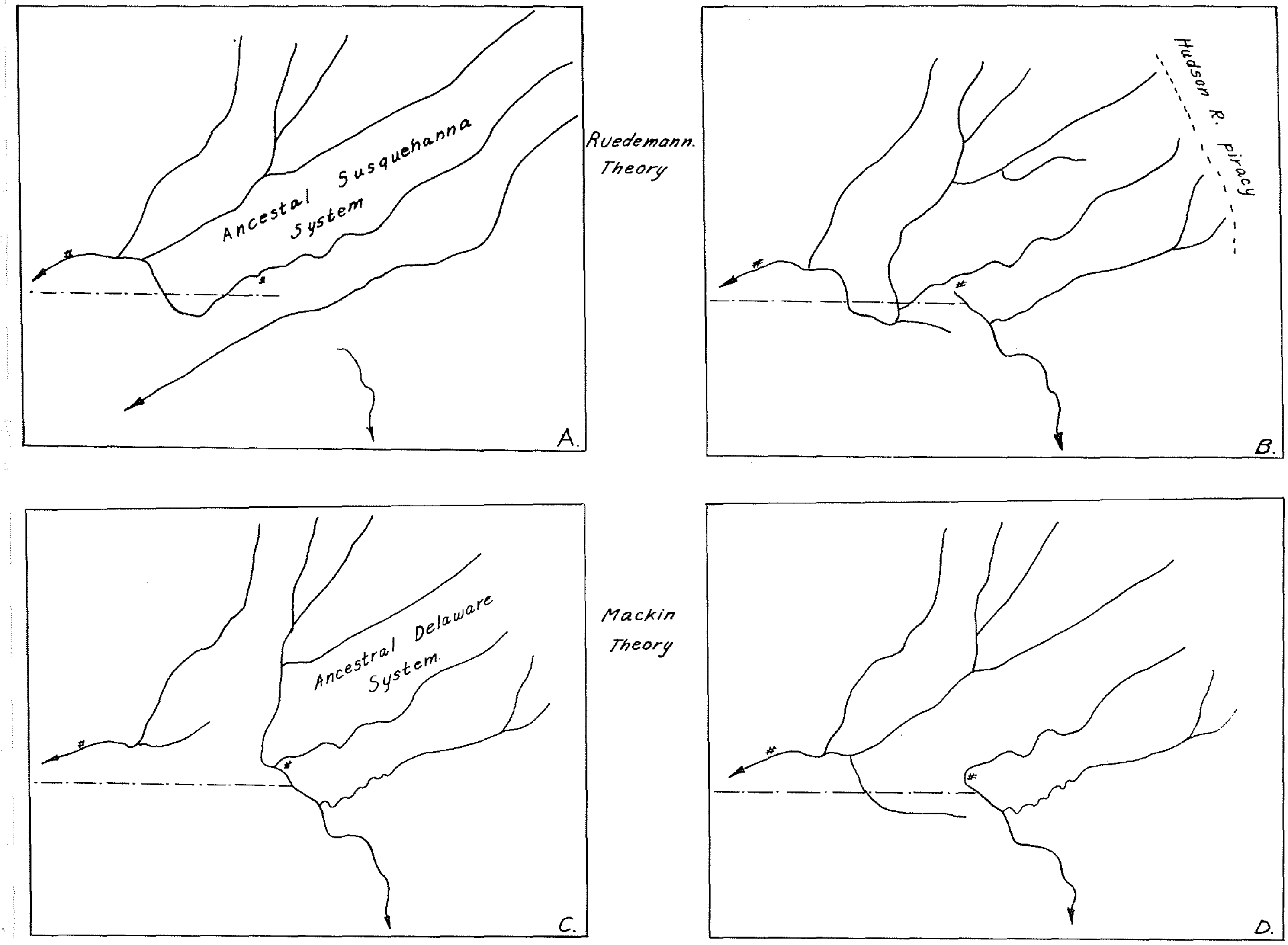
B. Initiation of subsequent streams as structural features and belts of hard rock are encountered.

