New York State Museum Bulletin

Published by The University of the State of New York

No. 336 ALBANY, N. Y. JUNE 1944

NEW YORK STATE MUSEUM

CHARLES C. ADAMS, *Director*

GEOLOGY OF THE CATSKILL AND KAATERSKILL QUADRANGLES

PART II SILURIAN AND DEVONIAN GEOLOGY, WITH A CHAPTER ON GLACIAL GEOLOGY

By
GEORGE H. CHADWICK
Temporary Geologist, New York State Museum

CONTENTS

ALBANY
THE UNIVERSITY OF THE STATE OF NEW YORK
1944

M-365n-Je41-2000

New York State Museum Bulletin

Published by The University of the State of New York

No. 336 ALBANY, N. Y. JUNE 1944

NEW YORK STATE MUSEUM

CHARLES C. ADAMS, *Director*

GEOLOGY OF THE CATSKILL AND KAATERSKILL QUADRANGLES

PART II SILURIAN AND DEVONIAN GEOLOGY, WITH A CHAPTER ON GLACIAL GEOLOGY

By

GEORGE H. CHADWICK

Temporary Geologist, New York State Museum

CONTENTS

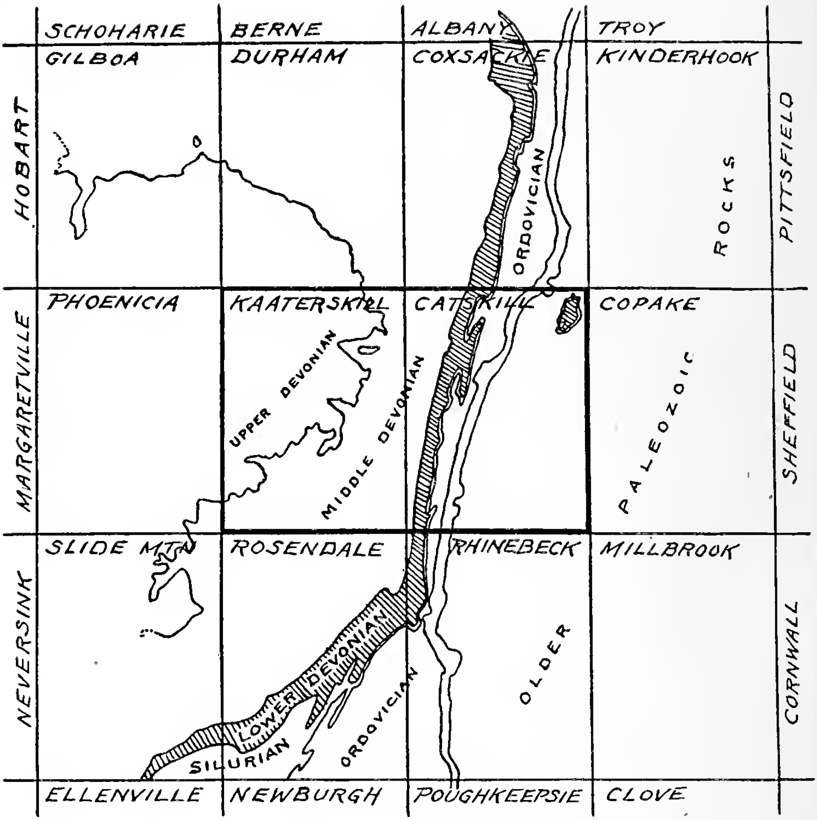
ALBANY

THE UNIVERSITY OF THE STATE OF NEW YORK

1944

M-365n-Je41-2000

ILLUSTRATIONS



Key map showing the relation of the Catskill-Kaaterskill quadrangles to the ten surrounding quadrangles geographically and geologically.

Geological maps and bulletins have been issued for the Schoharie, Berne, Albany-Troy, Newburgh and Poughkeepsie quadrangles; Coxsackie is being published.

The cross-lined belt marked "Lower Devonian" is actually the Kalk berg and thus includes also the (Middle Devonian) Onondaga limestone.

GEOLOGY OF THE CATSKILL AND KAATERSKILL QUADRANGLES

PART II SILURIAN AND DEVONIAN GEOLOGY, WITH A CHAPTER ON GLACIAL GEOLOGY

By George H. Chadwick

Temporary Geologist, New York State Museum

PREFACE AND ACKNOWLEDGMENTS

When, in 1926, the writer undertook the report on his home region, the Catskill quadrangle, it was with the request and understanding that the mapping of the east side of the river would be executed by Dr Rudolf Ruedemann, master of the Ordovician and Cambrian rocks there displayed. Doctor Ruedemann's consent to do this was the more appreciated because of the burden of his engagements already made, which indeed prevented its accomplishment for several years. Meantime there was promise of a topographic resurvey of the quadrangle, the map of which was finally issued from Washington in September, 1938, and the project was therefore held over until this new base became available.

Early we sought also the cooperation of John H. Cook on the glacial geology, to which he has brought a stimulating newness of interpretation. Since the exigencies of the work gave Mr Cook less opportunity to examine the glacial features of the west side, these have been touched upon by me for the sake of completeness, in doing which I have had to present and occasionally to defend the ideas of the old school.

It seemed best, furthermore, to extend the scope of the report to the mountain rocks and region by including in it the Kaaterskill quadrangle next west, and this work I undertook in 1933. In all of this I have had, and desire gratefully to acknowledge, the constant interest, assistance and advice of the State Museum staff, particularly of Doctors Ruedemann and Winifred Goldring but also in the matter of photographs that of W. J. Schoonmaker and the late E. J. Stein. Many others have generously contributed to the illustrations, acknowledgments to whom will be found on the plates. Equally cordial has been the attitude of the property owners on whose lands the field work has taken me, a list too long to itemize. To my wife's active aid during her lifetime I am heavily indebted.

To all of us collaborators the region, old and much visited as it is, has furnished surprises in the way of fresh discovery. Especially has this been true in Doctor Ruedemann's territory. Without his participation the report would in any case have been lame indeed concerning these older rocks. His astonishing finds speak for themselves.

The new base map of the Catskill quadrangle presented such a totally different picture of our topography from the old one of some 30 years ago and depicted its features in such beauty of detail that it became necessary to review in the field practically all of the Silurian and Devonian area. The geological map now presented is the work of 1938, not of 1926, executed with as minute accuracy as the scale would permit and the engraver could compass. The report on these rocks has likewise been wholly rewritten, in much greater detail and enlarged in accordance with the enlarging knowledge of these strata that has come so fast in the intervening 12 years through our own work and that of Dr G. Arthur Cooper and Russell M. Logie in particular, as well as of many others. To these gentlemen also I make cordial acknowledgment of aid and companionship.

There is a further debt to those who have gone before and opened the wonders of this region to our eyes, and whose names live in the bibliographies. Without meaning invidious distinction in a list so long, there yet come to mind the names of grand old Amos Eaton (of Catskill and Troy), of Professors Shaler and Davis, and of Mr Darton. No less is my personal debt for early and continued encouragement to Dr John M. Clarke, Dr H. L. Fairchild, Dr John C. Smock and Henry Brace (of Catskill), and to my enthusiastic boyhood friends, Robert Weeks Jones and Egbert Roy Beardsley.

No one using this book should think of it as a subject now finished and closed. What has been learned is but a stepping stone to further, larger understanding. Many unsolved problems are mentioned in the text in hope that new minds will attack them. The map of the Kaaterskill quadrangle is distinctly a preliminary one, for it was inexpedient at this time to devote to that area the funds for its minute elucidation and its correlation far afield. To the user of the book we wish pleasure as great as ours in the unparalleled geology this region contains.

THE PHYSIOGRAPHIC BELTS

The key to the geology of the west bank of the Hudson in the Saugerties-Catskill region is found in the belted hills (see Davis, 1882, 1883) that traverse it. These hill ranges trend in general parallel to the course of the river and also to that of the mural front

Figure 1 Austin's glen of the Cats kill, Jefferson Heights, Catskill. Mouth of main gorge seen from Eagle cliff (figure 16). "A": locality of figures 58, 12, 13. "B": locality of figure 25. "C": locality of figure 23. "D": locality (concealed) of figure 26. Syncline on left, up to Becraft limestone; anticline right, capped by Manlius. Note old railway grade. Looking north. Photo: March 1928, G. H. C.

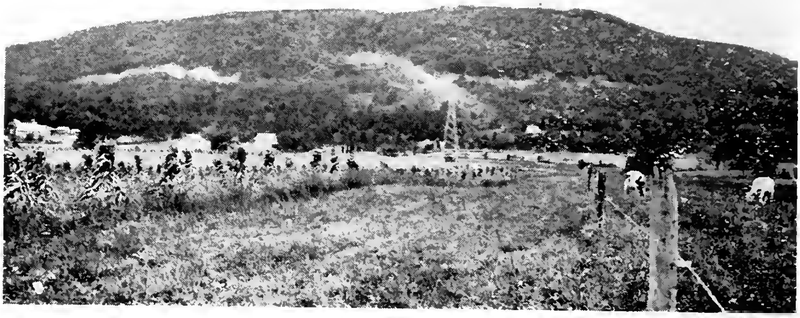


Figure 2 Mt Marion, highest peak of the Hooge berg, from the east, looking west across Albany clays of the Beaver Kill valley. Whole hill is in west-dipping Mount Marion beds. Starfish locality lies on crest above steeper decline to left (south). Photo: September 1936, G. H. C.

Figure 3 Hooge Berg range (two peaks of Vedder's hill, and Mt Potick) of visibly west-dipping Mount Marion beds, as seen from Rip Van Winkle trail west of Webber bridge. Looking east of north, down the Bakoven (Kaaters Kill) valley. Albany clay knolls and creek floodplain in foreground. (See figures 73, 74). Photo: April 1938, W. J. Schoonmaker.

of the Catskill mountains which Longstreth calls the "Wall of Manitou." By the old Dutch settlers the ranges were given names that still linger (see Beers, 1884). The first continuous range west of the Hudson was to them the Kalk berg (pronounced colla-barrakh) or lime hill (figures 1, 39), sometimes corrupted into "Collarback." The still larger or second range west of the long valley of the Beaver kill and Kaaters kill, they called the Hooge berg (hohga-barrakh) or high hill (figure 3), including Mt Marion, Mt Airy, Timmerman's and Vedder's hills. Lastly, the mountains were called the Kats berg (cots-barrakh) or wildcat hill.[1] These three "bergs" are in reality three escarpments, facing eastward, respectively Lower, Middle and Upper Devonian. The thin Silurian beds occupy the base of the most easterly, or Kalkberg scarp.

A space of a mile or two usually intervenes between the river and the Kalk berg. This space is much occupied by the clays and sands of the postglacial or pro-glacial water body familiarly known as Lake Albany (see Woodworth, 1905). But out of it rise here and there minor ridges, especially north of Catskill. None of these ridges on our map-area appears to have received any special designation save only the tiny "lookout" knoll or Kykuit (cake-out) just south of Catskill village (one mile south-southwest of the town bridge) from which the Catskill Indians caught their first glimpse of the sails of the "Half Moon"[2] and our own ancestors watched for the smoke-stack of the "Clermont." The rocks of this belt are Ordovician (Normanskill shales) described by Doctor Ruedemann.

The Kalk berg, on the other hand, comprises many minor ridges in its breadth of a mile or two, some of which, such as the West berg, the Luyster berg (lie-stair-barrakh) or echo hill, and the Sup berg or sap hill (from its sugar maples) retain their special appellations. The Kalk berg itself appears on our geologic map as the broad band of many colors extending west to the line of the black Bakoven shale and involving two great limestone series separated by the mass of so-called "grits," really impure shales. Where the eastern limestones make their sharp zigzag eastward, south of Cauterskill hamlet, they inclose a V-shaped valley, bounded by impressive cliffs (figure 17), that the Dutch called the Fuyk from its resemblance in shape to a conical fishing-net such as is still called locally a fyke. Here Gates's victorious army encamped on its return from Saratoga. The corresponding valley on the south, north of West Camp, holds the swamp yet known to the elders as the Great Vlaie (fly), *vlaie* meaning a swamp though derived from the word valley.

On the Kalk berg, intermediate between Fuyk and Vlaie, lies a narrow bit of meadowland similar to the limestone sinks (such as the Alachua prairie) of Florida. Here the drainage from Van Luven's lake and from northward nearly to the Palenville road (highway 23-A) plunges into a crevice in the lime rock to emerge as a "spring" over half a mile south on the main highway (9-W), under the east brow of the hill. The spreading of the waters in flood time has kept this sink area always treeless, and in the older deeds it became a headright for cattle pasturage under the title "een streeke land" (a strip of land), whence it is still known as the Streeke (pronounced stray-kay) and its occasional water body as the Streeke lake.

The double character of the Kalk berg range, divided by the "grits," is best shown south of Saugerties[3] where for four miles the Esopus creek trenches the belt of shale that bears the name of this stream. Both the Kaaters kill and the Cats kill (figure 78) also follow the Esopus shale outcrop but for only short distances.

