XVI INTERNATIONAL GEOLOGICAL CONGRESS

GUIDEBOOK 9A - - EXCURSION NEW YORK II

THE CATSKILL REGION

International Geological Congress
XVI session
United States, 1933

Guidebook 9a: Excursion New York 11

THE CATSKILL REGION

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WASHINGTON: 1933

This guidebook supplements Guidebook 9, New York and vicinity, by C. P. Berkey and others, in conjunction with which it may be used. The reader is referred to descriptions of the same general region in Guidebook 9 and on pages 6-13 of Guidebook 1, Eastern New York and western New England, by C. R. Longwell and others.

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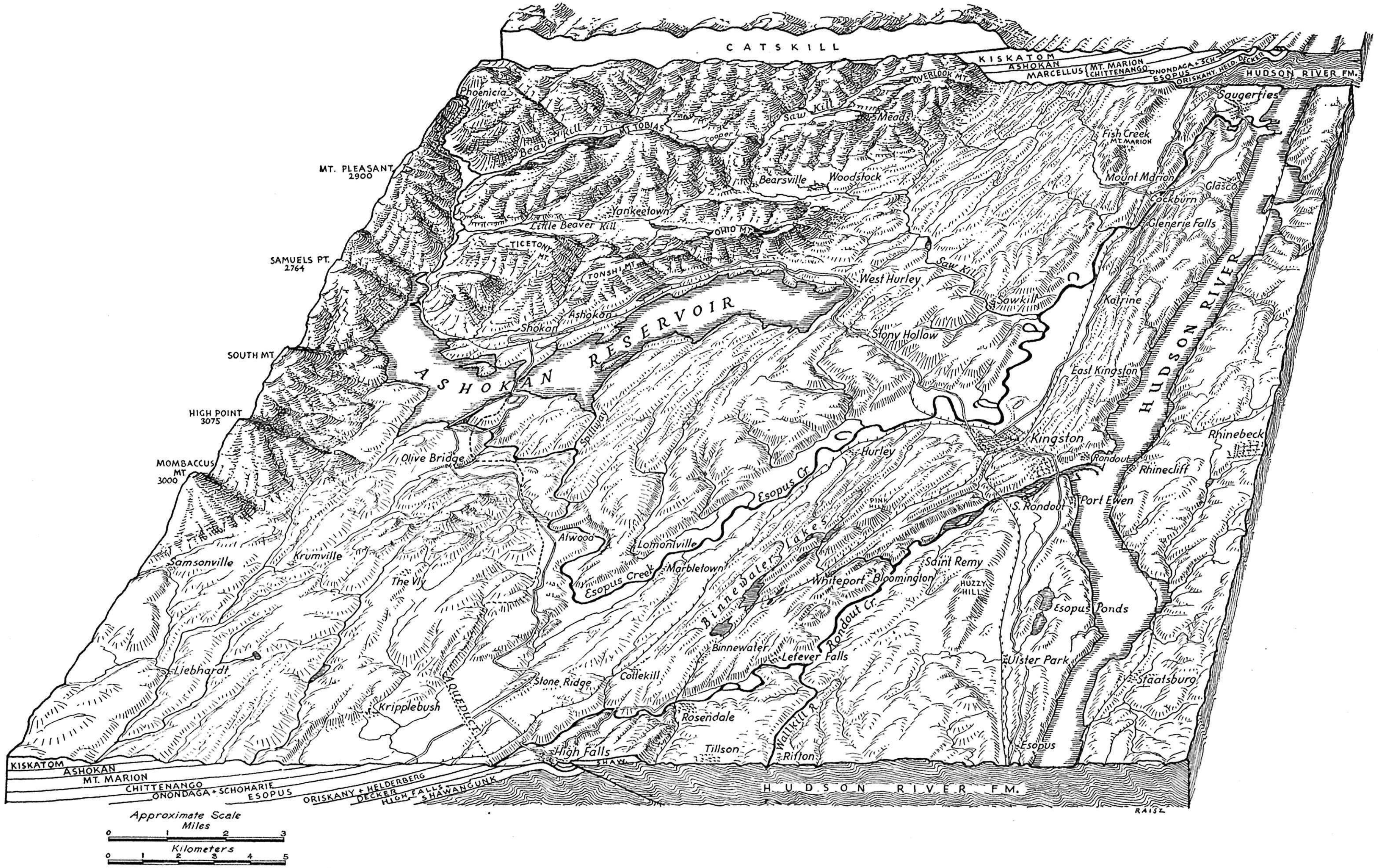
NATIONAL CAPITAL PRESS, INC., WASHINGTON, D. C.

CONTENTS

ILLUSTRATIONS



BLOCK DIAGRAM OF THE AREA AROUND KINGSTON, NEW YORK

THE CATSKILL REGION

By George H. Chadwick and G. Marshall Kay

INTRODUCTION

The Catskill region is adjacent to and west of the Hudson River about 100 miles (160 kilometers) north of the city of New York. The towns of Kingston and Catskill are in its eastern part. (See pl. 11 in Guidebook 9.) One of the first areas in North America where the stratigraphic sequence of the Silurian and Devonian systems was established, it has been for nearly a century a classic region in which to study these systems, and it contains type sections of upper Silurian and Devonian beds. The region is also distinctive in having well-displayed evidence demonstrating the presence of two of the Paleozoic disturbances that affected eastern North America, and there are exposures of the unconformity separating the Ordovician and Silurian systems. Concentrated in a belt a few miles wide are structural features that occupy a greater breadth in this Appalachian mountain system farther to the southwest. The surface expression of the folded rocks is in miniature that of the broader belt of the major part of the folded Appalachians. Thus the region has much of interest to those desiring to see the structure and geomorphology of the mountain system in an area where there are classic sections of the middle Paleozoic systems.

A map of the route is shown in Figure 1; the part of the region between Saugerties and High Falls is portrayed in Plate 1.

STRATIGRAPHIC SUMMARY

The rocks in the region belong to the Ordovician, Silurian, and Devonian systems. During these periods the region was at the eastern margin of the Appalachian geosyncline that extended southwestward to Alabama along the trend of the present Appalachian mountain system. East of the geosyncline, the geanticline forming the land mass Appalachia was a frequent source of clastic sediments throughout the Paleozoic. In consequence of the marginal position of this region, the sediments reflect in their distribution, lithology, and structure the changing extents of the seas and movements of the land mass.

The sequence of formations exposed west of Catskill is shown in the columnar section of Figure 2. The section at Kingston and to the south differs principally in the presence of