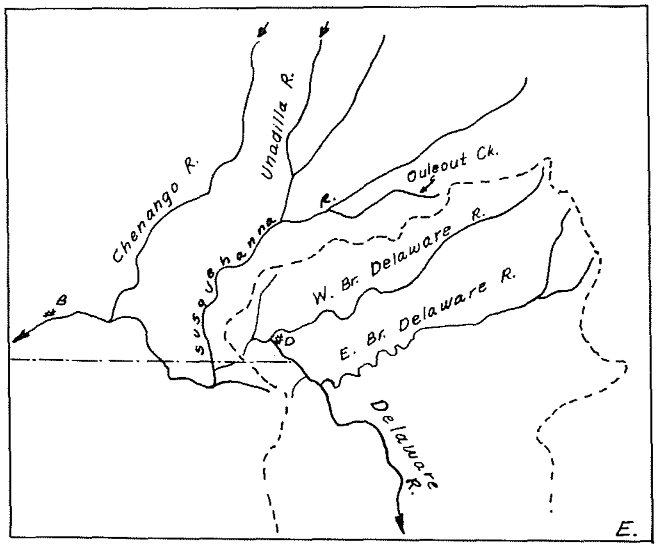
C. Present drainage in eastern Pennsylvania with water gaps, wind gaps, and compound stream systems.

(After D. Johnson (1931)