Behind the Kalk berg, between it and the Hooge berg, lies a longitudinal valley (figure 73), somewhat refilled by the "Lake Albany" clays and by glacial gravels. At the south the Esopus threads this vale as far north as the West Shore bridge. Farther on, the Beaver kill occupies it (figure 2), to its mouth, and then the Kaaters kill for nearly six miles, beyond which a small tributary is engaged in reexcavating it almost to our north limit. This valley owes its existence to the uptilted edge of the soft Bakoven ("Marcellus") black shale (figure 40). It is called the Bakoven valley from the rounded form of the scalloped clay-remnants left in it at various points and especially near the Palenville road (highway 23-A), suggestive to the Dutch of their bak-oven (bahk-ohfen) or bake ovens (figure 74). During the Revolution this valley was the scene of fierce and sanguinary raids on the part of Brandt and his savages.

The Hooge berg, next west, is the range of Mt Marion (figure 2), Mt Airy, Timmerman's and Vedder's hills (figure 3). Twice as high as the Kalk berg, it presents a long row of steep eastern fronts with gentle back slopes into the broad Kiskatom flats. The straight alignment of the peaks veers more to eastward through an angle of 10 degrees opposite Katsbaan,[4] and of course the Kalk berg bends with it; but the broken character of the latter range obscures the point of deflection. Perhaps the best index of this bend, in the Kalk berg, is the change in the course of the Old King's road[5] at Katsbaan four corners.

The width of country here assigned to the Hooge berg in Greene county (Catskill quadrangle) is from two to three miles, though its

Figure 4 Southern end of the Catskill front from Becraft limestone ledge (380 feet) at peneplain level on east ridge of Kalk berg between routes 9-W and 23-A two miles southwest by west from Uncle Sam bridge, Catskill. Late snowfall reveals gentle northwest dip of ledges in the mountain front. The sleeping "Old Man of the Mountains" consists of Overlook (knees) at left, Plattekill (body) and Indian Head. Profile of the last is outcrop of Stony Clove sandstones that also cap two "sawtooth" summits (High peak and Roundtop) to right, seen better in figure 5. A south-moving continental ice-sheet assisted in shaping all these. Monadnocks (Timmerman's hill and knob at High Falls), on the Hooge berg, surmount the peneplain. Looking southwest by west. Photo: April 1938, W. J. Schoonmaker.

Figure 5 "Wall of Manitou" from High peak to North mountain and Stoppel point, continuing figure 4 to north. Note a minor sag crossing all the ridges to west, to South mountain, through which runs the Rip Van Winkle trail. Looking south of west. Photo: April 1938, W. J. Schoonmaker.

Figure 6 Northern end of the Catskill front, completing the panorama of figures 4, 5, with outlying Cairo Roundtop (see figure 77) at right. Blackhead, in middle, is highest peak (3937 feet) visible from Catskill. North mountain (and Stoppel point) to left, Windham High peak to right. Foreground is finely developed Hudson Valley peneplain on summit of Kalk Berg and Hooge Berg hill-ranges. Looking west-northwest from same ledge as preceding. Photo: April 1938, W. J. Schoonmaker.

back line may be a debatable subject. Compared with the greatly folded and thrusted beds of the Kalk berg, the structure of this range is simple. All the strata have westward dip, which finds expression in the unequal opposite slopes of the hills and in the many east-facing minor ledges that give variety to its surface. It is, in short, a zone or belt of westwardly tilted rock terraces. The drainage is thus thrown against the faces of the ledges and constantly freshens them by undercutting.

Behind the Hooge berg, on the Catskill quadrangle, is a broad alluvial plain, the Kiskatom flats (figure 77), a name abbreviated from the Kiskatominakaukee, place of thin-shelled (i. e., shagbark) hickory nuts, of the aborigines. This plain represents a filling up of the glacial lake (Lake Kiskatom[6]) that had its outlet southward through the High Falls[7] pass (figure 44) of the Kaaters kill across the Hooge berg, plus the grade plain of that creek up to Saxton.

With the termination of these flats, on crossing into Ulster county east of Saxton the western limit of the Hooge berg shifts eastward to the two arms of the Miner kill, narrowing this range to about a mile width past Quarryville and Unionville, widening some thence to Fish creek as it reaches its culmination in Mt Marion but dropping almost into insignificance for a short distance southward from the Platte kill past Ruby. This broad gap in the range, like that where the Cats kill crosses it, just north of our area, may mark the course of ancient drainage.

West of the Hoogeberg in Ulster county, or of the Kiskatom flats in Greene county, begin the lower terraces, or piedmont, of the Catskill plateau, their width the counter of that of the Hooge berg since from Overlook mountain northward there is a nearly constant distance of four miles from the east base of the Hooge berg to the foot of the real mountain slope of the Kats berg or Catskill mountains proper. South of Overlook, however, the piedmont belt swings widely west, past Woodstock, Baehrsville and Yankeetown, while out of it rises the short recurved Catskill range of the Tys ten Eyck and Taantje mountains.[8] Less markedly, at the north edge of our area, the piedmont pushes northwesterly through the Kiskatom Brook gap behind the outlying knob of Cairo Roundtop.

This piedmont area has even more massive cliffs than those in the Hooge berg, but with much less west dip. The effect of master jointing is conspicuous in the cliffs, giving their eastern fronts great directness and parallelism, as is well shown by the straight course of the 400-foot contour line both north and south of Stony brook, and of the 500-foot contour northwardly from Palenville for two miles.[9]

Passing now from the Hudson valley up into the mountains, we find there a very different geography. The mural front or Wall of Manitou (figure 5) alone parallels the hill ranges of the valley. Instead, the mountain ranges run directly away from this front. Starting at Overlook and Plattekill mountains the great central range (figure 54) goes northwesterly, increasing steadily in height and massiveness to Hunter mountain (figure 55), its highest peak, 4,025 feet, beyond which (off our area) it gradually declines. The eastern or front range, starting with South or Kaaterskill mountain, likewise runs northwest, through North mountain and Stoppel point (figure 5), but reaches its culmination off our map (in Black Dome, 4,004 feet; see figure 10). Between these lie, first, the East Jewett spur range from Stoppel point west and, second, the short independent range of High peak and Roundtop[10] (figure 52), embraced between the two cloves. Spur ranges also fray out westward from the central range, especially the Olde berg south from Plateau mountain and the range from Overlook past Shady that suddenly swells up into Mt Tobias. The wholly disconnected range of Tys ten Eyck on the south, and its small companion, Cairo Roundtop (figure 77), on the north, have already been mentioned.

The explanation of this difference is in the rocks. In place of the upturned, folded and belted rocks of the valley, the mountains and their supporting plateau consist of nearly horizontal strata (figures 47-52) which have exerted no control over the courses of the streams. In these flat-lying beds the mountains are negative features, namely, what has remained after the valleys have been carved. Nevertheless, in this process of valley-carving, a slight southwesterly slope of the strata has edged the main streams over against the northeast fronts of the ranges, as is well shown by the Schoharie creek hugging the central range, and has favored the development of tributaries, hence of spurs, on the opposite side. Thus the central range (figure 54) is really a fourth escarpment (see page 11) to add to our list, though its direction is skewed from that of the others.

Not only these larger, but many minor features of the geography, will find their explanation in a study of the geologic mapping. But it may be noted in passing, for explanation later, that while the mountain ranges do not parallel the valley hills, nevertheless the valleys that cross these ranges do strikingly so parallel the hill ranges, the river and the Wall of Manitou, a fact illustrated best by Stony clove and Mink hollow (figures 76, 71; see Chadwick, 1916).

The drainage courses of our region tell also a geologic story. On the mountains, while the drainage pattern is dendritic (branching treelike), yet the flow is in general away from the Hudson valley instead of towards it and nearly all the stream-heads on the eastern edge of the plateau start off westerly, though some of them get turned back eastward after a bit through capture by Hudson tributaries, as described in a later chapter. There is in this westward flow convincing evidence that the Hudson valley is a late development in the erosional history of the region, and that the earlier drainage ran off from high ground where now is the Hudson river, to hurry westward towards the Mississippi if not to it (Ruedemann, 1932; Fairchild, 1925, 1928).

All the waters of our area eventually reach the Hudson, however, those of the southwest by the shorter route of the Esopus creek, those of the northwest by the 150-mile circuit of the Schoharie kill and Mohawk river (see Guyot, 1880). But this is not true of the western Catskills, which drain to the Delaware and the Susquehanna rivers.

The land is shaped by the streams, sometimes unhindered, but sometimes the land in turn shapes the streams, as is particularly evident in the adjustments that the creeks have made to the parallel belts of soft and hard rocks in the Hudson valley. Yet, unexpectedly, most of the mountain tributaries maintain this parallelism, as above noted, flowing not directly but slantingly down the slopes of the ranges. Evidently here, in these flat-lying rocks, there are still vertical zones of weakness that impress the brooks into their pattern and, since these conform in direction to the master joints of the piedmont terraces, it seems reasonable that they also are joints, closely spaced at rather regular intervals of about a mile. Such zones also invite faulting, especially the internal settling known as "keystone" faulting (Crosby, 1925),[11] but as yet actual faulting has been demonstrated in only the easternmost of these lines, namely that which is tangent to the east end of North lake.

Stream courses out of tune with the stratigraphy in the valley are chiefly the effects of glaciation. These include the tortuous postglacial gorge of the Cats kill in Austin's glen (figures 1, 78), and also the diagonal courses of both the Kaaters kill and Platte kill (figure 42) through the Hooge berg. There are similar courses of two small brooks farther north, on Vedder's hill, and there is the remarkable unexplained pass running northeast from High Falls. The Kaaterskill and Plattekill cloves are noted examples of "stream capture" (Darton, 1896; Salisbury & Atwood, 1908)[12] to be discussed in a later chapter and to these should be added the notch of the Saw kill at Shady.

Glaciation is responsible likewise for some of the peculiarities of the Hudson river, particularly for its curious expansion above Alsen called by the Dutch the Grote imbogt (or Imbocht), great embayment or bight, (of which the modern pronunciation is imbuff). It must be remembered that the Hudson is a drowned river, a tidal estuary, spilling up over its former banks, as it does markedly at Cruger's island below Saugerties, on the east side. The narrowing of the river below the mouth of the Cats kill and again at that of the Esopus at Saugerties is in each case due to recent delta building of these creeks. But Rogers island is a south outpost of an upsilting that extends all the way down from Troy and Albany—the "inner delta" of the Hudson itself.

Supplementary Notes

[1] Kill is Dutch for creek. The Cats kill is the stream, and to follow this name with the word "creek" is tautology, as it is also in the case of the Kaaters (pronounced, and sometimes spelled, cauters), the Platte (plahtay), the Beaver, Hans Vosen or other kills of this region. (See N. Y. State Mus. Bul. 92, p. 86, footnote.) The English unfortunately shifted the creek name to the mountains, which the aborigines had called Onteora (correctly On-ti-o-ra) or hills of the sky.

[2] Henry Hudson, often miscalled Hendrick (he was an Englishman in Dutch employ), sailed up the river in the autumn of 1609 on his voyage of discovery. In 1809, Robert Fulton brought the first steamboat up the Hudson. A joint celebration and pageant of these events was held in 1909 in the river towns.

[3] Saugerties, zaagertjēs (as the older inhabitants still pronounce it, and correctly) means the little sawyer's place, but the name of this dweller on the Saw kill or Sauger's kill has been long forgotten.

[4] Katsbaan (kahts-bawn), cats' haunts, because the pumas had a den under the low ledge, has one of the oldest churches of the region, with long records.

[5] The Old King's road or royal post road of 1703 followed an ancient trail that remained only a footpath until 1670. Its original course through the Fuyk, trod by Gates's army, was abandoned after the Revolution and the road relocated to follow the creeks. It was not only the first highway in this region but in 1830 it was the first "state road," as distinct from the turnpikes. Many old buildings line its route.

[6] Like most aboriginal names, Kiskatom is accented equally on all syllables—a safe rule generally. (For Lake Kiskatom see Chadwick, 1910*a*.)

[7] Known to the postal authorities as Great Falls, to distinguish from the post office of High Falls in Ulster county (Rosendale quadrangle).

[8] These names appear on maps in much corrupted forms, such as Ticetonyk and Tonshi. 'Tys is a Dutch abbreviation for Mattys (Matthew or Matthias), while Taantje means auntie and on the oldest maps we find it as Taantje Hoek, auntie's corners, at a road intersection. This last name and Ohayo ("Ohio") mountain have been much shifted around on the maps or interchanged. Ohayo is said to be correctly "Heigho-heigho," but I can not vouch for this origin.

[9] This parallelism of the contours has three significant interruptions: past Palenville, past West Saugerties and from Woodstock to Baehrsville. The "bulging" of the contours at these points signifies the great alluvial fans of cobbles and gravel and sand built respectively in front of the Kaaterskill clove, the Plattekill clove and the notch of the Saw kill in post-glacial time, these being the three main streams that come steeply down out of the plateau.