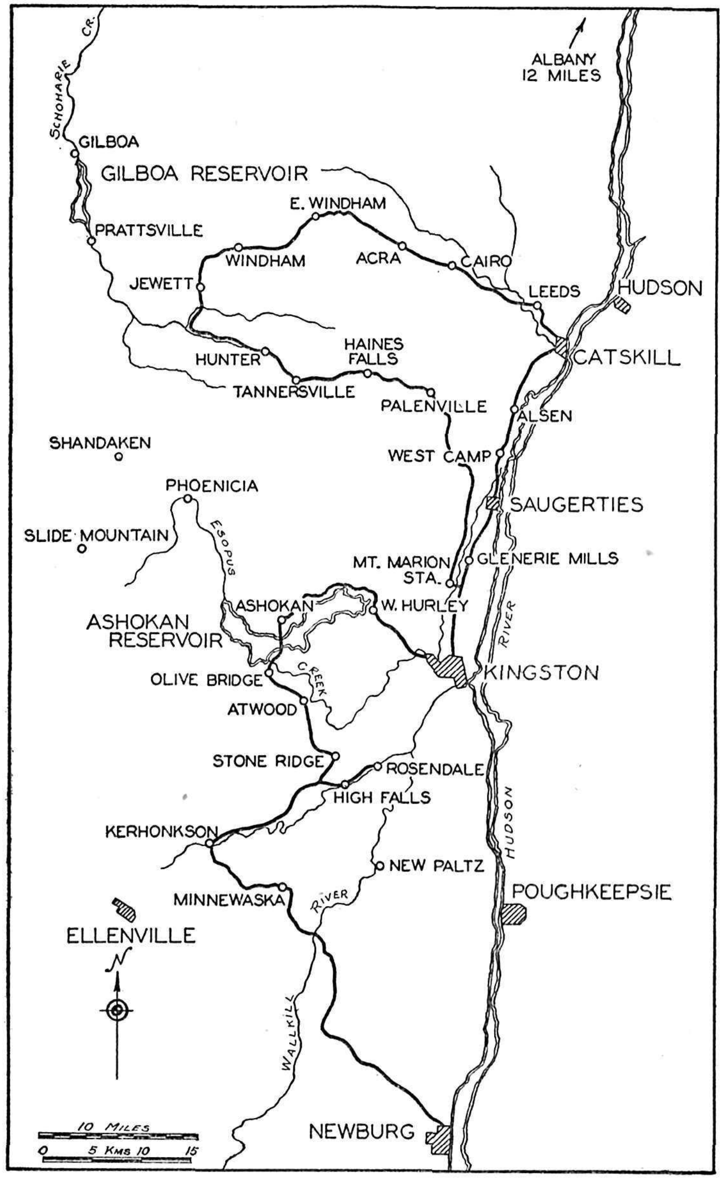


FIGURE 1.—Route map of the excursion in the Catskill region.

an older series of Silurian beds. (See fig. 3.) The classification of the younger beds of the Catskill Mountain front is shown in the subjoined table. The features that distinguish the formations and the interpretation of these features are summarized in the following pages.

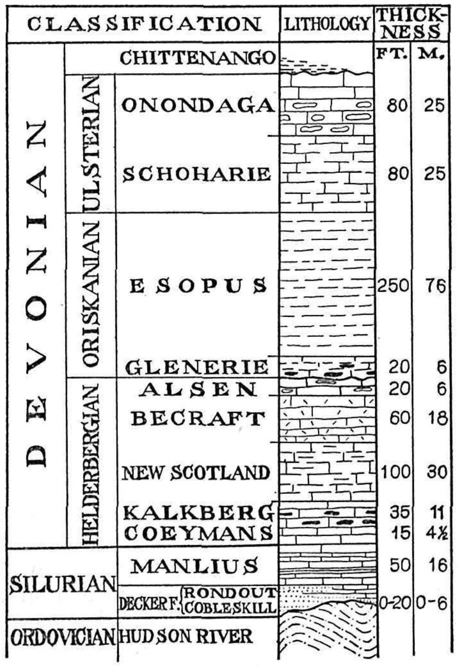


FIGURE 2.—Diagrammatic section of the lower beds outcropping west of Catskill, New York.

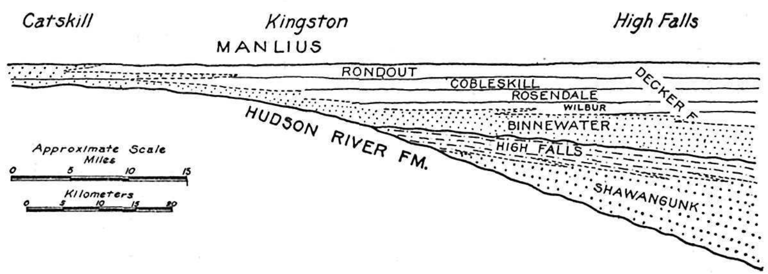


FIGURE 3.—Diagrammatic section showing relations of basal Silurian beds between Catskill and High Falls, New York.

Classification of the higher Devonian rocks west of Catskill, New York

Age				Formation	Thickness	
					Feet	Meters
Devonian	Senecan			Catskill red beds	5,000	1,500
Devonian	Erian	Hamilton	Higher Hamilton	Kiskatom red beds		
Devonian	Erian	Hamilton	Higher Hamilton	Ashokan bluestone	300	90
Devonian	Erian	Hamilton	Marcellus	Mount Marion sandstone	800	250
Devonian	Erian	Hamilton	Marcellus	Chittenango black shale	200	60

ORDOVICIAN SYSTEM

The Ordovician rocks, consisting of arenaceous shales, sandstones, and graywackes of somewhat varying age, crop out in a belt along the eastern margin of the region; they make up the Hudson River formation. They consist of clastic sediments carried westward from the rising land mass Appalachia and deposited in shallow marine waters. The beds were folded and faulted prior to the deposition of the overlying formations; the unconformity will be seen at Rondout. Faunules are rare in these rocks, but they suggest that in this region there are beds of Beekmantownian, Chazyan, and Mohawkian age. The paucity of fossils and the continuous similarity in lithology and structure make determination of the thickness difficult, but it is measured in a few thousand feet (1,000 meters or more). These rocks will be seen along the route from Kingston to Catskill.

SILURIAN SYSTEM

The Ordovician rocks are overlain unconformably by Silurian sediments. These rocks include an older group of continental beds that are restricted to the southern part of the region and a younger sequence of marine sediments that overlap northward and are overlain nearly conformably by the Devonian beds. To the south of this region great alluvial fans extended westward from Appalachia in Silurian time; the older beds in these fans are of early

Silurian (Medina and Clinton) age. The fans eventually became more extensive, and in later Silurian time they had overlapped Ordovician beds almost as far northward as Kingston. Near the source of the materials, the fans were composed of coarse clastic particles that have become the Shawangunk conglomerate (shon'gum); the younger beds in this formation seem to grade into and be overlain by finer sediments of the margin of the fan, which have formed the High Falls formation. The Shawangunk consists of white, coarse-textured quartz sandstone and conglomerate, well lithified and very resistant to erosion. The High Falls formation is composed of gray and red arenaceous shales, siltstones, and sandstones. At High Falls the Shawangunk is 275 feet (90 meters) thick, and the High Falls 100 feet (30 meters); 4 miles (6.4 kilometers) to the northeast, at Rosendale, the two total 80 feet (25 meters), and both disappear along the outcrop before Kingston is reached.

Toward the end of the Silurian period the margin of the fan was encroached upon by a northeastward-advancing sea; successively younger beds overlap on the older Silurian and Ordovician rocks toward the northeast. The clastic shore facies of this sequence is the Binnewater sandstone; the succeeding Silurian beds are calcareous and members of the Decker Ferry formation. The overlying Manlius limestone, with its several lithologic facies, is classified by some geologists as Devonian. The Binnewater sandstone is composed of about 60 feet (18 meters) of gray and buff sandstones at High Falls but thins to 30 feet (10 meters) at Rosendale; a few feet of beds of this facies are present farther to the north. The Decker Ferry formation includes several members. The Wilbur limestone is a dark, fine-textured impure limestone, 5 to 7 feet (2 meters) thick, containing fossils of which a species of the "chain coral," *Halysites,* is typical. At Kingston it lies directly on the Ordovician. The Rosendale waterlime was formerly quarried extensively at the type locality for the manufacture of cement. It consists of a dark-gray, fine-textured massive limestone that because of its alumina content forms a natural cement when burned; the member is typically 14 feet (4 meters) thick. The Cobleskill limestone, impure, dark colored, and of varying thickness, about 10 feet (3 meters) at High Falls, contains many specimens of a species of *Halysites* and associated stromatoporoids. The overlying Rondout waterlime is similar to the Rosendale in appearance, though usually somewhat lighter, and was similarly quarried; it is 15 feet (5 meters) thick near Kingston and extends northward to Catskill, where it locally is a sandstone. The character of the Manlius formation will be seen in the vicinity of Catskill.