SUPERPOSITION THEORY OF DRAINAGE EVOLUTION

Figure 7a

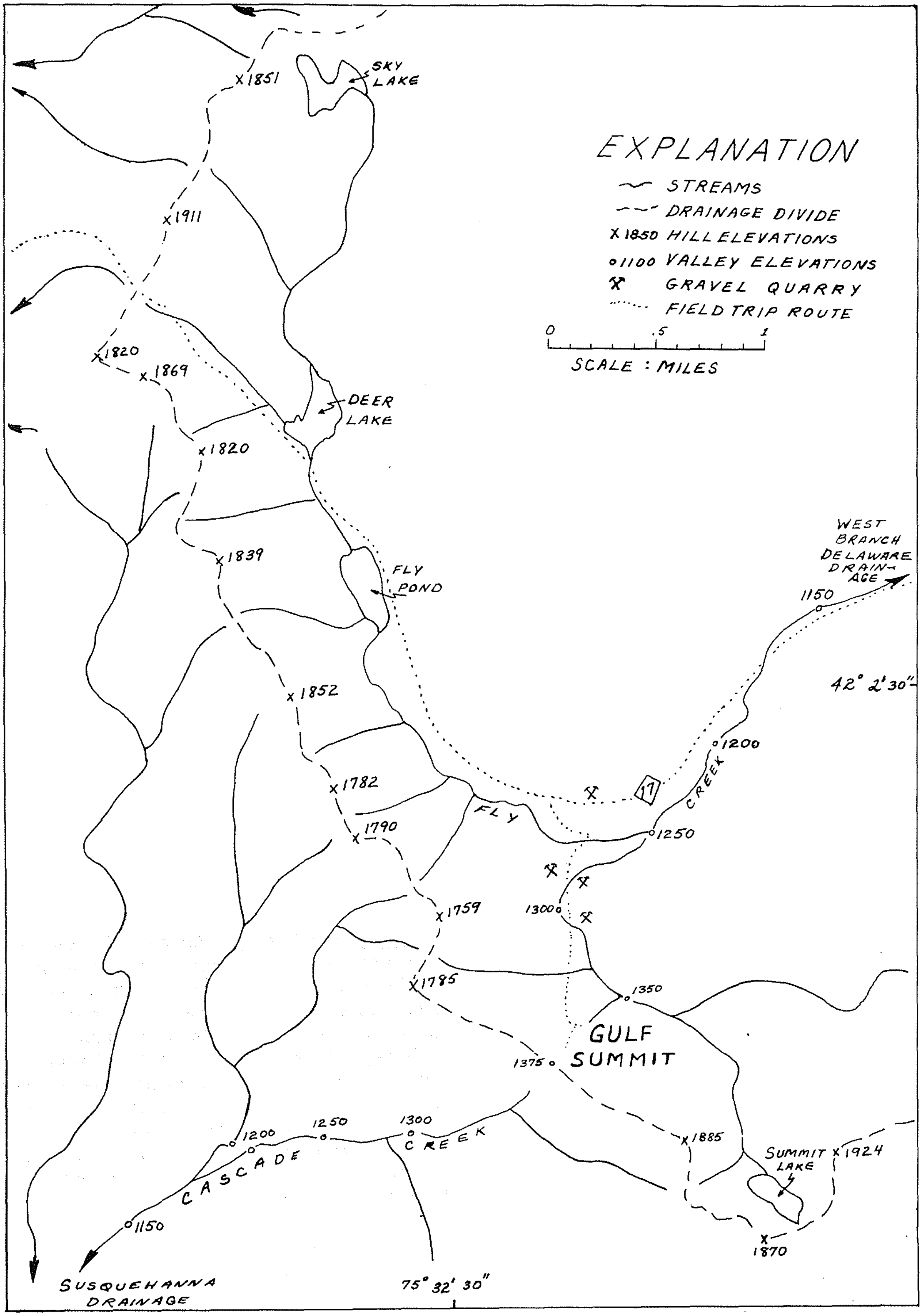




A. Ruedemann Theory. Ancestral Susquehanna is master system of primitive drainage.
B. The Delaware as subsequent stream has made one capture and is ready for a second piracy of the Susquehanna.
C. Mackin Theory. Ancestral Delaware is the original stream of primitive system.
D. The Susquehanna by headward growth has captured northern headwaters of the Delaware and is ready for a second capture.
E. Present relation of Susquehanna and Delaware drainages in the western Catskills.

THEORIES OF DRAINAGE DEVELOPMENT IN WESTERN CATSKILLS

Figure 7b.



DRAINAGE PATTERN OF THE GULF SUMMIT VICINITY

Figure 8.