[10] Namely, Kaaterskill (or Palenville) High Peak, and Kaaterskill Roundtop (or Mt Lincoln), for distinction from other High peaks and Roundtops.

[11] In Mather's cross section of the Stony clove (see W. W. Mather 1843: plate 25, figure 8), he shows a discordance of the beds on the opposite sides which suggests faulting. Attempts to check this in the field have been defeated by weather conditions.

[12] Clove is a Dutch term for these great clefts in the mountain, of which three principal ones appear in our area (Kaaterskill, Plattekill and Stony) besides the Rip Van Winkle (Sleepy Hollow of map) and Winter cloves. Platte (plahtay) kill or the flat (level) creek, is often misspelled "Plaater" or "Plaaters" by analogy with Kaaters, and this error is found in the postoffice name of the hamlet ("Plaat Clove") at its upper end. The locally erected signs read correctly: Platte Clove. "Platter" kill is another misspelling. (See Beers' History of Greene County 1884, p. 109.)

HISTORICAL ACCOUNT

Geological observations in the Catskills began, so far as found, with Dr Samuel Latham Mitchill (1764-1831), of Columbia University, before the opening of the nineteenth century and with William Maclure (1763-1840) of Philadelphia at about the turn of the century.

Mitchill's papers on our region were published in ephemeral ways or in medical journals and are known to me only through Mease (1807). He described as schist the compressed Ordovician rocks of Dutchess and Columbia counties, stating that it served "as a bed to the calcareous strata scattered throughout the country, and [he] mentions a block of this kind a mile from Claverack and four miles from the city of Hudson on the river of the same name, presenting a prominent mass eight hundred acres in superficies, filled with shells, none resembling which are to be found in the nearest sea, distant a hundred and forty miles!" (Mease 1807, p. 39; see also p. 42, 50, 403, 406.) This is Becraft's mountain.

Mitchill imagined (Mease 1807, p. 39-40) concerning Kingsbridge and Harlem

> that at a period unknown in history the ocean covered this ground and his opinion is supported by all the facts he mentions respecting the Kaats Kill mountains.
>
> These mountains he has found to consist of the same sandstone as Blue Ridge, of which he deems them a continuation. He first imagined these mountains to be of primitive formation, because the granites and sandstones contained no fossils; but he soon found contrary indications: as, 1st, the aspect of rocks containing pebbles or small stones of red and white quartz, sandstone and red jasper, all evidently rolled and worn by the waters; 2dly, horizontal and very [page 40] regular strata of these rocks; 3dly, fossil shells unknown in these seas, the clam and scallop excepted, and found on their summits in an argillaceous or in a siliceous bed.

In such quotations we see accuracy of observation struggling through the primitive state of geological science less than a century and a half ago, when Catskill with a population of only 1,000 was twice as large as Buffalo, and larger than Erie and Cleveland combined (see Melish 1818, p. 78, 87, 107).

Mease (1807, p. 8, 19, 22-24, 37, 40, 404) says that sandstone proceeds "up the western bank of Hudson's river to the group of the Kaats Kill mountains," the "highest peak" of which (then believed to be High Peak west of Palenville) was "measured in 1798 by Peter de la Bigarre" and found to be "3549 feet above the level of Hudson's river," which approximates the present accepted elevation of 3660 feet though this is far from being the highest peak. He thinks that all three of the Appalachian ranges (Blue Ridge, Kittatinny and Alleghany) lose themselves eventually in our mountains or their Delaware county extension (which is a mistake), says that roofing slate "(schistus tegularis)" "is now extensively worked" in the township of Rhinebeck and that Hudson's river below Albany to present Beacon "flows between two rugged declivities, covered with thin copses of oaks and firs" (a good description of the "inner gorge") and refers again to "the sandstone of Kaats kill" as characterizing the region from the Hudson and Mohawk as far as Georgia and west to Tioga, Pa. This is early recognition of the great redbeds delta deposit later passing current as the "Catskill formation" (see Chadwick 1936).

Mease gives (1807, p. 455-58) an unequalled word-picture of our two noted waterfalls, apparently taken from Doctor Mitchill (whom he always spells Mitchell), calling the creek "Kadir's kill" and "Kader's kill" and the Kaaterskill falls also "Mitchell's falls" possibly in honor of Doctor Mitchill. The latter he says are 162 plus 80 feet high, total 242 feet, while the other (Haines's) falls he makes 115 feet, with the small fall at top and the lower fall and cascades adding to 400 feet drop in a quarter of a mile. He alludes (page 59) to the clayslide at West Catskill occurring on June 1, 1796, (see the account by the Duke de la Rochefoucault Liancourt in 1799 quoted by Beers 1884, p. 124), as follows: "Instances of the effect of streams and rivers, in altering the disposition of the solid materials through which they run, occur . . . at Kaat's kill, where part of a hill has fallen down; . . ."

Maclure's work was part of a countrywide survey, the map of which appearing in 1809 (and 1817) is on too small a scale to give local detail, nor is such included in his text. The portion of the Catskill quadrangle between the Hudson and the Jansen kill is colored as "transition rocks" (which include limestone, graywacke and flinty slate in his tables), while the Silurian and Devonian area west of the Hudson is mapped as "floetz or secondary rocks" (which include old red sandstone and floetz-limestone) thus making them of Mesozoic age in modern parlance.

The cataclysmic philosophy of early earth-science is illustrated in the next accounts of our region, by Dr Samuel Akerly (1785-1845) in 1814 and 1820, who, after describing "the whole country north of the highlands as underlaid with primitive slate, most of the hills being composed of limestone" (Merrill 1906, p. 223), as they are around Poughkeepsie, explained his ideas thus: "The highlands of New York was the southern boundary of a huge collection of water, which was confined on the west by the Shawangunk and Katts-kill mountains. The hills on the east of the Hudson confined it there. When the hills were cleft and the mountains torn asunder, the water found vent and overflowed to the south. It was then that the channel of the Hudson was formed, and its stream has never since ceased to flow." Similar theories were held by Mitchill (Merrill 1906, p. 231) and others in those days.

The lengthy "account of the Kaatskill Mountains" given in 1820 by Henry Edwin Dwight of New Haven comes next, and was his sole geological publication. After extolling the scenery, referring to his description of our two cataracts (pages 17 and 21), he says (page 12): "The cascades which I have described, I visited immediately after the heaviest fall of rain that had occurred within the memory of the oldest inhabitant." (This was the storm of July 26, 1819, reported by Mather 1843, p. 42-43, and described by Benjamin W. Dwight in Silliman's Journal, v. 4, p. 124-42.)

"Some idea can be formed of the quantity of water that fell, when it is known that one mile north of the village of Kaatskill, a ravine was formed by the water directly through a wood, one hundred and ninety feet in breadth, by seventy-nine in depth, for the distance of nearly a furlong; when it united its waters with the Kaatskill creek." This I suppose to be the gully entering the Hans Vosen kill from the west where that is crossed by route 9-W and causing also a twist in route 23 on the plain above.

Dwight (1820, p. 12) followed Maclure and Eaton (see page 28, *postea*) in calling our mountain rocks "secondary" (that is, Mesozoic) but says that those of the river shore are "Wacke." Under the head of "Petrifactions" he says (page 13): "On the Kaatskill creek three miles above the town, is a cascade of about 20 feet in height." (See our figure 23.) "South of this fall, the rocks which form the bed of the stream, run parallel with the current and are composed of carbonate of lime. They are partially composed of petrifactions of the clam, entrocite &c. The entrocites vary in length from one to six inches, though they sometimes exceed this. I saw imbedded in one of the rocks, one fifteen inches in length. They lie on the surface and in oblique and right angled position." (Are silicious in the limestone.) "The entrocites commonly appear straight and resemble vertebrae united to each other. Sometimes they assume a twisted appearance, as if struggling to escape when first imbedded. I observed here several pieces of Madrepore adhering to the rock or imbedded in it, weighing from ten to twenty pounds." (Notes flint veins with quartz coatings.) "The rocks forming the bed of the stream appear to have been rent asunder, leaving cavities of several feet in breadth and ten in depth, in which, when the stream is very low, most of the water runs."

He next gives a good description (pages 13-14) of Diamond hill, the little knoll of Normanskill rocks opposite the Hoponose (figure 62) that furnished quartz crystals until destroyed about 1890, and discusses the crystals from here with fluid cavities containing what Professor Dewey (1819, p. 345) had supposed to be naphtha but which Dwight takes to be water since a friend's specimen froze and burst at —6 or 8° F. and the fluid evaporated.

Between the village and the mountain, [he says (page 15)] the country is altered in its appearance. Near the western end of the bridge, which crosses the Kaatskill at the village, a hill rises to the height of 150 feet. The rocks which compose this hill are much more compact than those near the river. They have a dark blue colour and bear a much stronger resemblance to trap. Half a mile west of this, a ridge of land rises to the height of fifty feet, when the country changes to carbonate of lime. These rocks are compact and filled with petrifactions of the clam, entrocite &c., often in so great quantities as to compose one sixth of the rock. [See our figures 19, 27.]

Two miles from the base of the mountain, the Limestone region terminates. Sand stone immediately appears. The earth here assumes a more reddish appearance and continues of this colour to the mountain. The sand stone terminates at the base of the mountain. As you ascend the mountain, slate begins to appear resting upon the sand stone below, varying its strata from nearly horizontal to an angle of 30° [page 16]. [Slate for a third of the ascent, then sand stone again.] On the peaks of these mountains, are many specimens of conglomerate or puddingstone. I observed a rock of this kind (on the peak north of Round Top,) of half a mile in length and from eight to ten feet in height, forming an immense band to the mountain, . . . [No limestone found on the mountains.]

On the same page he speaks of "the clove or cleft in the mountain, which appears to have been formed by some great convulsion of nature" (figure 7). Then follow (pages 16-23) paragraphs on the

Figure 7 Looking down the Kaaterskill clove east-southeast from bridge on brink of Haines' falls, Catskill mountains, to the distant mist-concealed Hudson valley. A bit of the Rip Van Winkle trail visible in center. Dark foreground is short postglacial gorge, with top ledges seen at left and lower right. Note contrast in slopes between the inner valley, of later development, and the matured upland surface on left (South mountain). One of the two great ravines opened back into the "Wall of Manitou" since the erosion of the Hudson valley to its peneplain level (figures 4-6). Photo: April 1938, W. J. Schoonmaker.

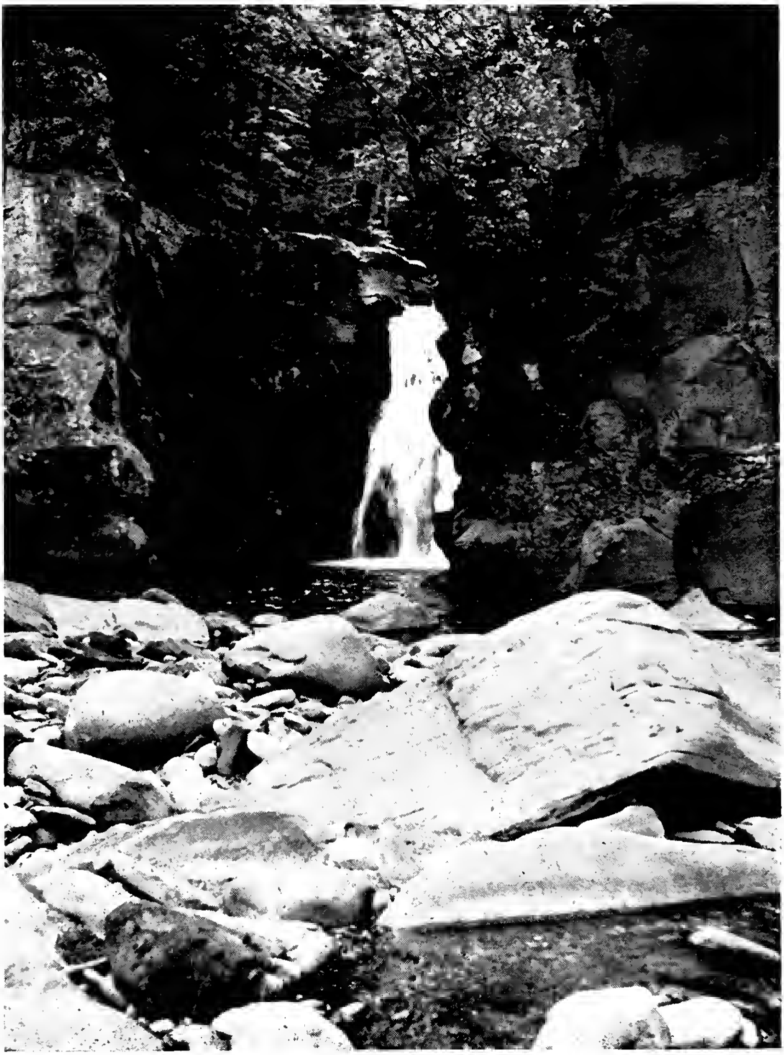


Figure 8 Kiskatom sandstones (Portland Point horizon?), the Kaaters kill at Fawn's leap (falls) in Kaaterskill clove on Rip Van Winkle trail about one and three-quarters miles above Palenville, a few rods above figure 9. Stream abrasion of transported rocks and boulders, giving rounded and sandpapered effects. Note "sandpapering" also of both bases of portal and on brink of fall. Looking west. Photo: May 1938, W. Storrs Cole.