DEVONIAN SYSTEM

The lowest of the Devonian formations are the limestones of the Helderbergian series; these and the succeeding formations of the Oriskanian and Ulsterian series are represented in Figure 3. The Coeymans limestone, the flinty Kalkberg limestone, and the shaly New Scotland limestone will be examined in the Turtle Pond quarry, west of Catskill; the overlying Becraft limestone crops out on the near-by Quarry Hill. The succeeding Alsen limestone forms the top of the Helderbergian at Catskill, but at Kingston is overlain by the argillaceous Port Ewen limestone, 200 feet (60 meters) thick.

In the vicinity of Catskill the Helderbergian limestones are unconformably overlain by the Oriskanian, the hiatus being represented in the Kingston region by a Helderbergian formation 200 feet (60 meters) thick. The Oriskanian series is represented by the Glenerie limestone with associated quartzitic beds, from which silicified fossils will be collected along Esopus Creek, and the Esopus shale, a dark siltstone with a few marine fossils at its base and the burrows of *Taonurus* (*"Spirophyton"*) *caudagalli* Vanuxem filling higher beds. The Ulsterian formations are the argillaceous gray Schoharie limestone, which weathers buff, and the cherty Onondaga limestone.

The Erian series, which overlies the Ulsterian, is composed of clastic rocks, marine below, becoming coarser in texture and nonmarine toward the top; they are of the age of the fossiliferous Hamilton formations of western New York. The changes are a reflection of the rising elevation of Appalachia, with a coinciding westward retreat of the sea in front of the extending alluvial plains. The Marcellus equivalents are the Chittenango shale, about 200 feet (60 meters) thick, and the Mount Marion formation, 800 feet (250 meters) thick near Catskill. The Chittenango consists of black fissile shale containing few fossils, of which *Leiorhynchus limitare* (Vanuxem) is typical. The beds contain *Agoniatites expansus* (Vanuxem) or similar cephalopods about 50 feet (15 meters) above the base along Kaaterskill Creek west of Catskill and are thus probably equivalent to the Union Springs, Cherry Valley, and Chittenango members of the Marcellus farther west in New York. The formation will be seen on the road to the Ashokan Reservoir. The Mount Marion contains calcareous siltstones and sandstones, sparingly fossiliferous, and will be examined at the type locality. Succeeding these beds is the Ashokan bluestone, 300 feet (90 meters) thick, a graywacke of such character that it has been extensively quarried west of Kingston for flagstone. The Kiskatom formation includes the continental red and gray shales and sandstones that have been called Oneonta, though they are considerably older than the typical Oneonta, which occurs farther west.

Continental sedimentation continues to be represented in the succeeding Senecan Catskill formation of sandstones and shales, many of which are red, and some conglomerates; the formation crops out to the top of the plateau. Its fluviatile sediments, like those of the underlying formations, can be traced westward into marine beds—those of the Genesee and Portage formations.

STRUCTURAL HISTORY

There is evidence in the region of at least two periods of deformation. In several exposures Ordovician beds lie in close contact with angular unconformity beneath the basal Silurian sediments. Formations as young as Middle Devonian have been folded and affected by faults of low angle showing relative overthrust from the east.

The first of these deformations is definitely assigned to the Taconian disturbance, for which this is the classical area of study. The later deformation may have been produced either in the Acadian disturbance at the end of the Devonian or in the Appalachian revolution, or in both. Inasmuch as late Paleozoic rocks are not present in the disturbed areas, it is not possible to date the movements precisely. The tectonic movements that produced the coarse clastic Upper Devonian sediments to the west may have been accompanied by this folding and faulting; if so the structures are Acadian. On the other hand, the structures are similar to those formed farther to the southwest and northeast in the Appalachian revolution, and it is probable that some of the effects were produced at that time.

GEOMORPHOLOGY

The erosion of beds that vary so much in lithology and structure as those in this region has been effective in producing distinctive topography in each of several geomorphic belts. (See pl. 1.) The relatively horizontal beds of the early Paleozoic were crumpled and faulted in the eastern part of the region at the end of the Ordovician period. Younger systems were deposited on their beveled surface, and late in Paleozoic time pressure from the east again produced folds and overthrusts in this eastern belt. At the end of the Paleozoic era this great crumpled mass of late Paleozoic rocks had been elevated above the monoclinally dipping equivalent beds extending to the west. Subsequent erosion has cut far into the weakened rocks in the eastern part of the region, reaching the lower Paleozoic beds, whereas the relatively undisturbed parts of the upper Paleozoic sediments to the west have been more resistant to denudation. The folded and faulted eastern belt forms a northern extension of the Newer Appalachian province that extends eastward to the New England upland of crystalline rocks. The gently westward dipping beds to the west form a part of the Appalachian Plateau province.

Erosion has been dominant in the region since the end of Paleozoic time. The presence of several peneplains makes it evident that the removal of this great mass of sediments has not proceeded in a single cycle; but the erosional history has not been precisely determined. Remnants of a peneplain may be preserved in the accordant summits of the higher peaks in the western part of the region, of which Plateau Mountain is typical. The high areas that bear these remnants seem to stand above an erosion level represented by the open upper valleys of the Catskills and by the beveled surface of the Helderberg Plateau, to the north, seen from Windham Notch. This lower level lies 2,500 feet (750 meters) below the supposed summit peneplain and has been correlated by some geologists with the Schooley peneplain of Pennsylvania, by others with the Harrisburg peneplain, of later Tertiary age. Further elevation and subsequent erosion produced a peneplain that bevels the weaker folded rocks in the Hudson River Valley west of the river. This later Tertiary surface is 1,500 feet (450 meters) below the last and has been called the Albany peneplain. More recent movements have elevated this surface a few hundred feet (100 meters or more) above present base-level, permitting the excavation of valleys in the weakest rock belts. Thus erosion has brought about the removal of a great mass of later Paleozoic sediments through several cycles of erosion with intervening uplifts, exposing early Paleozoic rocks in the eastern part of the region.

GLACIAL HISTORY

The only glaciation of which there is a record in the region is the youngest, the Wisconsin. This ice sheet extended over the entire region, as the summit of the highest peak, Slide Mountain, with an elevation of 4,205 feet (1,282 meters) bears glacial striae. These striae appear everywhere, in many places paralleling the river. Plucking is conspicuous on the south slopes of the mountains, producing sawtooth peaks in the horizontal strata, best seen from points north of Catskill. Moraines are small and poorly defined. It is believed that during the waning of the ice the Hudson Valley lobe sent prongs into the mountain valleys through the eastern gaps; some are of the opinion that the ice moved down these valleys. Crescentic moraines were formed with deltas extending out into glacial lakes in the northward-draining Schoharie Valley; a good example will be seen near Windham. Later, glacial drainage coursed between the mountain front and the retreating ice front, producing water-scoured channels.

Delta plains and lacustrine deposits are widely distributed; the most striking are those of Lake Albany, which now stand 120 to 160 feet (37 to 50 meters) above sea level, the deposits being associated with the major side streams. They consist chiefly of varved lacustrine clays, a section of which will be examined at Catskill, with sand beds at the top, formed when the waters shallowed.

Two opinions are held as to the nature of this body of water. It is considered by some to have been connected with the sea, the "Hudson-Champlain Strait"; others regard it as a body of fresh water which lay between a peripheral bulge to the south and the ice front to the north. In either case, the narrow pass through the Hudson Highlands, with the great influx of glacial waters from the north, including waters from the Great Lakes drainage basin, kept it fresh, so that the name Lake Albany is wholly appropriate. All now concede that it was raised and drained before the Champlain Valley had been opened to the sea from the north, and that the main element in its existence was land depression due to ice load, with subsequent and perhaps only partial recovery. No fossils are known in any of the lacustrine deposits.