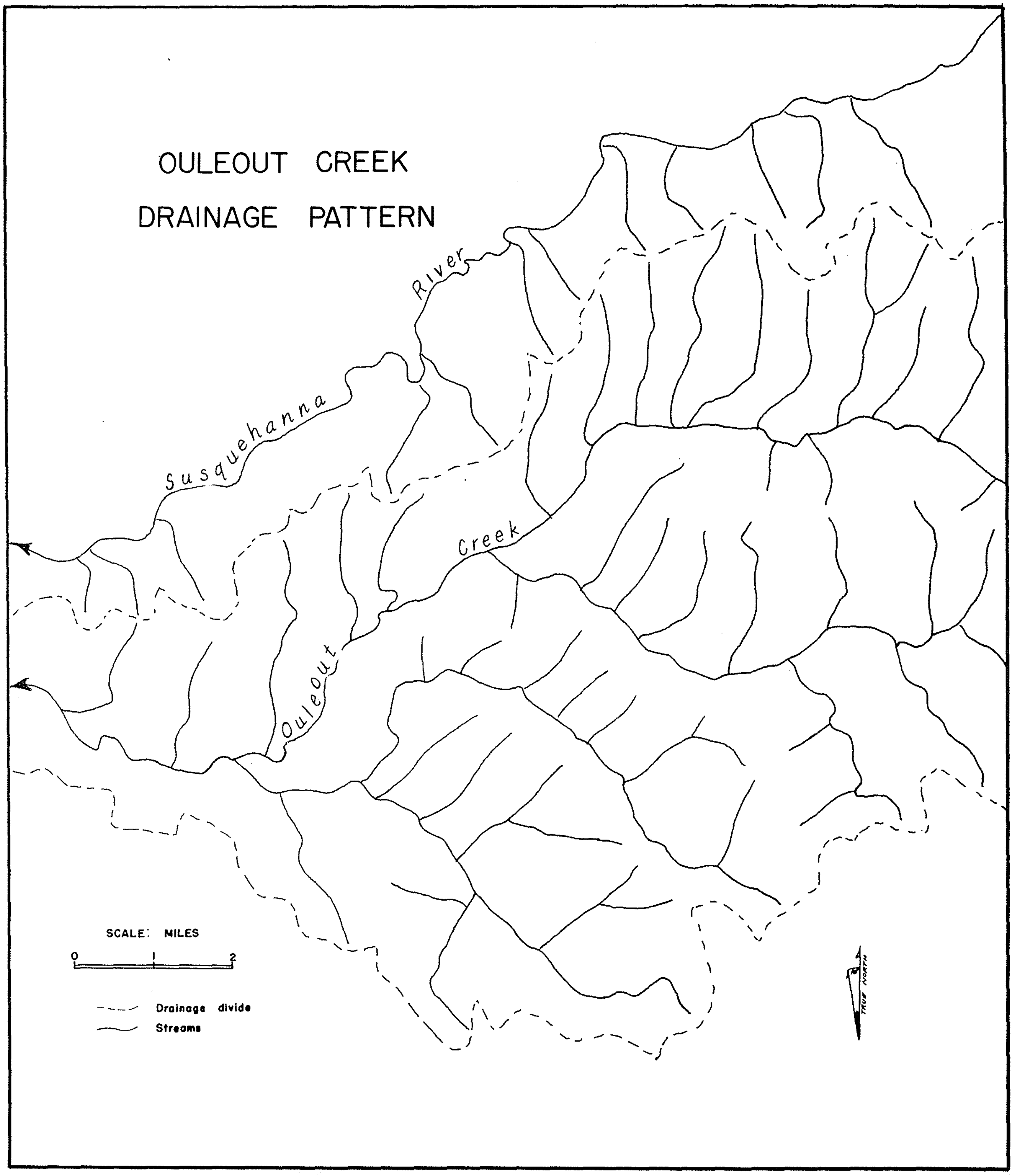
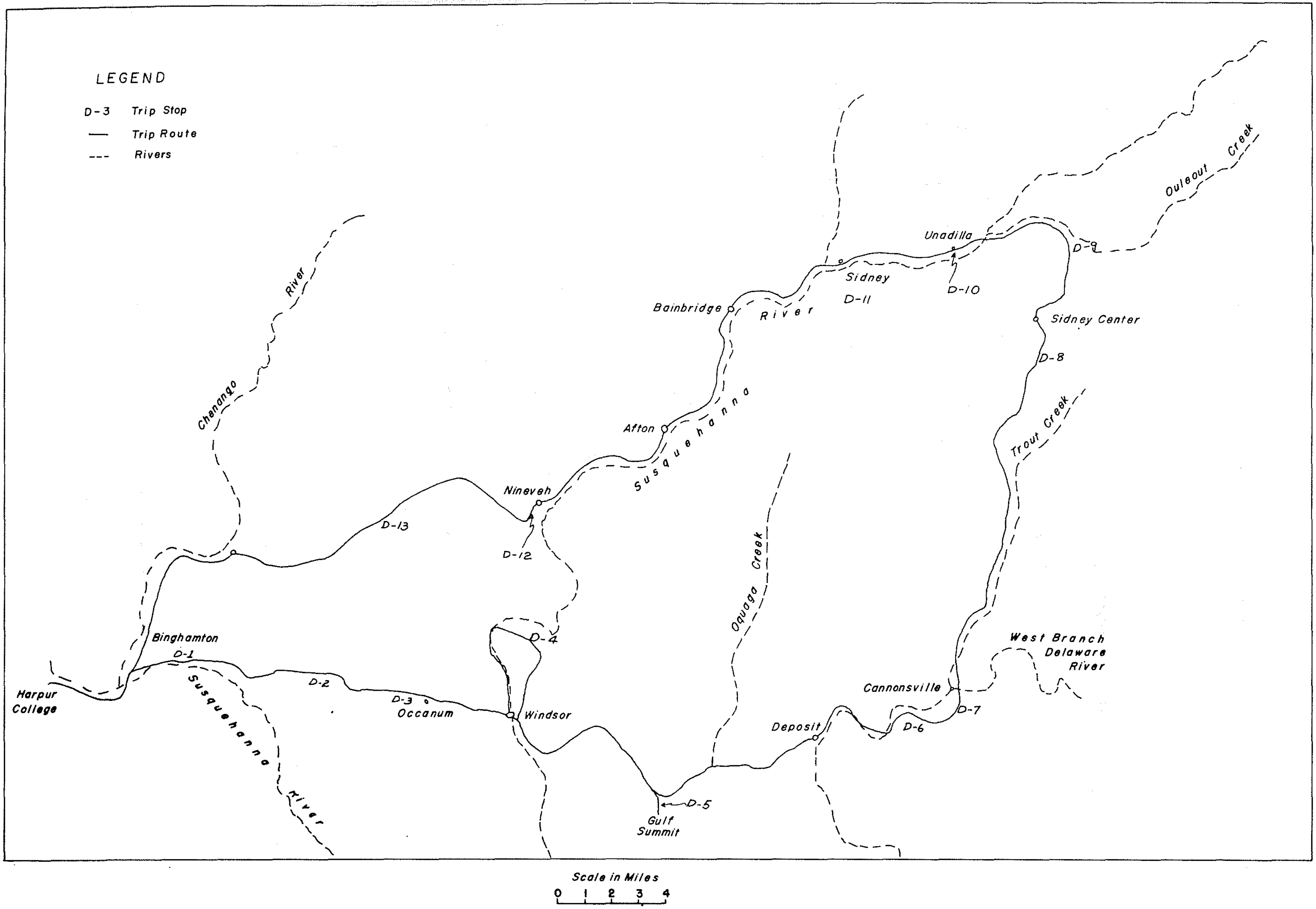