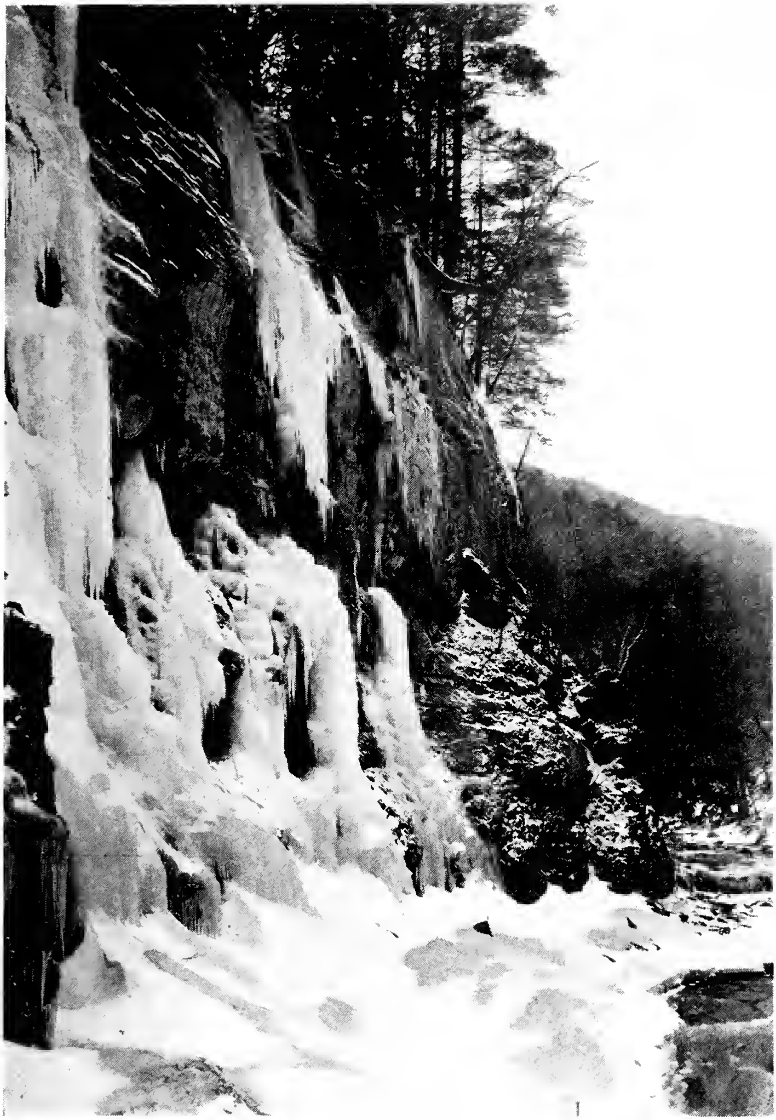


Figure 9 Ice hangings, plucking at Church's ledge above Moore's (Moe's) bridge on Rip Van Winkle trail in the Kaaterskill clove, about one and one-half miles west of Palenville and not far below Fawn's leap (figure 8). Heavy Kiskatom sandstones topping red shales give special susceptibility to ice pull. Looking south of west, upstream, from bridge. Photo: E. J. Stein.

Figure 10 More subdued older upland surface to north of the Kaaterskill clove (compare deep ravine of figures 50, 7) looking from roof of Hotel Kaaterskill (since burned), two miles east of Haines' Falls, N. Y., north-northwest past Stoppel point (right) to the distant Blackhead range (Thomas Cole and Black Dome mountains visible) on the Durham quadrangle, across the upper end of the north fork of the Schoharie Kill valley now captured by the Kaaters kill at Kaaterskill falls (figure 48) left of view. Photo: April 1923, C. A. Morrison.

Kaaterskill clove, its two waterfalls, the Stony clove, the altitude of the peaks (of which he takes Round Top at 3800 feet to be highest, meaning probably present High peak), the mountain lakes (said to be over a hundred feet deep in the center!), and other topics. After discussing the vegetation, he comes back (page 26) to the streams and says of the "Schohariekill" (on page 27): "Hence the waters of this stream, which originate within three or four miles of the Kaatskill, run about one hundred and fifty miles before they unite with them in the Hudson."

In 1821 appeared brief papers by Benjamin Wright and by John P. Jenkins (for titles, see the bibliography chapter), and in 1822 one by David Walker Barton "of Virginia," giving mineral occurrences and a map which divides the space between the foot of the mountains and the Hudson into fourteen parallel belts trending about 30° east of north, (described, pages 250-51). He says (page 249): "1st, on the side of the mountain which rises immediately to the north of Kaaterskill clove and about a quarter of a mile from the dwelling of Mr Absalom Smith, is a ledge of common argillaceous slate, from which during the winter and spring, issues a small stream, strongly impregnated with alum." (Deposits it in the form of a powder.) [Page 250] "It is here collected in considerable quantities and employed without farther preparation as a substitute for the imported alum." His "2d" is malachite, quartz and baryte in sandstone two miles east of the mountains and his "3d" is "Fer Ologiste" or specular iron which he says is frequent in detached quartz (glacial drift?). "4th, in the channel of a stream, two miles south-east of the Durhan meeting-house, (Greene county,) I found the sulphat of iron" associated with plant fossils, etc. Until 1851, Durham meeting-house with the crumbling village of 1784 stood on the now vacant hill a mile southeast of present Durham, and the stream referred to is probably Post's creek at the spot where stood Roswell Post's grist mill, now known as Shady Glen (see Beers 1884, p. 259), and where the name Catskill was first attached to the red-beds (Mather 1841, p. 81; see Chadwick 1936, p. 27).

In 1823, Dr James Ellsworth Dekay described under the name Bilobites what he correctly recognized as a double specimen of a bivalve shell (Conocardium; see *postea,* page 35) from our marine Devonian strata, but which was later confused with forms of "plant" origin (burrows) and solemnly still so listed in 1889 by Ward (1889, p. 854-55), collected at Cairo by James Pierce (of Catskill). The latter, in the same year, produced a rather lengthy paper on our mountains, covering their "topography, scenery, mineralogy, zoology, economical resources &c." in which the chief item of interest now is the report (pages 95-96) of a coal bed eight inches thick on the east face of the mountain (Overlook) in Woodstock.

Meanwhile there had come to our midst a struggling and always unsuccessful young lawyer, almost fresh from his graduation at Williams College in 1799, but destined to become the father of American botany and the pathbreaker for the great geological survey of New York. This man was Amos Eaton (1776-1842), until his death senior professor of sciences at Rensselaer Polytechnic Institute, Troy. He was admitted to the bar in Catskill in May 1804, his sons born here between that year and 1809, and his household as shown by the 1810 census, including his parents, totalled nine persons (Beers 1884, p. 33, 41). He was in such straits, according to Stuart Gager, that his popular manual of botany came to birth in a debtors' prison. In Catskill, his love for science developed; I believe he founded a local "lyceum" or natural history society (see Silliman's Journal, v. 3, p. 237) that continued to flourish after his departure (*vide postea,* page 30). For in 1816, at the age of forty, discouraged, his father and mother dead, he gave up law and went to study under Professor Silliman at Yale and began his marvelous career by tramping all over New England and New York giving short lectures and arousing such enthusiasm that he was drawn back to his alma mater, then to more profitable and permanent positions and, becoming the favorite of Stephen van Rensselaer, in 1824 to Troy. In that year was published his first short paper of local interest, having to do with the introduction in England of the new name "Carboniferous" including at base the old red sandstone, and the question of its adoption in America. This was followed by many others (see bibliography).

But already in 1818, while still lecturing at Williams College, he had put out his first 52-page book, known as the "Index," which in 1820 went to a second edition with 286 pages. Opposite page 6 of the first edition is a "geological traverse from Catskill mountain to the Atlantic," on which appear in order the names "Catskill Mt., Eaton's mill, Kiskatom, Cautrix kill, Catskill, Hudson river." I have not learned where Eaton's mill was situated. He classified our rocks (pages 25-33) as "8. Metalliferous limestone. 9. Argillaceous & Siliceous slate. 10. Graywacke slate. 11. Rubblestone."—these being included in the "transition" rocks, and "12. Red sandstone. 13. Breccia. 14. Compact limestone."—these being called "secondary" as by his predecessors. One does not get the idea that he saw as yet clearly the true stratigraphic succession of our formations. In the second edition he shifted the old red sandstone down into the transition rocks, but left the breccia and the compact limestone in the secondary. (See his pages 187, 190-91, 193-94, 207-9, 216-18, 225.)

Later in 1824 came from the press his book on the Erie Canal survey. That he was still classifying rocks by their mineral constitution instead of their time order is evident (page 34) in his statement under "13. Graywacke" (page 33): "But it is coloured . . . red with the peroxyd of iron near the foot of Catskill mountain. Localities.— . . . It constitutes most of the Catskill and Allegany mountains." On the same page he defines the "14. Old Red Sandstone." and says:

But it is very abundant near the top of Catskill mountain, about forty miles south of Schenectady. It contains petrifactions of branching corallines, resembling the roots of woody plants. These petrifactions, being mistaken for dry land plants, have caused this rock to be placed in the secondary class. I have traced a single branch of this petrification more than thirty feet in this rock. [Page 35] One mile south of Pine Orchard, on Catskill mountain, this petrifaction is very abundant in this rock.

Pine orchard is the site of the Mountain House, and the old flag quarries a mile south are good collecting grounds for fossil tree-ferns. On page 92 he again says of the old red sandstone: "It is in layers alternating with the highest layers of graywacke, towards the top of Catskill mountains, and of its subsiding ridges." And on page 93 he once more mentions "the old red sandstone of the Catskill mountains," foreshadowing the adoption of the name Catskill for these red-beds.

Yet to the (page 37) "22. Cornitiferous Limerock" of the valley (our Onondaga) he gives a higher position and says of it (page 38): "It seems to be the most extensively continuous shell-limerock in our district." On page 136 he calls it "(or Second Shell Limerock.)" There are other mentions of the Catskill mountains (pages 89, 151, 152) and Greene county (page 90), especially (page 44): "Whereas the Catskill mountains and their subsiding ridges, which manifestly appertain to the Green Mountain range, are very barren in useful minerals." And (page 45): "I venture to add that the Catskill Mountain graywacke does not cross the Mohawk any where west of Schoharie Kill." (This is perilously like a formation name.)

Adverting further to the age of the graywacke and its associated rocks, and having in mind Diamond hill, he says (page 84): "Do not the limerocks about Hudson and Catskill belong to the transition class, overlay transition sandstone and pass under the Catskill Mountain graywacke? Is not the rock at Catskill, from which so many crystals are taken, transition sandstone? All these localities ought to be attentively examined by the members of the Hudson and Catskill lyceums." (Page 86): "All the graywacke which lies south of the canal, is connected with the Catskill Mountain range."

(Page 87): "The *rubble* graywacke is very common in the vast graywacke district connected with the Catskill mountains. . . . The *red* wacke forms an extensive layer along the foot of Catskill mountain, west and northwest of the village of Catskill, about forty miles southwesterly from Albany. . . . My opinion has lately been confirmed by Prof. Silliman [page 88] and the president of the Catskill lyceum, who examined it in place. See Silliman's Journal of Science." (This reference seems to be to Pierce 1823; see Silliman's American Journal, v. 5, p. 405.)

"Grindstone grit and *hone slate* are very common in the graywacke rocks connected with Catskill Mountains." (The best are said to be at Blenheim, Schoharie county.)

Field classes in geology began with Eaton in 1817 at Williams, and Catskill became one of their objectives. We find his recording (1830*a,* p. 153-54) that he and his students "spent Sunday in Catskill" on June 27, 1830, but that was only one out of many such visits. There is direct mention of our region in every one of his writings that is listed in the bibliography.

Eaton lived to cooperate with (see Eaton 1839) and rejoice over the completed labors of the great natural history survey of New York that he did so much to have established, but not to enjoy the bulky volumes of the final reports. The work that he began of untangling the rocks of our Catskill mountains is now being furthered by the writer, just one hundred years his junior.