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ITINERARY

KINGSTON TO CATSKILL

Kingston[1] lies in the belt of folded early Devonian limestones. In driving northward toward Saugerties, the view down the dip to the west is across a broad glacio-alluvial plain (Esopus Creek) to the Middle Devonian (Mount Marion) escarpment, behind and above which rises the great scarp of the younger Devonian red beds of the Catskill Mountains. The road angles over folded strata as it goes toward Saugerties.

A quarter of a mile north of the New York Central (West Shore) Railroad crossing north of the city,[2] the white Onondaga limestone is exposed to the right of the road, which 2 miles (3.2 kilometers) farther north passes along the axis of a syncline in this formation. Just beyond Katrine (2.4, 3.9), Schoharie limestone is exposed on the right, and Esopus dark-gray siltstone crops out from a point half a mile (0.8 kilometer) farther on to the foot of the hill at Glenerie (4.2, 6.8). At Glenerie Mills Esopus Creek[3] offsets eastward across the westward-dipping Esopus beds, forming waterfalls, and then parallels the highway, which has extensive new cuts in the underlying Glenerie limestone.

As the road leaves the creek it climbs rapidly across the upturned Helderbergian limestones; the Alsen and Becraft are concealed, but the underlying New Scotland, Kalkberg, Coeymans, and Silurian Manlius are exposed. The Manlius is a dark limestone with white calcite veins forming a sharp anticline on the left and appearing again in a quarry on the left beyond the hotel at the road corners (6.1, 9.8). The road then emerges on the sand-capped Lake Albany clay plain east of the limestones, the underlying Ordovician rocks being concealed; this plain is here the raised delta of ancient Esopus Creek. The Ordovician sandstones show well to the right of the highway bridge (8.5, 13.7) on the east bank of Esopus Creek in Saugerties.[4]

The village of Saugerties lies on the Lake Albany delta of Esopus Creek. All outcrops as far as West Camp (12.6, 20.3) are Ordovician beds. Three escarpments can be seen to the west (left) of the road, that of the Lower Devonian limestones, the

[1] Population 28,088. Wiltwyck, 1658, became Kingston, 1669; capital of New York State, 1776-1797 (old Senate House now a museum); burned by British in 1777.

[2] Figures in parentheses refer to distances from this railroad crossing. The first figure indicates miles, the second kilometers.

[3] Esopus is the name of an Indian tribe.

[4] Population 4,060; inhabited before 1663. Dutch, saugertjes, possessive diminutive of sauger, a sawyer. Saw Kill or Sawyer's Kill is crossed just north of the village.

Kalkberg belt, appearing in front of the Mount Marion and distant Catskill Mountain escarpments. Two great notches, Plaatekill[5] and Kaaterskill[6] Cloves,[7] cut back into the east front of the Catskill (Appalachian) Plateau and have been the cause of stream captures.

The Hudson River comes into view on the right, the far bank rising to a well-marked late Tertiary peneplain with monadnocks, beyond which are the Taconic Mountains. At West Camp[8] the limestones offset eastward to the road in a large anticline and syncline. Thence to the edge of the village of Catskill the limestone scarp of this syncline overshadows the highway close on its west (left), the lower beds (Cobleskill limestone, Rondout

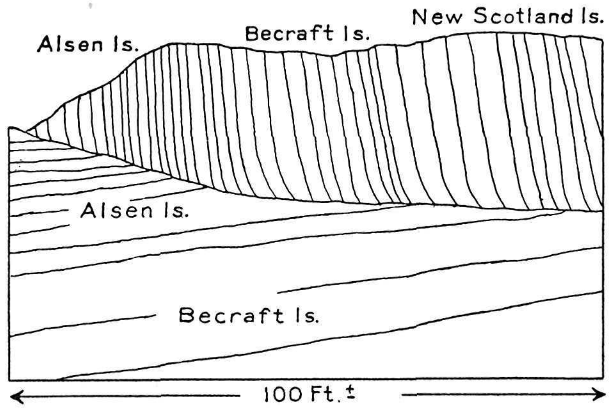

FIGURE 4.—Thrust fault in Helderbergian limestones in north quarry at Alsen, New York. Length of section about 100 feet (30 meters).

quartzite, and Manlius limestone) coming down to the road in many places and the Ordovician strata appearing at other points.

Three large cement plants, which use Becraft or Manlius limestone in combination with clay of the Lake Albany plain, are passed at Cementon and Alsen. Excellent exposures in the limestone quarries (entrance 15.0, 24.1) reveal the jammed and overthrust condition of this east margin of the limestones. (See fig. 4.)

Beyond these quarries the dissected raised delta of the Catskill into Lake Albany extends on the east (right) to the village of

[5] Dutch, flats creek.

[6] Dutch, tom-cat (puma) creek.

[7] Dutch, a cleft or notch.

[8] A Palatine German settlement under Queen Anne in 1710.

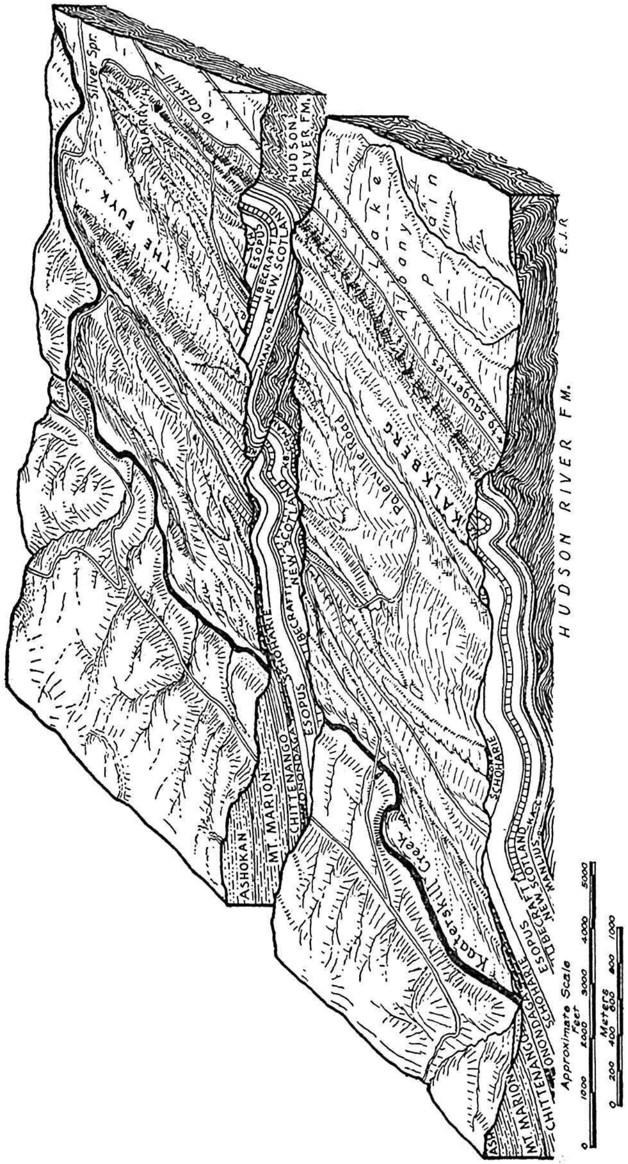

FIGURE 5.—Diagram of an area about 3 miles square southwest of Catskill, New York.