OULEOUT CREEK
DRAINAGE PATTERN
Susquehanna River
Ouleout Creek
SCALE: MILES
0
1
2
Drainage divide
Streams
TRUE NORTH

Figure 9



TRIP D FIELD TRIP ROUTE

TRIP D ROAD LOG AND ROUTE DESCRIPTION

GENERAL GEOLOGY OF THE WESTERN CATSKILLS

Donald R. Coates

Total miles	Miles	ROUTE DESCRIPTION
0.0	0.0	Harpur College entrance. East on Rt. 17. Will turn off 14.8 mi. at Occanum.
6.6	6.6	<u>STOP 1</u>. Outcrop of glacio-fluviatile and glacio-lacustrine beds intermixed with till and a deltaic complex. Lithology of the larger rocks includes red sandstone, local siltstone, and coquinite, and some igneous-metamorphic crystallines. Limestone is rare. The Susquehanna River is 810' and adjacent hills are 1500'-1600'.
7.7	1.1	Stay on Rt. 17 as Rt. 11 turns south. The wide area of unconsolidated materials was produced by junction of the west-flowing Park Creek and south-flowing Stanley Hollow. The latter stream was a major overflow channel of glacial waters when the ice front was north of the area.
8.4	.7	Stay on Rt. 17 at Penn-Can turnoff. Climbing out of the Susquehanna valley. Will see Susquehanna again at Windsor.
10.4	2.0	<u>STOP 2</u>. West Falls Group. Lithology is largely shale and siltstone with some fine-grained sandstone. A few thin coquinite beds are present containing brachiopods and crinoid columnals. The original limestone has been removed. Several excellent horizons of flow rolls occur. The lack of parallelism of flow rolls and bedding planes is seen in the easternmost part of the outcrop. Radiographs done at Harpur (Greene and Coates, 1963) of sections cut at different orientation of the flow rolls indicate some interior structures of small-scale folding and gravity faulting. An angular unconformity occurs at this stop. Rocks also contain many other structures, both primary and secondary in origin. Next to the bedding characteristics in rock importance is the universality of the joint patterns. Two sets are well-developed throughout the Catskill region.
11.5	1.1	West Falls Group on south side of road. Similar to Stop 2. Throughout this area the hills are capped by sandstones of the continental facies of the Catskill delta-alluvial plain complex, but only marine facies rocks are visible along the road at the lower elevations.
14.8	3.3	Take Exit 78. Right to Occanum, and in .2 mi. take another right (east).
16.1	1.3	<u>STOP 3</u>. Walk on the west side of house down to flood plain of Occanum creek about 500 feet. On south side of creek is 50' high outcrop of Olean till (Catskill phase). The bedrock that occurs upstream indicates that in places Occanum Creek occupies a post-glacial channel.
16.3	.2	Excellent terrace development at the community of Occanum. The origin of this type feature will be discussed later.
17.3	1.0	Thick till "choker moraine". This feature is also common along the route that will be travelled and it will be discussed later.
18.0	.7	Windsor. Turn left (north) at red light on Rt. 79 to Ouaquaga 4.0 mi.

The Susquehanna River, elevation 920', flows south. The hills are 1700'-1900'. Occanum Creek forms an alluvial fan and the village of Windsor is built on the junction of the alluvial fan and the 980' level of outwash developed by the Susquehanna River in glacial times during ice recession. This terrace extends to Sage Brook and Rt. 79 utilizes it. Well-developed flood plain occurs in the present Susquehanna channel area.

21.0 3.0 Sage Brook. Top of alluvial fan is 1000'. Olean till (Catskill phase) is exposed on north side of stream. This is the southern edge of the morainic barrier that extends northward around the river meander.

22.0 1.0 Turn right (east) at Quaquaga over Susquehanna River and keep left at road Y .2 mi. Good view of present channel, plains and terraces on this west-flowing stretch of river.

24.4 2.4 STOP 4. This is a .25 sq. mi. area of stratified glacial deposits. Materials have a wide range of size, composition, and structural forms. The history of this area originated with blockage of the river by ice and morainic deposits in the channel to the west. The glacial meltwaters were diverted to a low pass east of the former valley, causing incisement of the former divide. Further recession of the ice front occurred with the abandonment of stagnant blocks that melted more slowly owing to favorable positions of insulation. These conditions account for the complex bedding, size, and sorting of material relations. Much evidence of ice-contact deposits, lacustrine conditions, deltaic sedimentation,and valley train outwash is visible. Disconformities occur indicating an erosional interval separating deposition of older and coarser materials from younger sands. In some of the outwash sands there are veinlike structures composed of "bridged" grains. Normal faulting is also present. Travel in and out of quarry is .6 mi.