Before the state survey was organized, Dr James Eights (1798-1882) of Albany, explorer later of the Antarctic, ran some articles in a short-lived magazine. Accepting the term Carboniferous, inclusive of the old red sandstones, he says (1835, p. 27) of "that magnificent carboniferous group:" "Its eastern origin is along the shores of the Hudson river, from which it stretches out, in a nearly horizontal position, far away into the remote regions of the west, . . . the base of the Rocky mountains." The descent from the Pennsylvania line west of Broome county to the St Lawrence river he describes as "down a series of gigantic steps—first, the great coal measures; next, the carboniferous limestones; then, the old red sandstone; fourth, the graywacke slates, and lastly the transition limestones," showing that he confused the Silurian red rocks with the old red sandstone (see *postea,* page 119).

The most recently indurated rocks of the South of New York [he says] are unquestionably the Coal Measures of foreign geologists. They are of great extent, covering about one-third of the whole State; and passing into Pennsylvania, . . . Their eastern termination is by an irregularly elevated ridge of hills, commencing in the western part of the county of Orange, and extending in a north direction a few miles from the Hudson river, until they reach the county of Albany, including in the range, the whole of what are denominated the Catskill mountains. [This description includes the Hooge berg.]

The greatest elevation of these coal measures [he continues] are the Catskill mountains, whose summits attain the altitude of three thousand eight hundred and four feet, above the tide water of the Hudson river, nearly two thirds of which may with propriety be considered as being occupied by its numerous strata, but in proceeding west, they by no means retain this considerable thickness, for their superior strata appear to have been swept almost entirely away. From this great elevation, in descending along its eastern face, these alterations may be seen projecting one beyond the other, in such a manner as to form a seemingly regular series of steps, plainly exhibiting a southerly inclination, which is distinctly visible, from any elevated situation along the opposite shore of the river, and more particularly so, should their upper surfaces be covered with the snows of winter.

The southerly dip was of course what Eights saw from Albany or Greenbush, and so does not fit the Wall of Manitou.

Mentioning the Blossburg coal field, he thinks (page 28) that no workable coal "can ever be found of the like importance along this northern termination of the coal measures, for I conceive it to be probable, that these beds occupy a situation in the series, much superior to the strata found in our State, with the exception of those at their eastern confines, where the whole series swells out to their entire thickness, and forms the elevated range of the Catskill mountains." (In this, as in the previous paragraph, Eights was of course mistaken as to the horizontality and correlation of the layers.)

Continuing, he says:

From the summit of these mountains, red sandstones may be distinctly seen descending by repeated alternations, each succeeding stratum, becoming gradually thinner and thinner, and finer in its particles, until they terminate nearly midway in the series, and although they very much resemble the old red sandstones of the west, they can readily be distinguished by their organic remains.

This may be a comparison with the Medina sandstone of western New York, which is early Silurian.

In his "notes," Eights (1836, p. 114) describes the "Great Falls" of the Esopus (Glenerie falls) and adds:

It is near this place that the Catskill mountains attain their greatest altitude, being elevated nearly four thousand feet above the tide water of the Hudson river, and the whole mass is unquestionably constituted by the millstone grits and shales of the true coal measures of foreign geologists. The upper stratum, and that which forms the summit of the mountain, is a coarse conglomerate of great thickness, [on "red sand-stone," while lower is "grauwacke slate"].

On page 115 he speaks of the "gritty clay-slate" (our Esopus shale), occurring in the bed of the Esopus and containing "a multitude of cock-tails," which caused Mather (1843, p. 342) and Vanuxem (1842, p. 127) to refer to it as the "cocktail grit of Dr Eights." A woodcut section from the Catskill mountains to the Hudson river at Glasco is given by him (page 116), and later (page 147) he speaks of the plant fossils "so abundantly to be met with in ascending the zigzag road, to the mountain house of Pine Orchard, from below." (See figures 5 and 6 of Chadwick 1936.)

The geological (and natural history) survey of New York was organized in 1836, following a report to the Legislature by John A. Dix, secretary of state, who gave a list of papers published to date in Silliman's Journal (American Journal of Science) on the geology of New York, and Lieut. William Williams Mather (1804-59) of West Point was assigned to cover our district. Other survey members whose names concern us are Lardner Vanuxem and James Hall, the latter entering the ranks in 1837 and becoming the renowned state geologist for a period of over half a century after the close of the survey.

Mather's first annual report (1837, p. 64) mentions only (so far as we are concerned) the occurrence of limestone for lime and hydraulic cement in the "Helderberg and Catskill Mountain ranges." These first reports were reviewed by Professor Chester Dewey (1837). Mather's second report (1838, p. 166) interests us only for his account of Becraft's mountain, Hudson. He speaks of "The lower beds of limestone of Becraft's mountain," meaning the Manlius; "The middle beds of Becraft's mountain," meaning the New Scotland, and says: "The upper beds of limestone in this mountain, are distinctly crystalline," referring to our present Becraft limestone.

From this beginning of real discrimination of geological formations in New York, five years of work by the survey gave us that elaborate succession of rocks in the "New York series" which immediately became the pattern for the rest of the country and which has so marvellously stood the test of time. Upon what slender basis the survey had to build is evident in the quotations above given at some length chiefly because they are comparatively inaccessible today, but also to emphasize the strides that were made in each successive annual report of these men.

In the third report, Timothy Abbott Conrad (1803-1877), paleontologist of the survey, gave (Conrad 1839, p. 62-63) an inchoative classification of our "transition" (that is, Paleozoic) rocks, the Devonian not having then been distinguished from Silurian and Carboniferous, which may be summarized briefly (see Merrill 1902, table). Below the "10. Carboniferous strata, (in Pennsylvania)," he groups all the rest as "ROCKS OF NEW-YORK" in four divisions: "Old Red Sandstone Group, (Murchison.)" "Medial Silurian strata." "Lower Silurian strata." and "Cambrian System, (Sedgwick.)" These are pretty closely what the survey later called respectively the Erie division, Helderberg and Ontario divisions and Champlain division, with a long belated recognition of the Cambrian. Under the highest, with a subhead *"Old Red Sandstone?"*, he has "9. Olive sandstone, (organic remains undetermined, except a few land plants, very rare,)" which is possibly our Ashokan, and "8. Dark coloured shales" of which the fossils listed are plainly Hamilton forms, and "Black slate" with "Posidonia" which is the Marcellus.

Under the medial Silurian come "7. Gray Brachiopodous sandstone, Helderberg sandstones, Helderberg limestones, Second Pentamerus limestone" tabulated and followed by their diagnostic fossils; these show an inversion of order of the first three, the brachiopodous sandstone being the Oriskany and the Helderberg sandstones the Esopus (and probably our Schoharie), while the Helderberg limestones have a bare sprinkling of Lower Helderberg species in a goodly list of Ulsterian (Upper Helderberg) fossils, chiefly of the present Onondaga limestone. The last member is Lower Helderberg. Then (page 63): "6. Gypseous shales" now Bertie and Camillus, "Rochester shales," with no mention of the Lockport limestones, and "Pentamerus limestone" which is Clinton, together with "5. Green slate, lenticular iron ore, &c." "4. Niagara sandstone, (red)" which is the Medina.

In the lower Silurian: "3. Salmon river sandstone, (olive)" with Lorraine fossils, and "Green slate" with "Agnostis pisiformis" which he wisely qualifies with the statement: "The position of this rock with Agnostus was determined by Mr Vanuxem," for (see change to *A. latus* in Conrad 1840, p. 201) it belongs up in the Clinton group. Then "2. Gray crinoideal limestone" (with the fossils of the next), "Trenton limestone and slate," "Mohawk limestone" now Black River group, "Gray limestone with sparry veins" meaning calcite, now

Lowville, "Gray calcareous sandstone" later the "Calciferous" or Beekmantown in its broad sense.

What interests most is what Conrad at this early day put in the Cambrian, as not adequately shown by Merrill (1902), namely "1. Olive sandstone and slate" with *"Fucoides serra,* (Brong.)," a graptolite of the "Quebec group" and of the Deepkill "Hudson River" beds of New York (Ruedemann 1904, p. 655); "Variegated sandstone, (Potsdam sandstone of Emmons,)" with *"Dictuolites radians"* (unidentified). The inclusion of Hudson River rocks in the Cambrian was no accident. On page 57, after stating that the Cambrian and Silurian systems are unconformable in Europe, Conrad says: "The upper term of the Cambrian system may be recognized in the vertical and contorted slates and olive sandstones of the Hudson river, extending from Newburgh to Glen's Falls." Again: "Over the highly inclined strata of the [page 58] Cambrian or Hudson system, rest in a nearly horizontal position the Silurian strata," and: "In the report of the geologist of Pennsylvania, the olive sandstone of the Cambrian or Hudson strata, has been confounded with the fourth rock of the Silurian system, known by the name of Salmon river sandstone, which formation is admirably characterized in New-York, Pennsylvania and Ohio, by the *Pterinea carinata* of Goldfuss."

Conrad describes (pages 64-66) from other localities some new species that are now known also from our area.

In the same volume, Vanuxem (1839, p. 272) says that "the water lime group of Manlius, . . . well characterized by its fossils," is "found from the Hudson to Cayuga Lake"; adding in the next report (Vanuxem 1840, p. 376), where he calls it the "Manlius water lime group," "I have traced it . . . to the hills in the rear of Hudson. It affords the most profitable limestone for burning of the whole series of limestone rocks, . . . requiring less wood to calcine a given measure . . . From Cayuga to Hudson river, kilns are arranged by the sides or upon the top of this rock." The Hudson reference is to Becraft's mountain.

This fourth annual report holds much on our region. Dekay (1840, p. 18-19, 26) lists fossil mammals. Professor Lewis Caleb Beck, chemist, and mineralogist of the survey, describes (Beck 1840, p. 40, 52) the quartz crystals of Diamond hill and along the Canajoharie and Catskill railway in Austin's glen, with other minerals from the Normanskill strata; also (page 60) gypsum at Hudson and (page 68) calcite on the railway in the glen, with a list of other minerals in Greene county and analyses of marl from near Catskill and of Lower Helderberg limestone from Austin's. Conrad (1840, p. 204-7) describes further species from elsewhere that occur here too, and especially (page 206) *"Pleurorhyncus cuneus"* (now *Conocardium*) of which he says: "This is the fossil well-known as the bilobite, which is a crushed specimen."

In the same fourth report, Mather (1840) gave about six pages to our rocks and their local exhibition, under the headings "Hudson River Slate group, Helderberg group, Catskill Mountain group and tertiary and alluvial formations." He describes the first (page 212) as "consisting of slates, shales and grits, with interstratified limestones, all of which occur under various modifications," and says: "This group is overlaid unconformably in many places by the various rock formations of more recent origin." Further (page 257): "The Hudson slate group corresponds in many respects with the 'Cambrian system' of Professor Sedgwick, to which it may be a geological equivalent. . . . From Kingston, the Hudson slate group ranges along the right or western bank of the Hudson to Albany, underlaying the superincumbent rocks unconformably, with few exceptions." Coal had been sought in it (page 256) at Coxsackie.

Of the Helderberg group, which he describes (page 212) as "composed of various strata of common and hydraulic limestones of various colours and textures (enclosing a great variety of fossil remains), interstratified with grits and shales," he says: "It includes the limestones of the Helderberg, of Schoharie, Saugerties, Kingston, . . ." and (page 236) that it skirts the Catskill Mountain rocks "in a parallel zone, and underlies them, it is supposed, through their whole extent," while it extends from New Baltimore "southwardly, by Catskill and Saugerties, to Rondout." On page 238: "Near New Baltimore, Coxsackie and thence on by Catskill, . . . the principal masses of this formation are similar to those of Becraft's mountain, near Hudson and contain the pentamerus limestone, tentaculite limestone and water limestone. In some places the sparry limestone and shale are found in addition to the preceding, which are the principal extensive strata of this formation, in the district under examination this year." The names used denote respectively the Kalkberg-Coeymans, Manlius and Rondout; the Becraft and Catskill limestones of our map. As uses for these rocks Mather gives building stone, marbles, common lime and hydraulic lime.

His comments on structure (of the Helderberg rocks) are brief. (Mather 1840, p. 213): "from Kingston to Coxsackie, the rocks are upheaved, and sometimes overturned." (Page 241): "The cement beds and overlying limestones, up the valley of the Rondout, (and in fact north to New-Baltimore), are very much broken up, upheaved, overturned even, and contorted very much."

Mather's discussion (1840, p. 212, 213, 227-28) of the Catskill mountain group or series has been reprinted in Museum Bulletin 307 (Chadwick 1936, p. 7-11) except the following portions. After delimiting the group to "the high mountain region of Greene, Ulster" and adjacent counties, he goes on to say (page 213): "The streams flow in deep valleys which seem to have been formed by erosive action, since the strata in most instances correspond on the opposite sides of the valleys. There are some exceptions, where there are indications of great fractures and rents of the strata, which traverse the country for many miles, and give direction to the streams." Does this refer to the supposed keystone fault valleys? He adds that the soils, though good, are laborious to bring under cultivation in the heavy timber.