Catskill, inclosing many Hudson River hills. The relations of the topography to the rock structure are illustrated in the block diagram of an area southwest of Catskill (fig. 5); the road enters this area less than half a mile north of the school house (17.5, 28.2). The Turtle Pond (Holdridge) quarry, a short distance southwest of the junction of the Palenville road with the Kingston highway (19.3, 31.1) gives an excellent exposure of the lower Helderbergian limestones; the section of westward-dipping beds is shown in the following table:

Section exposed in Turtle Pond (Holdridge) quarry 2 miles (3.2 kilometers) southwest of Catskill

	Ft.	in.	Meters
Devonian system:			
Helderbergian series:			
New Scotland limestone:			
Yellow-weathering calcareous shales exposed on extreme west of quarry.			
Gray argillaceous shaly limestones, weathering to brownish porous shale; fossils abundant, the more common species including *Dalmanella (Levenea) subcarinata* (Hall). *Eatonia medialis* (Vanuxem). *Leptaena* sp. cf. *L. rhomboidalis* (Wilckens). *Leptostrophia becki* (Hall). *Meristella laevis* (Hall). *Orthostrophia strophomenoides* (Hall). *Rhipidomella oblata* (Hall). *Schellwienella woolworthana* (Hall). *Spirifer (E o s p i r i f e r) macropleura* (Conrad). *S. (Delthyris) perlamellosus* (Hall). *Actinopteria textilis* (Hall). *Diaphorostoma ventricosum* (Hall). *Platyceras gebhardi* (Conrad). *Dalmanites micrurus* (Green). *Phacops logani* (Hall).			
Exposed	48		15
Kalkberg limestone: Dark-gray, somewhat argillaceous thick-bedded limestone, with beds of black chert particularly abundant in the lower part; fossils abundant, and silicified on weathered surfaces; species similar to those in the New Scotland and in addition, *Enterolasma strictum* (Hall). *Favosites helderbergiae* (Hall). *Atrypa* sp. cf. *A. reticularis* (Linné). *Bilobites varicus* (Conrad). *Gypidula coeymanensis* Schuchert and Maynard. Stems of *Mariacrinus stoloniferus* (Hall)	22		6.7

	Ft.	in.	Meters
Devonian system—Continued.			
Helderbergian series—Continued.			
Coeymans limestone: Gray medium-textured nodular limestone, lighter in color than the Kalkberg and lacking chert, darker on weathering, and coarser textured than the Manlius; basal beds containing fragments of Manlius limestone above a thin calcite vein; Fossils abundant, including *Hindia inornata* (Hall). *Atrypa* sp. cf. *A. reticularis* (Linné). *Camarotoechia semiplicata* (Conrad). *Gypidula coeymanensis* Schuchert and Maynard. *Leptaena* sp. cf. *L. rhomboidalis* (Wilckens). *Meristella laevis* (Hall). *Uncinulus mustabilis* (Hall). Stems of *Melocrinus* sp.	15		4.6
Silurian system:			
Manlius limestone:			
Dark-gray medium-textured, rather massive limestone, approaching the Coeymans in lithology	3	2	.95
Gray, light-weathering, fine-textured thin-bedded "ribbon" limestone, forming conspicuous band in face of quarry		10	.25
Dark-gray medium-textured, rather massive limestone	1	9	.55
Gray medium-textured nodular limestone with an abundance of specimens of the stromatoporoid *Syringostroma barretti* Girty	9	8	2.95
Gray, light-weathering, fine-textured thin-bedded limestone, with conspicuous prismatic columnar jointing, presumably mud cracks	7		2.15
Beds of similar lithology but without apparent columnar jointing	9	2	2.80
Gray nodular limestone, with *Syringostroma barretti* Girty	6		1.85
Blue-gray fine-textured thick-bedded limestone	2	4	.70
Gray fine-textured papery shaly limestone	4	9	1.45
Blue-gray fine-textured thick-bedded limestone	10		3.05
Thin-bedded limestone to base of exposure.			
Total exposed thickness of Manlius	54	8	16.70

Fossils are not abundant throughout the Manlius, but in some of the thin-bedded limestones the following are common:

Brachyprion varistriatum (Conrad).
Spirifer (Delthyris) vanuxemi (Hall).
Megambonia aviculoidea (Hall).
Tentaculites gyracanthus (Eaton).
Leperditia alta (Conrad).

The steeply westward-dipping Ordovician sandstones crop out along the roadside a short distance to the north.

At Silver Spring, at the north end of Quarry Hill (see fig. 5), the Ordovician sandstones are disconformably overlain by 2 feet (0.75 meter) of brownish arenaceous limestone and 4 feet (1.5 meters) of blue-gray fine-textured massive limestone of the Decker Ferry formation. In ascending the hill the Manlius, Coeymans, and Kalkberg formations are crossed, the Kalkberg underlying the surface of the meadow at the top of the hill; the rolling topography of that surface, with the steep rise to the northeast, reflects the folded character of the Kalkberg beneath it. Across the country road to the southeast, a bluff of New Scotland argillaceous limestone is capped by the cliff-forming Becraft limestone. The Becraft is a white to pinkish coarse-textured crystalline limestone. This limestone has been used for building stone, decoration, and cement (it contains 96 to 99 per cent of $CaCO_3$); the quarries at the top of the hill have been the source of building stone. Fossils abound, and the following species are common:

Aspidocrinus scutelliformis (Hall).
Atrypa sp. cf. *A. reticularis* (Linné).
Gypidula pseudogaleata (Hall).
Spirifer concinnus (Hall).
Uncinulus campbellanus (Hall).
U. nobilis (Hall).
Trematonotus profundus (Hall).

From the top of the hill can be seen to the west the Mount Marion escarpment with the Chittenango shale-belt valley in front of it, and the more distant Catskill Mountains rising above it. Nearer, beyond the Kalkberg escarpment in the foreground, is the broad valley (The Fuyk on the block diagram, fig. 5) underlain by Ordovician sandstones that are covered by clays of the Lake Albany plain; beyond are the steeply westward-dipping Helderbergian limestones on the far side of the eroded anticline. To the north the Austin's Glen gorge of the Catskill has resulted from glacial diversion. The level Tertiary peneplain surface is also evident, truncating the structure of the hills to the west. In descending to the foot of the hill on the east, a section similar to that in the near-by Turtle Pond quarry is crossed; this point is a short distance north of the junction of the main roads north of that quarry (19.3, 31.1).

At the Broome Street quarry, to the right of the road in the western part of the village of Catskill[9] (20.5, 33), the varied facies of the Ordovician rocks are exhibited. The beds are of

[9] Population 5,082. Dutch Kats Kill, wild cat creek; was Het Strand (The Landing), settled in 1664. See beyond (Leeds) for Old Catskill.

Normanskill (Chazyan and lower Mohawkian) age, and have yielded a rather extensive fauna of eurypterids and graptolites, most of which have come from the thin beds of olive-gray argillaceous shale that are associated with the massive beds of light blue-gray graywacke and clay-gall conglomerate. The beds from which eurypterids have been collected are no longer exposed, but graptolites may be obtained from the shales and certain beds in the graywackes; the fauna includes

Climacograptus bicornis peltifer (Lapworth).
Dicellograptus gurleyi (Lapworth).
Cryptograptus tricornis (Carruthers).
Dolichopterus breviceps (Clarke and Ruedemann).
Eurypterus chadwicki (Clarke and Ruedemann).
Eusarcus linguatus (Clarke and Ruedemann).
E. nasutus (Clarke and Ruedemann).
Pterygotus normanskillensis (Clarke and Ruedemann).
Stylonurus modestus (Clarke and Ruedemann).