25.3 .3 From the quarry take the road south to East Windsor, pass under the tracks and turn right (south) at the T. This valley is the former overflow channel of the Susquehanna that was in turn abandoned when the drift dam was breached in the older channel to the west. Elevation of the pass is 1000'.

28.6 3.3 Intersection of old Rt. 17, turn left (east) and stay on road until Gulf Summit, 7.7 mi.

30.2 1.6 Damascus. To this point the route elevation has been 900'_1050' and at this level all bedrock is marine. Rock exposures in the new Rt. 17 roadcuts at Damascus indicate this is the strand line at road level. There are many interfingerings of marine and non-marine beds at this locality. Eastward the rocks are mostly non-marine. Damascus is on an incised alluvial fan of Tuscarora Creek. The road now climbs what is locally called "Tuscarora Mountain", and hill elevations are over 1900'.

32.9 2.7 South of the road is the first visible exposure of the non-marine strata of the Catskill delta-alluvial plain complex. Formations are still in the West Falls Group and are continuous for more than one mile.

33.9 1.0 Deer Lake. This lake along with Sky Lake one mile north and Fly Lake one mile south occur in the drainage of Fly Creek. The amphitheater-like basins all contain constrictions on the south suggesting their glacial origin of impoundment of south-flowing Fly Creek behind morainic loop dams. This pattern is repeated throughout the Catskill area.

36.3	2.4	STOP 5. Turn right (south) to Gulf Summit. This area contains a great variety of glacial deposits, many are stratified. This is a topographic hollow with slopes rising on all sides, and thus was the locus for a large stagnant ice mass. The meltwater drainage was southwest and a deep notch was incised southwest of the village. This is now the divide, elevation 1375', between Cascade Creek flowing west to the Susquehanna River and a tributary of Fly Creek flowing east to the West Branch Delaware River. (see Fig.7 and 8) Cascade Creek with greater gradient is capturing drainage that formerly went eastward. 2.2 mi. round trip to Gulf Summit and return to Rt. 17.
39.0	2.7	North of road is sand and gravel quarry developed in materials that indicate deltaic and glacio-fluviatile origin. These deposits are typical of the Otisville gravelly loam that occurs as a terrace-band through this area at elevations that reach 1410'. Thus, at a minimum there has been more than 35' of post-glacial incisement through the pass at Gulf Summit.
40.8	1.8	Junction of Rts. 17 and 41. At this location on north side of road was a well-developed esker, recently demolished during construction of the new road. From this point to Deposit in the Oquaga Creek valley are many glacial deposits, including high-level hanging deltas. See text for data on Oquaga Creek.
44.3	3.5	Deposit. LUNCH STOP at the Jordan House. This town is often given as the western boundary of the Catskill Mountains. Eastward the rocks are all continental, (Fig.4) and the stratigraphy for the general area is the Sonyea Group, with the Stony Clove and Lower Katsberg formation in the valley and lower slopes and the Upper Katsberg formation of the West Falls Group on the higher slopes and capping the mountains.
45.5	1.2	Turn on Rt. 10 left (east) at stop light. Stay on Rt. 10 to Cannonsville, 9.2 mi. The route parallels the west-flowing West Branch Delaware River. Upper Katsberg beds will be seen on left, with cross bedding, typical of many non-marine sandstones. Large outwash area is present on south side of river.
47.2	1.7	Old Rt. 10 has been abandoned east of intersection of Rt. 8 and Cold Spring Creek. This is new bridge over the river and all the new construction was necessitated by development of Cannonsville dam and area as a reservoir for New York City. Work is done through the office of the Board of Water Supply.
48.6	1.4	Massive continental sandstones. This is near contact of Upper Katsberg and Slide Mountain formations. Good exposures for .8 mi.
50.2	1.6	STOP 6. Picture stop for Cannonsville dam area. The Board of Water Supply, City of New York was created in 1905. Since that time water use in New York City has risen from 400,000,000 gallons per day to 1,200,000,000 gpd in 1955. Estimated usage for the year 2000 is more than 1,900,000,000 gpd. The Catskill system of reservoirs was started in 1907 for eastern drainages. When these supplies appeared inadequate for continued growth of the City, enabling interstate legislation was undertaken to use Catskill drainages of the west-draining Delaware

River. In 1931 by court action 440,000,000 gpd could be used by the City and this was increased to total usage of 800,000,000 gpd in 1954. Total cost for the present Catskill reservoir system is well over $1 billion.