His account of the minerals in cornstone (see note 5, page 121, *postea*), following his statement (page 228) that the group is barren of useful minerals, is incorporated into his final report (1843, p. 314), which is on the shelves of most libraries.

Under the head of "Flagging stones, grindstones &c." Mather (1840, p. 231) says: "The only rock of the Catskill mountain series that is applied *extensively* to useful purposes, is a bluish gray slaty sandstone which is quarried as a flagging stone." Saugerties and Bristol (Malden) are mentioned among shipping points on the river. (See Mather 1843, p. 318-19 for the rest.)

"The tertiary and alluvial lands," Mather says (page 213), "are level or with small hills. The former are generally terraces of nearly level land, at an elevation of 10 to 150 feet above the streams in the valleys." Under "Alluvions" (page 214) he lists "those of the Esopus creek . . . to near the Esopus Falls; those of the Catskill and Katerskill creeks; and the Schoharie flats" which he says "have long and justly been celebrated for their exuberant fertility." Speaking of the mud flats along the river, he remarks (page 215): "The most extensive and important of these alluvial flats may be classed as *deltas* on a small scale and they extend some distance above and below the mouths of the Rondout, Esopus and Catskill creeks."

From the clays of the "tertiary" (page 226): "Bricks are extensively manufactured in Greene and Ulster counties. The principal places of this manufacture are Coxsackie, Athens, Glasco, Catskill &c. and the average aggregate number made in these two counties may be estimated at 20,000,000 of bricks per annum." A further paragraph covering the "range" of the clay past these localities is reproduced in Mather 1843, page 131, and a mention of a sulphur spring (page 257) in 1843, page 93.

In the fifth (last) annual report Mather (1841, p. 66-67) gave further account of the progressive filling up of the Hudson with alluvium (see Mather 1843, p. 4-5), and (pages 72-73) of the glacial and postglacial deposits of the Hudson valley, correcting his former reference of the clays to the tertiary and correctly assigning them to an age between the tertiary and the alluviums, though not using the name Quaternary for them until 1843. His lengthy description of the Catskill Mountain series is mostly copied in Museum Bulletin 307 (pages 12-20) or repeated in 1843 (pages 302-7, 313, 316, 318-19), while the latter (pages 351-52, 368-69, 394) contains the essence of his remarks on the lower formations.

"A line of fracture and anticlinal axis," he says (page 64), ". . . passes near Kingston, thence on by the falls of the Esopus creek (half a mile east of them,) by Saugerties, along the ridge between Catskill village and the Katerskill creek on the road to the Mountain House; near Madison three miles northwest of Catskill; four miles west of Athens; . . ." And further: "On the west side of this axis of fracture and elevation, the rocks dip to the westward at variable, but generally at small angles, while on the east side, they dip at a high angle to the eastward and are frequently vertical in their stratification." In a footnote he speaks of "a great variety of curious contortions of the rocks." Madison is now Leeds, N. Y.

In this volume, Conrad (1841) reported Calymene Blumenbachii (page 38) from "the grit slate of Eaton" (now the Schoharie shaly limestone) "at Col. Clarke's, near Saugerties." The rock named is number 18 of his more complete but still faulty table of Silurian formations on page 31. The name Devonian seems here (page 41) to make its first appearance in these reports, including only the old red sandstone, and Conrad now writes (page 43) of the Carboniferous: "This system is not known to be represented within the limits of New York, unless it be on the summit of the Catskill mountain." On page 47 he lists it as among those that are wanting. He describes about 60 new fossils, (pages 48-57), of which a number occur also hereabouts, and particularly (page 55) two "Oriskany sandstone" (Glenerie limestone) forms from "near Saugerties," namely *Atrypa* (now *Leptocoelia*) *flabellites*, as "abundant," and *A.* (now *Plethorhyncha*) *pleiopleura*.

The great tomes on the natural history of New York followed, namely, for earth-science: Beck 1842 on the minerals, Dekay 1842 on zoology but with fossil mammals and a list of fossil fishes included, Vanuxem 1842 on the geological district to the west of Mather's but with matter bearing on our area as quoted or alluded to beyond, and the geological map of the State (New York Geological Survey 1842; a second edition in 1844); then Mather 1843 on our district. Contemporaneous with the last was the paper of the brothers Rogers (1843) on the Appalachian folds to the southwest. Then came Emmons 1846 on the rocks and soils of New York. From this point onward it is unnecessary to dwell on more than the outstanding contributions; the others will in most cases merely be listed. Many titles included in the bibliography of Museum Bulletin 307 (Chadwick, 1936) and which have no further special bearing, are omitted entirely.

There followed a breathing spell while the world digested these herculean labors, broken only by Emmons (1854, American Geology) and Marcou's map (1855) of the geology of the United States and Canada. Emmons says (1854, p. 29): "The Hudson river runs upon a line of fracture which extends from New York to Montmorenci in Canada East, Lake Champlain being a wider and deeper fissure than that along which the river flows." Announcement of this great overthrust is generally credited to Logan, of Canada, in 1863.

In 1858, Dr John J. Bigsby, an Englishman, gave an extended review of New York geology and in the same year Professor Andrew C. Ramsay, later director of the geological survey of Great Britain, described glacial features of the Hudson valley and Catskill mountains, giving a map of the striae in the vicinity of the Mountain House and a section of the Kaaterskill clove "below the Falls of Catskill, showing boulder-drift covering its sides." (For Hall's mention of his visit see Bulletin 307: 51.)

Publication of the Paleontology of New York by James Hall was already actively under way. In 1859 appeared the great volume on the Lower Helderberg and Oriskany fossils, with plates bound separately, and including many mentions of localities within our area where the given species had been found; but more important is the review of the geology of New York and all eastern North America constituting the 96 pages of Introduction. (The distinction between Lower and Upper Helderberg had been made by Hall in 1851.) This was followed in 1861 by Lincklaen's summary (museum guide) of the stratigraphy of New York. Each of these marks progress in knowledge of the rocks of our area. Minor papers are those of Hunt 1864, Dwight 1866.

The brachiopods of our middle Devonian appeared in the next volume of the Paleontology (Hall 1867); then a compendium of all Silurian fossils by Bigsby (1868), and in 1869 the large scale map of Canada and adjacent states by Logan and Hall. Vigorously working on our fossils, Hall put out in 1874 the descriptions of bryozoa and corals of our Lower Helderberg, the figures not issued till 1879 and the whole volume in 1883, and another (very rare) book of plates of middle Devonian corals in 1876. In the latter year there was a paper by Rossiter W. Raymond (1876), on the Burden iron ore; in 1877 came the first edition of S. A. Miller's compendium of American Paleozoic fossils and in 1878 Bigsby's of all Devonian fossils.

Callaway (two titles, 1878) was an English professor temporarily at the State Museum, bringing English ideas to bear on our rocks and their correlations. Sherwood's section (1878) of our red-beds was based on a suite of specimens deposited at Albany which was discarded when the Museum moved into the Education Building. The year 1879 saw another volume (plates separate) of the Paleontology (Hall 1879), comprising the middle Devonian univalve molluscs, and the first edition of Macfarlane's geological railway guide. The miniature folding of our limestone belt came as a new discovery to Professor Nathaniel Southgate Shaler (1879) of Harvard University, who at about that time, in conjunction with Professor William Morris Davis, his colleague, began bringing geological parties to Catskill. Davis's papers are mentioned shortly.

The influence on geological thought of Professor James Dwight Dana's great "Manual of Geology" has not been noted in these pages. Dana fell heir at Yale to Silliman's mantle, having married Silliman's daughter, and became the leading geologist of our country. His manual went through five editions, in 1863, 1864, 1875, 1880 and 1895. The 1880 edition (denominated the "third") still holds pretty closely to the nomenclature and classification of the earlier ones, as far as our region is concerned, and still puts the Lower Helderberg and Oriskany in the Silurian, where Hall had them in 1859. In 1880 came Guyot's important paper on the altitudes and physiography of the Catskills, pointing out the peculiar cross-direction of the ranges, the unsymmetrical development of the spur-ranges on west side only, the abnormalities of drainage and the suggestion of what we would now call a peneplain in the decline in both directions of their summits from a ridgepole of the three highest peaks (see pages 229 and 232). A short paper by Julien was published in 1881.

Davis's paper of 1882, the first working out of our folded structures, was epochal and was followed by three other illuminating articles in the next year that focussed attention on the marvelous development here of Appalachian tectonics and physiographic types in convenient compass, with a concentrated cross section of nearly the entire New York series of the Paleozoic, and brought the world to our doors.

In 1883 also, Hall on bryozoa and corals (two titles) and the second edition of Miller's fossil lists preceded the appearance (1884, 1885) of Hall's two volumes of the Paleontology comprehending the middle Devonian bivalve molluscs and completing volume V (in four covers). Beers (1884), partly written by Henry Brace, included various pages on local geology. Smock (1885) raised the question of local glaciers in the Catskills. In 1887 Hall brought together his accounts of the corals and bryozoans of our Lower Helderberg and of middle Devonian bryozoans, in volume VI of the Paleontology. A paper by Hinde (1887) is on a fossil sponge, abundant in our Kalkberg limestone and higher.

Dr John Mason Clarke, Hall's equally illustrious successor, collaborated in volume VII, appearing in 1888, in which year Professor Ashburner of Pleasantville, Pa., the oil and gas expert of the survey of that state, gave a summary of the rocks and their thicknesses in our mountains and the log of a deep well drilled (unsuccessfully) for oil near Cairo.

Then came (1889) Clarke's important paper (with a second one in 1891) opening up the question of the Devonian age of our Lower Helderberg rocks, instead of their being Silurian as so long regarded, a proposition that gained favor but is now being reexamined; in the same year, Newberry's monograph of fossil fishes, largely from other parts of the country, Ward's long compilation on fossil plants, including "fucoids" and the Bilobite of Dekay, the new enlarged compendium of Miller, and Upham's discussion of mountain glaciation appeared, with Hubbard's first mention of the pothole at Church's opposite Catskill; in 1890, Beecher, Kimball, Smock, the second edition of Macfarlane (inaccurate as to the Catskill Mountain Railway, supplied by W. B. Dwight); in 1891, Beecher, Hall, Prosser, Clarke's second paper on the Lower Helderberg as Devonian, and Ries (two titles) on our clays.

In 1892, Beecher announced the finding of the Oriskany (later the Glenerie) at Becraft's mountain, giving a list of fossils by Doctor Clarke; there also were papers by A. H. Cole and W. M. Davis, and Miller's first appendix to his compend. More important were Darton 1893, Hall and Clarke 1893, Willis's great work in the same year on the manner of formation of folds such as we have in our limestones (no local mention). Darton's two reports in 1894 have much on our area and it is worthy of note that with Nelson Horatio Darton of the U. S. Geological Survey and Professor Heinrich Ries of Cornell we come to the first names of men now living who have worked in our quadrangles. Both made lasting contributions. Nason's report (1894) accompanied Darton's. There was a popular article by Ingram (1894) on flagstone quarrying and McGee's large geological map of New York State, an enterprise long awaited and eagerly welcomed, in which the state and federal surveys c operated.

In 1895 the new (and last) edition of Dana's manual put the Oriskany into the Devonian and reflected the newer thought of the red-beds in our mountains as a facies rather than a formation. Instead of deposits of a lagoon, estuary or fresh-water lake (as previously they had been considered), Dana now calls them "sea border deposits," which was a step ahead of calling them marine as he did in 1880 (page 290), and it is specially worthy of note that he extended them down into the Hamilton (pages 576, 603). There is also Bather 1895.

In 1896 Darton called attention to stream piracy in the Kaaterskill and Plattekill cloves. Ries (1897) also referred to the Hamilton the red shales near Cairo Roundtop used for paving brick manufacture in the newly opened shale-brick plant at Catskill. Paleontological papers in that year include Girty 1897, the second appendix to Miller, and Schuchert's synoptical index to our fossil brachiopods. Merrill's bulletin 19, in 1898, with its wealth of illustration, a glorified and modernized edition of Lincklaen's guide, was unfortunately soon out of print. The report by Prosser (1899) and the bulletin by Ries (1899), the papers by Eastman and by Grabau, and Clarke's handbook (1899) all concern our area, but are overshadowed.

For late in that year, with the turn of the century, came Clarke and Schuchert's epoch-making, sweeping revision of our stratigraphic nomenclature and classification, immediately republished in Clarke's memoir (1900) on Becraft's mountain; in 1900 also, Nickles and Bassler, Osborn, Schuchert; in 1901, Brigham, Clarke, Ries and the greatly improved new geological map of the State (not yet superseded) compiled under F. J. H. Merrill, the new director of the state museum after Hall's death, and explained by him (Merrill 1902) with a summary of the history and evolution of the study of New York strata; in 1902 also, two papers by Clarke, now state paleontologist, and one by Ulrich and Schuchert explaining by an ingenious theory of barriers and basins (troughs) some things that we now understand as due to facies. The year 1903 has Clarke (three titles), Dickinson, Grabau, Hartnagel, Prosser, Schuchert, Upham, van Ingen and Clark, and Whitlock, the most novel of these being Hartnagel's determination of the "Coralline" (Cobleskill) limestone as of Cayugan instead of Niagaran age.