The varved clays of the Lake Albany plain are exposed in the brickyards a short distance to the south. The clay contains much lime flour and tends to develop lime concretions ("clay dogs"). Thin partings of pink sand mark wash from the red beds of the mountains to the west.

CATSKILL TO WINDHAM MOUNTAIN

From the turn at the west end of the bridge over the Cats Kill the route will run northwest diagonally across all the geomorphic and stratigraphic belts to the Catskill Plateau at Windham Mountain. Above the bridge over the Cats Kill on West Main Street a sharp anticline in the Ordovician beds is exposed in the north bank of the stream (21.25, 33.8). The road ascends a large remnant of the Lake Albany plain known as Jefferson Heights,[10] from which in the mountain view the sawtooth peaks shaped by glacial erosion and plucking are apparent. Beyond, the limestone folds are seen as far as the bridge at Leeds[11] (24.5, 39.4), causing repetitions in the strata as they are crossed in a generally ascending order. On entering Leeds a high cliff on the far side of the Cats Kill to the south (left) shows an anticline in Esopus shale, with a core of Glenerie chert in the stream bed, flanked by the Schoharie limestone, forming a fall.

[10] At Jefferson (22, 35.4) the Old King's Road, the first highway in this region, a footpath until 1670, the royal post road of 1703, is crossed.

[11] Old Catskill (1644). Stone church built in 1818; stone bridge opened in 1766, built with the help of the Indians. The present name, from Leeds, England, was given at the time of woolen manufacture in this village.

Recrossing the Cats Kill, the road spans the Chittenango shale valley on a deep alluvial fill bordered by Lake Albany terraces, to which it presently climbs (25, 40.2). The decreasing west dip may be seen on the north (right) in the flanks of Mount Potick,[12] a peak on the Mount Marion escarpment; these beds are poorly exposed beyond on the south (left) of the road.[13]

The first conspicuous outcrop 1½ miles (2.4 kilometers) farther on (26.9, 43.3) is a bank of shale on the west (left) representing the beginning of the continental Catskill sort of sedimentation, though the beds are older and of Hamilton (Kiskatom) age. Red beds with intercalated flagstones continue to the mountain summits (about 4,000 feet, or 1,200 meters); the beds are cross-bedded in places, show current structure, and carry plant remains, mostly pteridosperms.

Glacial moraines and channels of strong marginal glacial stream wash are visible to altitudes well up the mountain side. Cairo is passed (30.5, 49.1), and Blackhead Mountain (3,937 feet, or 1,200 meters) is conspicuous on the left. The road climbs toward Windham High Peak (3,505 feet, or 1,070 meters) and reaches Point Lookout before passing through the notch at 1,900 feet (606 meters) at East Windham (40.5, 65.2). From the lookout platform can be seen the great level sky line of the Helderberg[14] Plateau and, if the day is clear, the distant border chain of the Green Mountains, Berkshire Hills, and Taconic Range of Vermont and Massachusetts on the east.

In the quarry in the notch the Catskill beds are well exposed and contain many specimens of plants such as *Archaeopteris jacksoni* (Dawson) and *Eospermatopteris textilis* (Dawson) or similar species.

WINDHAM MOUNTAIN TO KINGSTON

The route from Windham Mountain to Haines Falls passes through East Windham, Windham, Jewett, Hunter, and Tannersville. The red beds of the Catskill formation are exposed at many points along the roadside and in the adjacent mountains, but the features to be examined are chiefly glacial and geomorphic. The

[12] Indian, a waterfall, from rapids in Cats Kill; here stood Potick Indian village.

[13] The route follows the early turnpike (1804), the main artery of travel to western New York and Ohio until 1830. At intervals to and beyond South Cairo it parallels or crosses that of the first railway chartered in New York State (1826; operated 1839-1842; partly reoccupied, 1882-1916). Early settlement in the red-beds portion of the area centered around tanneries using the hemlock forests.

[14] Dutch, hero hill; pronounced "hel'der-barrakh."

front range, trending northwestward, throws off spurs declining westward to the Schoharie [15] Kill, beyond which rises the abrupt scarp of the central range, also trending northwestward. Each valley consists of an upper open portion corresponding to the peneplain truncating the Helderberg Plateau, and a narrower inner portion cut below; the peneplain may be seen where the road rises to the higher levels.

During the waning of the ice glacial lobes pushed across the notches of the front range from the main Hudson Valley ice lobe, building crescentic recessional moraines or hollow-backed gravel deltas into lake waters impounded in the Schoharie Valley by ice dams farther north. One of the best displayed of the deltas is that in the valley on the left beyond the road junction 5 miles (8 kilometers) west of East Windham (45.7, 73.5); the succeeding cemetery on the right is on this delta. A short distance south of Batavia Kill crossing on the Jewett road (49.7, 80), Huntersfield Mountain (altitude 3,450 feet, or 1,052 meters) may be seen to the right in the rear, surmounting the Tertiary erosion level; the road passes between Cave Mountain (3,043 feet, or 928 meters), on the left, and Tower Mountain (2,980 feet, or 908 meters), on the right.

At Hunter (60, 96.6), Hunter Mountain (altitude 4,025 feet, or 1,227 meters) rises on the south (right) and the Jewett Range runs along the north side of Schoharie Valley. Beyond, the Stony Clove notch through the main range is visible to the south. This notch served as an outlet for glacial waters at a higher level than the Windham delta but has since been partly filled by talus. The peaks of the central range to the southeast (right) are Plateau Mountain (3,844 feet, or 1,175 meters), the nearest, and, in order, Sugar Loaf (3,782 feet, or 1,153 meters), Twin Mountain (3,647 feet, or 1,111 meters), and Indian Head Mountain (3,585 feet, or 1,093 meters). Isolated ahead are the adjoining Roundtop Mountain (3,476 feet, or 1,060 meters) and High Peak (3,660 feet, or 1,115 meters). Stoppel Point, at the end of the Jewett Range on the left, reaches 3,425 feet (1,044 meters).

The broad valley of Gooseberry Creek to the south of the road beyond Tannersville (64.7, 104.1) is the beheaded remnant of the once longer stream. As the road crosses a divide just west of Haines Falls (66.5, 107), the view ahead shows the deep notch of the Kaaterskill Clove opening out into the Hudson Valley and

[15] Indian, flood wood. The Gilboa Dam of the New York City Board of Water Supply impounds the water from the Schoharie drainage basin and transfers it to the Esopus basin through the Shandaken Tunnel, 18 miles (29 kilometers) long and 11 feet (3.3 meters) in diameter, which emerges west of Phoenicia. The capacity is about 600,000,000 gallons (2,250,000,000 liters) a day.