The Cannonsville Reservoir will impound 97.4 billion gallons in the 450 square mile drainage area of the West Branch Delaware River. The dam is an earth embankment about 1,500' long and 175' high. The water supply will move by gravity through the West Branch Tunnel to the collecting Rondout Reservoir. The tunnel will be 44 miles long and 11.3 feet in diameter. Estimated cost of the dam and reservoir construction is about $60 million and the tunnel at $81 million. (Source: 50th Anniversary Report of the Board of Water Supply).

53.6 3.4 STOP 7. Catskill-type red beds. View of the village of Cannonsville that will be inundated when construction of area has been completed. (see Cover page for picture taken prior to construction).

54.7 1.1 Pass over West Branch Delaware River and at Cannonsville turn right .2 mi. then left (north) up Trout Creek. (see text for Trout Creek data) Cannonsville was built on materials that developed a small alluvial fan and terrace. Soil classification is Tunkhannock gravelly loam. It is 114' to bedrock.

A variety of phenomena can be seen during ascent of Trout Creek. The valley slopes are in places bedrock (lower Katsberg Formation), and in others show unconsolidated materials some till, some stratified outwash and kame terrace deposits, and probably some of the large blocky rocks are in the range of congeliturbites. In places the road is on a terrace and there are constructional hills, mostly kames, developed in a valley-choker type of morainic complex. North of the kame and terrace area are flat plains of lake deposits impounded by the stagnant ice.

57.8 3.1 Lacustrine sands were uncovered during construction of the new bridge and another well-developed lake plain occurs upstream from this locality.

60.0 2.2 Rock Royal. Sherruck Brook has developed an alluvial fan and associated with it is glacial outwash. On east side of Trout Creek are more exposures of stratified outwash. Lake plain occurs north of this area.

63.4 3.4 Village of Trout Creek and intersection of Rt. 206. Continue north. Valley fill is 60' thick.

64.0 .6 Glacial constructional topography of knobby-morainic hills, incised by a post-glacial, V-shaped gorge. This pattern will be seen many times on the trip.

65.4 1.4 Turn right, stay on blacktop.

65.9 .5 Bedrock and morainic loop.

67.9 2.0 STOP 8. Stone net in lower Katsberg Formation. This was first noticed by E.H. Muller. Open meadows as this, throughout the Catskills, often show similar features. The slabs develop polygonal shapes, and constantly change in attitude from the center of a net. There is also some tendency for size-sorting of slabs. The original spacing of joints seems to influence the location and development of the nets. Frost heaving and ice wedging aid in detioration and movement of the slabs.

68.2 .3 Drainage divide for Susquehanna and Delaware systems.

69.9 1.7 Turn left at T to Sidney Center.

71.0 1.1 Turn right in Sidney Center on blacktop at Flying A sign.

72.0 1.0 Keep to left at Y in the road. Morainic loop on left side of road with post-glacial gorge.

73.0 1.0 Man-made lake.

73.5 .5 This is site on right side of road of Gulf Oil Company test well drilled by Delta 29. On March 16,1963, 3800' of rock had been drilled in about a month. Apparently the hope is that Oriskany sandstone when encountered will contain oil or gas of commercial value. From this position the road descends to Ouleout Creek drainage area.

74.8 1.0 STOP 9. Rt. 7B, East Sidney Dam and Ouleout Creek drainage area. See manuscript for data on Ouleout Creek and Figure 9. Turn right .3 mi. to dam. Oneonta formation red beds occur at base of dam.

East Sidney Dam built by Department of Army, Corps of Engineers. Completed 1950.

Dam characteristics:	
Quantity of concrete	156,000 cu. yd.
Height above Ouleout Ck.	130'
Length of Spillway crest	240'
Total length of concrete dam	750'
Embankment	
Length	2,010'
Rock Fill	113,000 cu. yd.
Earth Fill	194,000 cu. yd.
Excavation	
Earth	323,000 cu. yd.
Rock	113,000 cu. yd.

Take Rt. 7B from the dam going east until intersection with Rt. 7. This part of road traverses excellent kame and kettle topography. There are two well-developed lower terraces before Ouleout Creek unites with the Susquehanna River. Sands and gravels are Tunkhannock gravelly loam, the upper terrace is Tioga silt loam and lower terrace is Chenango silt loam.