In 1904 came Grabau (two titles), Jackson, New York State Museum, Peet, Ruedemann, Ulrich and Bassler; in 1905, Clarke, Hartnagel, Rafter, Talbot, Upham and particularly Woodworth. (In 1905 also began the long series of annual bulletins by David H. Newland, later with Hartnagel, on the mining and quarry industry of New York, not included in the bibliography chapter.) Grabau's work in 1906 contains a good deal on our area and is useful locally for its figures of the characteristic fossils of the various formations. In that year, John Lyon Rich announced his discovery of an indubitable local glacial circ and moraine in the Catskills, west of Prattsville. Clifton James Sarle, 1906, showed the burrow nature of the supposed algal plant (fucoid) *Taonurus cauda-galli* of our Esopus shale and opened a new field of thought concerning many so-called fucoids. George P. Merrill's indispensable history of American geology came out in the same year. The eminent mineralogist, Samuel Lewis Penfield of Yale University, a native of Catskill, passed away in his prime; his biography was published by Miers, 1907.

In 1907, besides Eastman's memoir, appeared a paper by Professor Angelo Heilprin of the University of Pennsylvania accompanied by a beautifully engraved map reduced from the topographic sheets (American Geographical Society 1907), on our Catskill mountains. This map is still purchasable in New York or Catskill.

In 1908 came Berkey, Chadwick, Grabau, Ruedemann, Salisbury and Atwood; in 1909, Clarke, Cook, Grabau, Grabau and Shimer; in 1910, Chadwick (two titles), Schuchert, Whitlock; in 1911, Berkey, Merwin, Rich, Ulrich; in 1912, Berkey, Chadwick, Clarke (two titles), Clarke and Ruedemann, Grabau, Hartnagel, Stevens, Willis. Many of the above are large and important works but with little local matter.

The most illuminating paper of the period was Barrell's (1913) on our great Devonian delta, which gave an entirely new slant to the whole problem of the red-beds. The same year has Chadwick, W. B. Clark, Eckel, Grabau; in 1914, Brigham, W. J. Miller; in 1915, Bassler's index of fossils, Clarke (three titles), Collison and Barker, Grabau, Prosser and an interesting paper by Rich, himself a native of Hobart in the Catskills. Two more papers by Barrell in 1916 developed further his invigorating new concepts of our upper Devonian. In the same year came Brigham, Chadwick, Johnson (not local), Newland; in 1917, Barker and Baer, Barrell, Bowles, Elston (not local), Johnson, Rich (three titles); in 1918, Clarke, Fairchild (two titles), Rich, Stansfield (not local), van Tuyl (not local); in 1919, Fairchild, Robert Weeks Jones.

In 1920, besides Bucher, Merwin and George F. Wright, there was Daly's paper on the bulge peripheral to the great ice sheets, a concept long held in Europe but slow of headway here; in 1921, T. H. Clark, John M. Clarke, two papers by Miss Goldring, Grabau's textbook with local matter, Lobeck's clever diagram-map, Newland's mineral resources of the State; in 1922, Cook, Davis, Goldring, Hartnagel and Bishop, Reid; in 1923, Miss Goldring.

John H. Cook's paper (1924) emphasized the stagnation of the glacial ice sheet in its final waning; in that year, also came Miss Goldring, Grabau, W. J. Miller; in 1925, Bancroft, Barrell, the Crosbys (father and son) on keystone faults, Fairchild, Goldring, Schuchert; in 1926, Coleman, Dorsey, R. W. Jones; in 1927, Chadwick, Goldring, Percy W. Raymond, Schuchert; in 1928, Alling, Chadwick, Fenneman; in 1929, Adams, Fairchild, Burnett Smith; in 1930, Cook, Fenneman, Grabau, Hubbard and Wilder, Leverett, Ruedemann, Schuchert's important paper, Ulrich and Ruedemann (1931).

In 1931 were Chadwick, Fullerton and Cox, Goldring, Ruedemann; 1932, Chadwick, Fairchild, Lobeck, Ruedemann (two), Schuchert and Longwell, Ver Wiebe; 1933, Berkey, Chadwick (five), Kay, Longwell, Mackin, Newland and others, with two important papers by Dr Gustav Arthur Cooper of the National Museum; in 1934, Bassler and Kellett, Bassler, Fenton, Pepper, Rich, Ruedemann; 1935, Ashley, Chadwick (eight), Cook, Cressey, Goldring, Henderson, Parks, Ruedemann, Willard, Robin Willis, and Rich's great bulletin on the glacial geology of the Catskills.

In 1936 came Chadwick (N. Y. Mus. Bul. 307 on the name Catskill in geology), Cooper, Meyerhoff and Olmsted, A. K. Miller, Parks, Rich, Ruedemann and Wilson, Zodac; and in 1938, W. Storrs Cole, Fenneman, Grabau, Mackin, Meyerhoff and Olmsted, Ruedemann, Swartz, Wilmarth. See addenda (to 1942) on pages 233 and 234.

The principal topics of debate at the present time in our area are physiographic and glacial—the evolution of our drainage pattern, the number, location and age of the peneplains, the extent of late Wisconsin local glaciation, the manner in which the ice departed from our terrane, the history or existence of "Lake Albany," the effect of the hypothetic peripheral bulge—but also the times of mountain making, the significance of the breaks in the stratigraphic succession, the levels at which we should draw period and epoch lines, the precise correlations in what is herein called the Rondout, while in the mountains the whole subject of formational boundaries and their tracing is still wide open. Petrographic study of our sediments has but just begun. The preglacial courses of our streams are almost unknown. The search for fossils and fossiliferous horizons is far from complete. New problems await discovery. The geology of a region is never finished.

THE ROCK FORMATIONS

The Silurian and Devonian bedrocks of our quadrangles are all sedimentary, that is to say they are water-laid deposits, and consequently they are distinctly stratified or in regular layers. Moreover, with the exception of the upper part, namely the flagstones and red-beds, at the west, they are all marine; that is, they were deposited in salt water and they contain fossil remains of sea animals not unlike some of the smaller ocean creatures of today. The highest members, the red-beds and flagstones, contain land plants, besides shells peculiar to fresh waters and fresh-water or anadromous fishes, only; from which it is clear that they were laid down in the open air—are "continental" deposits.

Twenty divisions or "formations" are now recognized by name in the Silurian-Devonian succession of our map area, though but 16 colors have been employed on the map to represent them, chiefly because of the thinness of some of them in the valley or of the still rather indefinite limits of the newly defined members in the red-beds of the mountains.

The complete list, in proper order with the highest at the top, is:

DEVONIAN	Upper	Katsberg sandstones and red shales, with Stony Clove gray flagstones at base	
		Onteora puddingstones, flags and red shales	
	Middle	Kaaterskill sandstones and red shales	
		Kiskatom red shale, with flagstones	
		Ashokan gray flagstones and olive shales	
		Mount Marion shales and sandstones	
		Bakoven black shales	
		Onondaga limestone	
		Schoharie mud-limestone	
	Lower	Esopus shale	
		Glenerie limestone and cherts	
		Port Ewen limestones, with Alsen cherty limestone member at base	
		Becraft limestone	
		Catskill shaly limestone	New Scotland beds
		Kalkberg cherty limestone	
		Coeymans limestone	
SILURIAN	Upper	Manlius (Olney) limestone	
		Rondout waterlime (Fuyk sandstone locally) with Glasco limestone lentil near top	

These beds will now be described, beginning with the oldest, or bottom, ones. Their total thickness on our quadrangles approximates eight thousand feet. This means that the waterlimes exposed in the Kalk Berg front must go four thousand feet below sea level under

Hunter mountain. It means also that at least these eight thousand feet of strata, perhaps an additional one or two thousand feet, once extended eastward over the sites of the present villages of Catskill and Saugerties, and of the city of Hudson.

1 RONDOUT WATERLIME

To speak of the Rondout formation[1] in our area under its established name of waterlime is to tell but a fraction of the story. Over a considerable section of its local outcrop it is a massive sandstone (figures 11, 15), running as high as 94 per cent of silica in some exposures. Through a long stretch, also, its conspicuous member is a highly fossiliferous and attractive "coralline" limestone ledge (figure 14), formerly mistaken for the Cobleskill limestone.

As variable as its lithology is its thickness. Entering our map-area from its type region around Kingston, it is thicker than there and can not be far short of 40 feet though exposure of both top and bottom contacts is lacking. Three miles north it has seemingly decreased to not much over 30 feet, which thickness it appears to maintain past Saugerties nearly to West Camp. In the unbroken section at Cementon, where route 9-W goes under the cable-bucket line, there are almost 30 feet, which is thought to be essentially the whole thickness although neither the soft Normanskill shale below nor the Manlius paper shale is here seen in contact. Thence north the loss of basal beds is marked, as the sands replace most of the limes. Beyond the Red Schoolhouse, where about five feet of very fossiliferous limestone (absent to north) is overlaid by still nearly 20 feet of Fuyk sandstone, the thinning of the sandstone is more rapid, so that within a mile it has almost ceased exposure. At the north end of this syncline the whole Rondout is not much over five feet thick, less than two north of Cauterskill and only six or eight feet as it goes off the map.

This variability is in keeping with its origin as the deposit of an encroaching sea transgressing over an eroded land-surface of older rocks. The distribution of the sandstone member (Fuyk sandstone) suggests that that is precisely a wave-built sandbar and the comparative absence of marine fossils on its lee (east or landward) side in contrast with their exceptional abundance on its wave-swept outward slope is consonant with the idea of lagoons hemmed in behind it. The northward extension of such thin and barren stuffs around the Helderberg front accords further with the inferred conditions. Only as we go west again across Schoharie county does the Rondout (Chrysler) resume its normal thickness and aspect, with marine fossils, though without return of the organic reefs that margined its southeastern shore. Landward, behind the strand, it is a dirty and variable deposit of small bulk.

As might be expected, exposures of this thin formation, tucked away beneath the massive Manlius cliffs and overmasked by their talus, are infrequent in the north part of the quadrangle (figures 12, 13). Farther south, the Fuyk sandstone and the Glasco limestone lentil make at times outstanding ledges, crags and terraces over the rest of the map area. The most notable long gap is between a mile north of Schoentag's, on route 9-W, and Fera's hill east of Katsbaan Church, five miles throughout which the Rondout outcrop goes under sands or clays except for the crest of one close-pinched anticline of Glasco limestone on the north corporation line of Saugerties village, midway.

The passing motorist on route 9-W can see the whole thickness (10 feet) of the massive Glasco limestone and something of the few feet of waterlimes above it up to the ledges of Manlius, on the west of the highway north of Schoentag's from the big old quarry northward behind the chicken-yard at West Wood farm. Requiring walking but repaying a visit is the Limekiln hill west of Flatbush school, which is rimmed around on all sides by the ledges, under a Manlius cap. This is on route 32. The unbroken Cementon section already mentioned is in the road cut of 9-W at the "aerial tramway." On this highway at the Alsen underpass, in the cut opposite the Alsen railway station and in the hilltop cut beyond the North American cement company, are conspicuous exposures of the Fuyk sandstone where it still has limestone interbeddings. By the roadside, also, is the exposure (Davis 1882, p. 24) at the north end of Quarry Hill.[2]

Two north-south lines a half mile apart will embrace all the heavy sandstone exposed on route 9-W and in the Fuyk, but to match similar sections these lines must be swung five degrees west of north thus widening the belt to nearly a mile. The same direction gives the best matching of sections in the limestones southward, is employed in the construction of figure 11, and may represent the trend of the Silurian shore line hereabouts, as far as the Helderberg front. Curiously, the cleanest-washed, most quartzitic portion of this sandstone occurs on its seaward (west) side where interbedded with purest organic limestone, from Alsen to the North American plant. Here it has been called "Binnewater" by field parties, from a lithologically similar sandstone that underlies all the Rondout from Kingston (Wilbur) southwestward. Our rock is of later age, is not connected