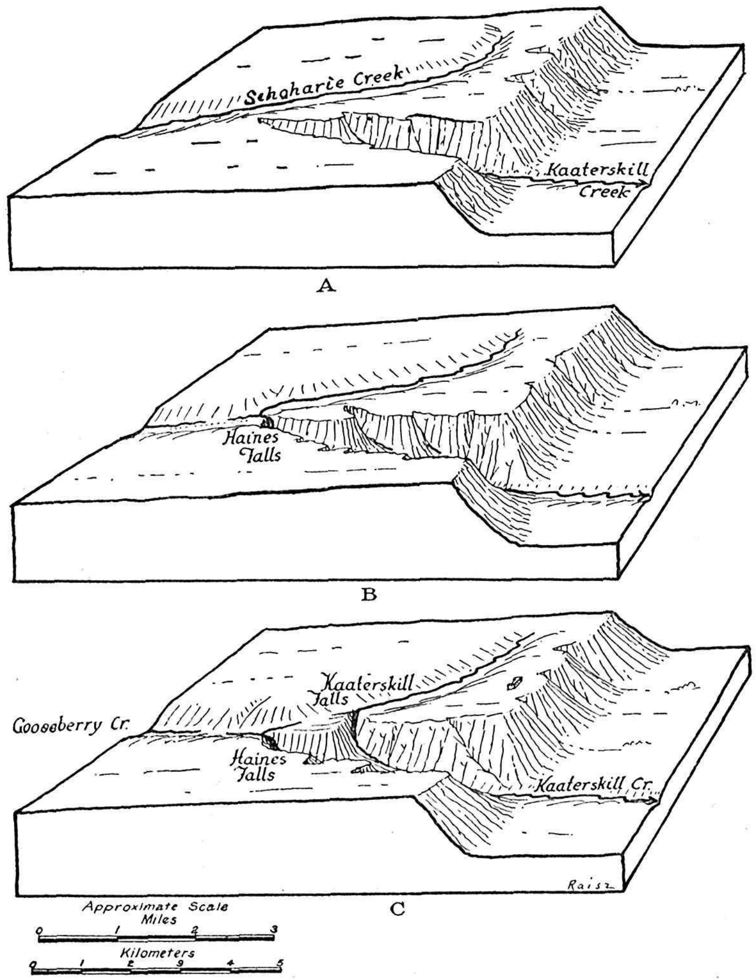

FIGURE 6.—Diagrams representing (A) the courses of the ancient Schoharie (Gooseberry) and Kaaterskill Creeks prior to capture; (B) the initial capture of Schoharie Creek at Haines Falls; and (C) the later capture of the stream in a second stage by one of its tributaries to form the course of the present Kaaterskill Creek.

diverting waters which once flowed through the valley that has been followed on the right. The upper reach of this beheaded valley can be seen to the left ahead; the drainage from this upper captured valley plunges over a series of falls into the young Kaaterskill below. The main features of the capture are represented in Figure 6.

If the day is clear a side trip will be made from Haines Falls (66.7, 107.3) to the Catskill Mountain House, 3 miles (4.8 kilometers) to the east. The road passes along the broad valley of the captured head of Gooseberry Creek; the lakes are of glacial-dam origin. From the Mountain House (altitude 2,150 feet, or 655 meters), there is a fine view over the eastern part of the region.

Returning to Haines Falls, the route follows down from the mountain through Kaaterskill Clove. Haines Falls is passed on the right at half a mile (0.8 kilometer) and Bastian (Rip Van Winkle) Falls (68.2, 109.8) is on the stream that drains the valley to the west of the Mountain House and forms Kaaterskill Falls. Descending from the clove the road passes down to a great alluvial fan with Palenville (71.6, 115.2) at its higher end.

Taking the right fork in Palenville, the route parallels the remarkably rectilinear front of the Catskill Plateau to the Ashokan flagstone quarries at Quarryville (76.1, 122.5). A mile (1.6 kilometers) beyond, the road descends the Mount Marion scarp and crosses Beaver Kill in the Chittenango shale valley, joining the Old King's Road with its stone houses, some of which are nearly 200 years old (76.6, 123.3). This road parallels the Schoharie-Onondaga contact, and the Onondaga limestone forms a low scarp at intervals on the right. Before reaching the New York Central (West Shore) Railroad depot, Mount Marion (altitude 719 feet, or 216 meters) is near by on the right; half a mile (0.8 kilometer) west of the road corners (83.8, 134.9), a fine exposure of the Mount Marion beds occurs at the type section beyond Plaate Kill.

In the bluff, nearly 100 feet (30 meters) high, are a few calcareous beds containing Marcellus (Cardiff) fossils, including

Camarotoechia congregata (Conrad).
C. prolifica (Hall).
Chonetes coronatus (Conrad).
C. vicinus (Castelnau).
Spirifer acuminatus (Conrad).
S. audaculus (Conrad).
S. granulosus (Conrad).
S. mucronatus (Conrad).
Grammysia alveata (Conrad).
G. bisulcata (Conrad).
G. circularis (Hall).
Taonurus velum (Vanuxem).

At Mount Airy, 5 miles (8 kilometers) to the north, near Quarryville, the beds have yielded many specimens of *Devonaster eucharis* (Hall). The basal portion of the sandstone, forming a small fall in the creek a short distance to the east, is of poorly bedded massive but nonresistant sandstone.

From Mount Marion station the route turns east across the Onondaga, Schoharie, and Esopus beds to the Oriskany limestone exposure at Glenerie Mills that was passed on the northward trip. The section from Mount Marion station across Esopus Creek is represented in Figure 7.

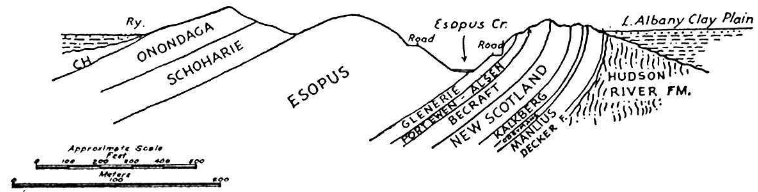

FIGURE 7.—Generalized section from Mount Marion station across Esopus Creek near Glenerie Mills, New York.

Silicified fossils are abundant in the weathered Glenerie (Oriskanian) and include

Beachia suessana (Hall).
Eatonia peculiaris (Conrad).
Hipparionyx proximus Vanuxem.
Leptaena ventricosa (Hall).
Leptocoelia flabellites (Conrad).
Leptostrophia magnifica (Hall).
Meristella lata (Hall).
Plethorhyncha speciosum (Hall).
Rensselaeria ovoides (Eaton).
Rhipidomella musculosa (Hall).
Spirifer arenosus (Conrad).
S. murchisoni (Castelnau).
Diaphorostoma ventricosum (Hall).
Platyceras gebhardi (Conrad).

At Catskill, in black cherts in this formation, *Palaeoglossa* sp. is found, and in shale partings, species of the ostracode genus *Thlipsurella*.

KINGSTON TO MINNEWASKA

The city of Kingston lies in a belt of folded and faulted Devonian limestones corresponding to the Kalkberg belt in the Catskill area. In the Hill quarry, on Union Street in the Rondout section of the city, the Ordovician Hudson River beds are overlain with great angular unconformity by the Silurian Decker Ferry limestone. Northwest of the city Esopus Creek flows in a valley in the Chittenango (Marcellus) shale, the escarpment of the Mount Marion formation rising 500 feet (160 meters) above it on the west. Between this escarpment and the Catskill Mountains, 8 miles (12.8 kilometers) to the northwest, is the Kiskatom belt underlain by the Ashokan bluestone and the Kiskatom sandstones and shales. The route crosses the several rock belts to the Ashokan Reservoir, at the base of the mountains, to the west. This and the succeeding route are portrayed in the block diagram (pl. 1).

The Chittenango shale is exposed along the roadside at the base of the bluff at the far side of the alluvial plain of Esopus Creek, an abandoned meander of which can be seen south of the road. Specimens of the brachiopods *Leiorhynchus limitare* (Vanuxem) and *Chonetes mucronatus* (Hall) are frequent in the black shales. Half a mile (0.8 kilometer) or so to the west the Mount Marion formation is exposed in a quarry on the right. The road parallels the New York Central (Ulster & Delaware) Railroad and a tributary of Esopus Creek from this point to the northwest. To the south of the road, about a mile (1.6 kilometers) west of Stony Hollow, the Ashokan bluestone occurs in a quarry. The beds are nonfossiliferous; their occurrence in massive beds has warranted their being extensively quarried in this region for use as curb and flagstone in New York City and elsewhere. Other outcrops of the formation occur along the road to the Ashokan Reservoir.