79.1 4.3 Rt. 7 turn left (south) to Unadilla. Oneonta formation crops out along railway cut. Susquehanna River flows south, elevation 1000'. Hills rise to 1900'.

81.0 1.9 STOP 10. Quarry southwest side of Unadilla. This area is kame and kettle topography within a morainic complex that impounded meltwaters during glacial recession. Extensive lake plains and terraces levels and remnants of levels occur from this position upstream several miles. This pattern is repeated several times downstream in the Susquehanna valley. See text for description of lithology.

84.4	3.4	Rt. 8 intersection and Sidney. If time permits a left turn will be made, to quarry site 3.3 mi. south of Rt. 8 and .4 mi. east off of main road.
88.1	3.7	STOP 11. The Masonville Quarry owned and operated by The American Blue Stone Company, New York, N.Y.: has been in operation since 1945. (See Fig.6) Current level working area is about 250' x 100' and production is confined to mill blocks. The processing plant is in South Unadilla. The quarry is flooded during the winter months to a height five feet above the lower bench to protect the stone from ice and frost damage. Mr. James J. Newberry has kindly given information about the quarry and has given permission to visit it. The mill processes 16,000 cu. ft. of stone from this quarry.
91.8	3.7	Back to Sidney and intersection with Rt. 7. This is near the confluence of the Susquehanna and Unadilla Rivers. Streamflow of these rivers in this area are: Susquehanna River at Unadilla, N.Y., 1,626 cfs for 984 sq. mi. drainage area, and Unadilla River at Rockdale, N.Y., 842 cfs for 518 sq. mi. drainage area. Although the Susquehanna has two times the flow today owing to the larger drainage area, it is probable that the Unadilla carried more water during the ice ages. The headwaters of the Unadilla are at lower elevations than most Susquehanna tributaries and the major tributaries of the Unadilla occur in through-valleys. Overflow of the glacial lakes in the Mohawk Valley Region therefore found ready-made outlets in such rivers as the Unadilla and Chenango, and turned these valleys into giant sluiceways for the impounded glacial waters. There is a high-level drainage channel of the Unadilla in the saddle that occurs just east of Mt. Moses, the hill that rises north of the intersection of Rts. 7 and 8. Throughout the Sidney area are outwash sand and gravel quarries. Terrace development is common and a good view of the 1010' level occurs on the south side of river.
94.6	2.8	Quarry outwash materials, coarse and rubbly at the bottom and finer sands and gravels at the top. The road is built on the 1010' terrace level.
97.0	2.4	Bainbridge stoplight intersection of Rt. 206. Bainbridge is built on the 1010' terrace. Susquehanna River is 975!
97.7	.7	Olean till on right side of road. (See text for description).
100.5	2.8	Sand and gravel area. Ice contact features are present. The Susquehanna is incised through the outwash plain.
101.9	1.4	Afton Lake, a kettle hole lake. This is kame and kettle topography, created in part by a morainic complex. The locale is characteristic of many others in the Susquehanna valley, in which the constructional topography occurs near the junction of the Susquehanna and a tributary. The south-flowing Kelsey Brook is an underfit stream and the morainic areas are upstream in the Susquehanna valley.
102.7	.8	Afton and Rt. 41 intersection. More kame and kettle topography near the mouth of the north-flowing Cornell Creek on the south side of the Susquehanna valley.

107.8	5.1	STOP 12 near Nineveh. The Susquehanna River 950' elevation has incised more than 100' through a broad and exceptionally well-preserved 1060' terrace level, called "The Plains". Remnants of this level can be found several miles along the Susquehanna.
108.8	1.0	Wylie Brook and Rt. 235. Continue west on Rt. 7 to Binghamton. We are now leaving the Susquehanna River which turns south. The road ascends Belden Brook up to Belden Hill.
110.0	4.8	STOP 13. Parking area, elevation 1650'. Near the Chenango-Susquehanna drainage divide. View to the south provides appearance of accordant summit levels. The summits actually range between 1600' and 1850'. Westward the road follows a tributary of Osborne Creek, an underfit stream. There are a series of at least four different morainic loops in this tributary system of the Chenango, These choker moraines occur at intervals from the parking area of 1.6 mi., 1.6 mi., .5 mi., and .9 mi. Notice the flat topography that is always upstream of these constructional areas.
122.2	7.4	Intersection of Rt. 369. (See Trip B Road Log and Route Description for remainder of the route, although the writeup is in reverse order). Travel back to Harpur College via Rt. 7 and then Rt. 17.
132.5	10.3	Harpur College entrance.