The route follows the north side of the reservoir from West Hurley through Ashokan to Shokan, from which it turns southward over the dividing weir to the aerating basin at the intake to the Catskill Aqueduct north of Olive Bridge. The reservoir, with a capacity of 82,000,000,000 gallons (310,000,000,000 liters), has an area of 13 square miles (34 square kilometers) and a shore line of 40 miles (64 kilometers). Not only does it store water derived from the 250 square miles (648 square kilometers) of drainage area of Esopus Creek, but it also receives 600,000,000 gallons (2,270,000,000 liters) of water daily from the Schoharie drainage basin through the 18-mile (29-kilometer) Shandaken Tunnel. After passing through the hundreds of aerating nozzles, the water enters the 17-foot (5.2-meter) aqueduct that carries it more than 80 miles (129 kilometers) to New York City. The engineering geology of this water-supply system is described in Guidebook 9.

The rocks that crop out between West Hurley and Shokan are the red and gray sandstones and shales of the Kiskatom formation. From the south side of the reservoir the route parallels the cut and

cover aqueduct through Olive Bridge and Atwood; 2 miles (3.2 kilometers) south of Atwood the road leaves the Mount Marion escarpment to pass across the Chittenango shale belt, occupied a mile or more to the northeast by Esopus Creek. The Onondaga limestone may be seen in the fields north of the road just west of Stone Ridge.

For a mile southwest of Stone Ridge the route follows the strike of the beds near the Onondaga-Schoharie contact, the Schoharie cropping out beyond the turn eastward toward High Falls. The rocks outcropping by the underpass beneath the New York, Ontario & Western Railway tracks at High Falls station are in the Helderbergian New Scotland formation.

At High Falls and in the gorge of Rondout Creek below the following Silurian section is displayed:

Silurian section along Rondout Creek at High Falls.

	Feet	Meters
Decker Ferry formation:		
Cobleskill limestone: Dark-gray fine-textured massive conchoidally fracturing limestone forming the top of the falls; fossils abundant; *Halysites* sp. and *Stromatopora constellata* Hall common	10	3
Rosendale waterlime: Dark-gray to black fine-textured thick-bedded conchoidally fracturing limestone extending almost to the base of the falls; apparently nonfossiliferous	15	4½
Wilbur limestone: Black, yellow-weathering impure limestone in reentrant at the base of the falls; fossiliferous; *Halysites* sp., *Favosites* cf. *F. niagarensis* Hall, *Enterolasma caliculum* (Hall), and *Atrypa* sp. common	3	1
Binnewater sandstone: Upper beds of white ripple-marked and cross-bedded quartzitic sandstone grading downward to alternating beds of buff, gray, and greenish fine sandstones and shales, exposed along the road to the power house and beneath the falls; about	25	10
High Falls formation:		
Dark-gray and greenish quartzose shales, with reddish shales at the base	27	8
Dark-colored calcareous sandstone and impure gray limestone, forming ledges in stream north of grist mill and exposed at power house	13	4
Reddish and greenish shales and fine sandstones, mostly concealed	45	14
Total thickness of High Falls	85	26
Shawangunk conglomerate: White, well-cemented, resistant quartz sandstone and conglomerate, forming ledge in Rondout Creek above old canal bridge; thickness in borings	270	80

High Falls is west of a series of anticlines and synclines with overthrust faults that are transgressed at an angle to the strike by the road from High Falls to Rosendale, 4 miles (6.4 kilometers) to the northeast.

The outcrops along the road to Rosendale illustrate the structure. At the sharp turn in the road by the hotel in the eastern part of the village of High Falls is a ledge of Shawangunk conglomerate (mileage 0.0). At 0.3 mile (0.5 kilometer) ledges of eastward-dipping Rosendale and Cobleskill limestone are exposed to the north (left) of the road, and Binnewater quartzite forms the floor of the long shallow quarry that lies to the north. The same beds, dipping on the east limb of the syncline, form a falls in Coxing Kill beneath the bridge southeast (right) of the road at 0.95 mile (1.5 kilometers). At 1.4 miles (2.3 kilometers) is a cliff of westward-dipping New Scotland beds, the eastern limb of a narrow syncline that is followed to the west by the sharp anticline, which can be seen along the Delaware & Hudson Canal [16] on the northwest (left) from the highway bridge over Rondout Creek; this Lawrenceville anticline exposes 20 feet (6 meters) of Coeymans limestone [17] in its axis, beneath New Scotland beds.

Half a mile (0.8 kilometer) farther east, at 2.1 miles (3.4 kilometers) from High Falls, the eastward-dipping Shawangunk is exposed along the roadside; beyond, the High Falls and Binnewater are obscured, but in the cliff back of the kilns the Rosendale waterlime has been mined from the overlying Decker Ferry formation. The next exposure on the side of the road, at 2.25 miles (3.6 kilometers), displays a thrust fault bringing Binnewater sandstone over Manlius limestone; this repetition of beds is evident in the fact that there is another mine in the Rosendale beyond, the Rondout waterlime also having been mined from above the intervening Cobleskill.

At 2.55 miles (4.1 kilometers) the Shawangunk beds form the rapids in Rondout Creek; the Coeymans limestone is exposed at the foot of the bluff on the northwest (left). A high bluff now comes in view beyond the trestle of the New York Central (Wallkill Valley) Railroad. The beds in this section have been disturbed by a thrust fault that cuts diagonally across the face of the cliff from upper left to lower right. Moreover, the rocks have been affected by the collapse of the mines that were driven into the hill in the removal of the waterlimes. The Shawangunk conglomerate is exposed on the edge of the creek beneath the bridge; the High Falls and Binnewater are concealed, but the

[16] This canal was placed in operation in 1829 and abandoned about 25 years ago; it connects the anthracite region of Pennsylvania with the river at Kingston.

[17] The Kalkberg formation is not separated in this region.

succeeding limestones can be recognized along the west end of the bluff to the lower New Scotland; above this lower New Scotland the Manlius and Coeymans recur over the fault plane, beneath New Scotland that continues to the top of the hill.

At the east end of the hill, north of the highway bridge over Rondout Creek in the village of Rosendale, in a mine in the Rosendale waterlime, corals and stromatoporoids project from the roof, which consists of the overlying Cobleskill limestone. The Shawangunk conglomerate is exposed south of Roundout Creek as the northern outcrop of a plunging anticline that is evident in the railroad cut east of Rosendale station at the top of the hill; the creek is thus flowing in the belt of nonresistant High Falls and Binnewater formations. Across the road from the church southeast of the bridge the Shawangunk has been thrust over the Rosendale, eastward-dipping Cobleskill, and Binnewater beds; the Rosendale has been mined, and the Binnewater forms the ridge between the highway and the mine. Mention has been made of the sharp anticline in the Shawangunk east of the railroad station at the top of the hill; farther east, the railroad turns southward along the fault line that has just been mentioned, the Shawangunk forming a projecting ridge to the east of the tracks.

From Rosendale the route will return through High Falls to the road south of Stone Ridge. As it proceeds southwestward to Kerhonkson, the Shawangunk Mountains become higher to the east as the formation thickens southward, until their altitude exceeds 1,500 feet (450 meters), the thickness of the Shawangunk being about 500 feet (150 meters). This range is the northernmost extension of the Tuscarora ridges that are prevalent in the Ridge and Valley belt of the Newer Appalachians farther southwest. The route of the excursion turns eastward over the mountains by Minnewaska Pass. Where the road reaches the escarpment on the east, the unconformity between the highly tilted Ordovician rocks and the westward-dipping Silurian Shawangunk conglomerate is shown clearly; the Ordovician beds were folded during the Taconian disturbance, toward the end of the Ordovician period, and were eroded prior to the deposition of the Shawangunk.