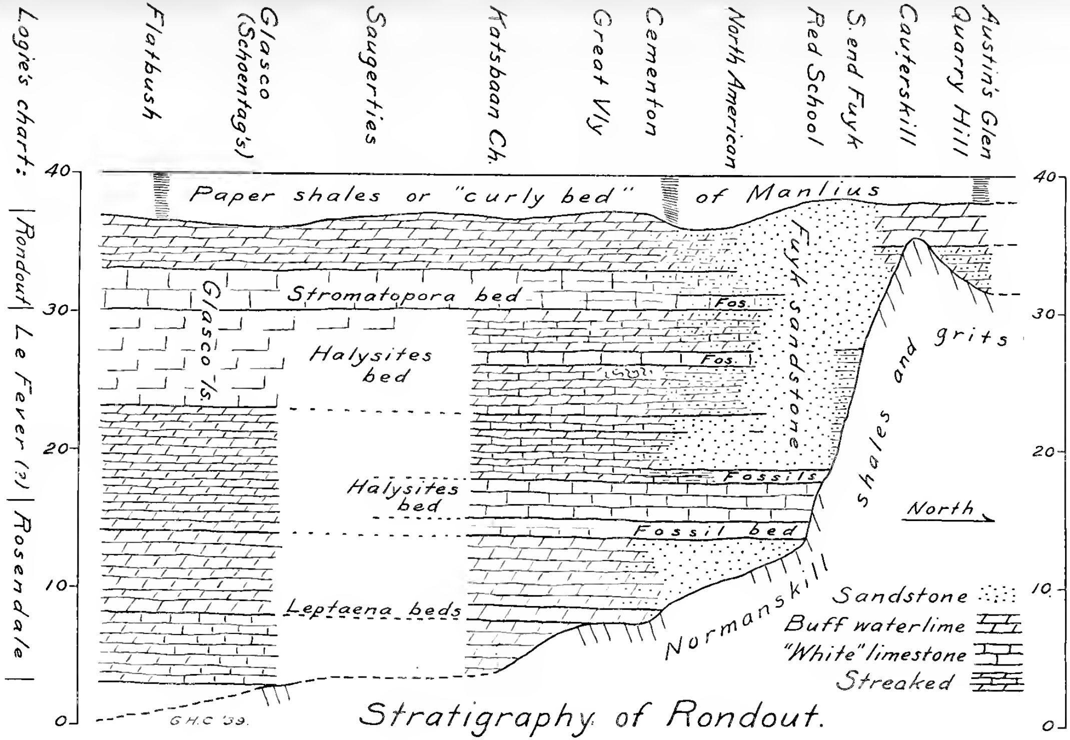


Figure 11 Preliminary correlation chart of the Rondout formation across the Catskill quadrangle, based on the mostly imperfect and unsatisfactory sections and exposures. Vertical sections accurately drawn to scale; horizontal spacing as projected north 5° west, in the direction of the Fuyk sandbar, which brings all sections into harmony. Only uppermost beds exposed past Saugerties. Logie's identifications approximately given in left margin.

Figure 12 Rondout waterlime and higher strata on Cats kill in Austin's glen, to right of figure 58. Shows two fault-wedges of hackly (upper) Rondout in foreground, overthrust by Rondout sandy layer topped by third slice of the waterlime, behind the shrub. A fourth wedge of Rondout concealed beyond, beneath heavy Manlius, which crosses the creek. Distant cliff is New Scotland; see figure 25. Looking northwest. Photo: April 1921, Edith Nusbickel.

Figure 13 Part of an S fold in sandy (lower) Rondout, just to right of figure 12, enwrapping horizontally bedded soft Normanskill shale. Hackly waterlime wedges of figure 12 down left. Just under camera, middle limb of fold is overturned nearly 200°, then rolls back to cross creek at figure 58. Manlius does not participate in this contortion. Looking west of north. Photo: August 1912, H. L. Fairchild.

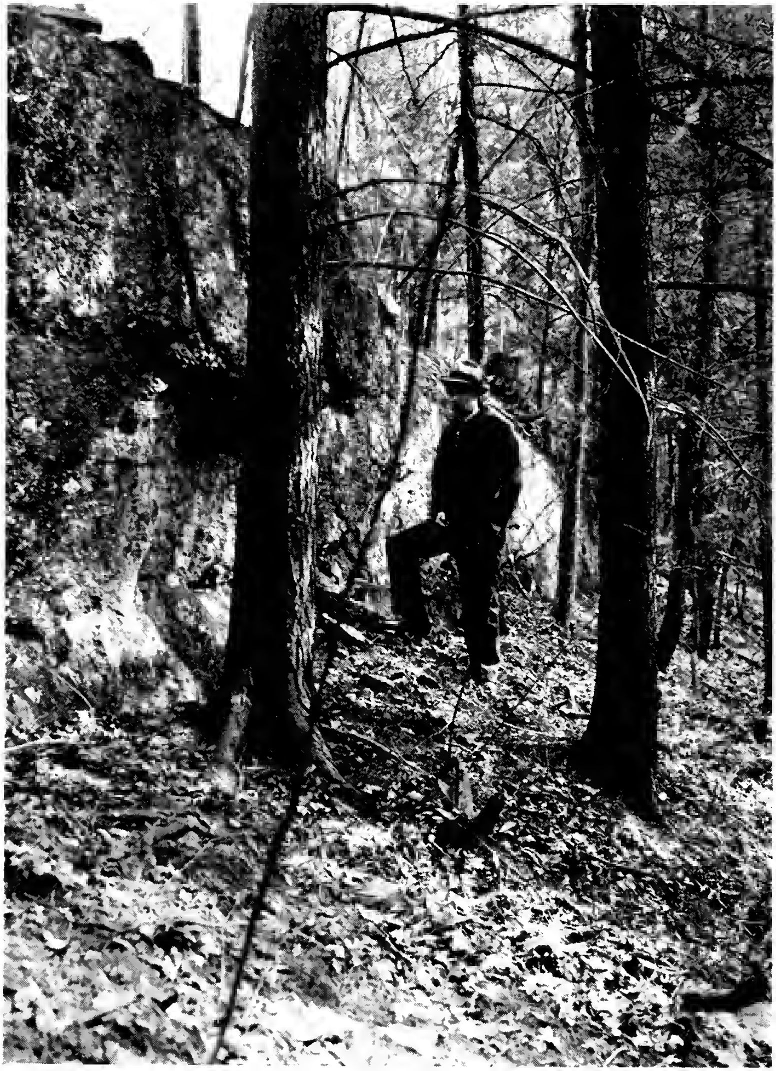


Figure 14 Rondout (Glasco) limestone on west slope of Limekiln hill, Flatbush, two miles south by west of Glasco. A major joint face on this reef rock full of corals and bryozoans. Mr Kilfoyle gives a measure of thickness. Looking south. Photo: April 1938, W. J. Schoonmaker.

with the Binnewater and is here called the *Fuyk sandstone* from the fine ledge of figure 15 overthrust on the west ridge of the Fuyk, west of Catskill (Chadwick, 1927).

The diagram (figure 11) shows the inaccuracy of trying to apply the name Le Fever to the limestone lentils in our area. Mr Logie's chart indicates that that limestone lacks continuity with these across the Rondout area nor do they agree with it in vertical limits. Therefore, to the conspicuous ten-foot ledge seen at Flatbush and Schoentag's (Glasco) the name *Glasco limestone* (lentil) is here applied, with type exposure on the West Wood farm, route 9-W, west of Glasco.

The unconformable contact of the Rondout on the Normanskill is described in a later chapter, with the localities where it may be observed.

Awaiting Mr Logie's monograph on the Cayugan rocks and fossils of New York,[3] it is probably safe to record at present the following species from these Rondout limestones in our quadrangle:

1 the ostracod, *Leperditia jonesi;*

2 the trilobites, *Corydocephalus ptyonurus* and *Calymene camerata;*

3 stems and fragments of crinoids;

4 the brachiopods, *Leptostrophia bipartita, Camarotoechia litchfieldensis, Chonetes jerseyensis, Atrypa reticularis* and *Leptaena rhomboidalis;*

5 the corals, *Halysites catenularia* and *Enterolasma caliculus;*

6 the alga(?), *Stromatopora constellata?.*

Supplementary Notes

[1] The taxonomy of the old "Waterlime group" is in confusion. Mather (1843, p. 349), in common with his colleagues, separated this group from the Onondaga salt group under it, and united in it (page 350) both the "Water limestone" and the "Tentaculite limestone" above that. The latter is approximately our Manlius, though at some points Mather included in it (as a "lower part," page 350) some fossiliferous beds (Glasco, etc.) of the Rondout while conversely at others (page 331) by implication he extended the "water limestone" up to include a cement bed that is in the Manlius. The important thing to note is that these rocks were not considered by any of these men as of Salina age but were always associated by them instead with the Manlius. Hall in particular (1843, p. 128-29, 141) took pains to discriminate between them and the hydraulic cement beds or water lime in the upper part of the Salina (then Onondaga) salt group.

Half a century later (1893, p. 159), Hall applied the name Rosendale limestone to the entire series of cement rocks quarried at Rosendale, N. Y., southwest of Kingston. This name was promptly forgotten. The next year (1894, p. 16), Hall reversed his early position, referred these cement beds of our region to the top of the Salina group and made them equivalent to the (Bertie) waterlimes of western New York, which lie below the Akron (Cobleskill) limestone. In the same report, Darton (1894, p. 400, 410) discussed them as the "Salina waterlimes." Subsequently Clarke and Schuchert (1899, p. 876) renamed the whole series the *Rondout waterlime,* assigning it anew a place between the Salina and the Manlius. The terms Rosendale and Rondout are thus originally synonymous, for the whole group.

Nevertheless Hartnagel (1903, p. 1166), after stating correctly that the name Rondout was intended to apply to "the upper beds of the Salina," gave it quite another meaning restricted to the part of our waterlimes that he considered as later in age than the Salina, while to the subjacent "waterlime of the Salina" as he then understood the correlations he reapplied (1905, p. 355, 356, 358) in a thus limited sense the forgotten term Rosendale. This was because of his belief that a "coralline" limestone lentil intervening between these two waterlimes was the Cobleskill limestone at the base of the (comprehensive) Manlius group of Vanuxem and of Schuchert. Still beneath his restricted Rosendale, Hartnagel recognized another "coralline" limestone by the name Wilbur (1903, p. 1145; Clarke 1903, p. 857), which was preoccupied.

Hartnagel's subdivision of the former Rondout or Rosendale waterlime group into Wilbur limestone and Rosendale waterlime of Salina age, and Cobleskill limestone, Rondout waterlime of post-Salina ("Manlius") age, has remained in current use. Meantime Chadwick (1930, p. 81) introduced a third term, Chrysler waterlime, for beds called Rondout in central New York, lying between the Akron (Cobleskill) and Manlius (Olney), because of his belief that they were not coextensive with the Rondout as that name was being used in the Hudson valley.

In his rather recent tracing of the Manlius and "waterlime" beds across New York (unpublished), Russell M. Logie has confirmed this belief that the Chrysler covers a greater interval than the restricted Rondout, but one practically identical with that of Rondout (or Rosendale) in its original scope. He finds the "coralline" limestone between Hartnagel's Rosendale and Rondout to be later than the Cobleskill and renames it the LeFever limestone. The name Rosendale he extends downward to include the true Cobleskill horizon and the lower "coralline" zone, but rejects the name Wilbur as not representing this bed at the Wilbur type exposure.

The terms applied around Kingston, N. Y., therefore stand thus:

1843 *Mather et al.*	1893 *Hall*	1899 *Clarke and Schuchert*	1903, 1905 *Hartnagel*	1933 *Logie*
Tentaculite.	Tentaculite.	Manlius.	Manlius.	Manlius (Olney).
Water limestone (i.e. Cobleskill and higher).	Rosendale limestone (1894 Salina, below Cobles.).	Rondout waterlime (above Salina; Cobleskill not named until 1902).	Rondout. Cobleskill. Rosendale. Wilbur.	Rondout. LeFever. Rosendale (with Cobleskill horizon).

In the Catskill quadrangle the entire series of these beds behaves as a unit and is not subdivisible into distinct formations. Limestone lentils come and go in the waterlimes, fossils of the Cobleskill congeries appear at all levels in increasing abundance as the beds lap against the Fuyk sandbar, what seems a valid classification at any given locality fails at another. Regardless of who may be right as to the position of the Cobleskill limestone with reference to these beds, there is here found no such continuous and sharply delimited stratum as is the true Cobleskill (Akron) from Schoharie valley into southern Ontario, Canada. Logie has rightly limited his Le Fever limestone, a massive lentil, to the country from Wilbur (Kingston) southward, indicating doubt as to correlation of it with the lentils of our area. Our chart (figure 11) shows how it fails, as a term and as a subdivision, to accord with the field facts here. However minutely, in Kansas fashion, we may some day divide this less than forty feet of strata, we shall always need a single name for the entire span.

As such a name for these waterlimes as a whole, Rondout in its original and comprehensive sense has a better claim and more familiar sound than either Rosendale or Chrysler. It retains the familiar succession (if Logie is right): "Cobleskill, Rondout and Manlius." Again (if Logie is right), it agrees with Mr Hartnagel's intention so to use it, an intention defeated only by probable misidentification of the Cobleskill in our region. This leaves Rosendale for employment in Hartnagel's (restricted) sense, its original claim having been lost through immediate disuse by its author or others, and makes Chrysler an unnecessary synonym, though it is "runner-up" for our beds in case a return to Rondout for them is not found acceptable. For Rondout in Hartnagel's restricted sense there is all ready a much older name, the Stormville waterlime of White (1882, p. 136-37) which White correctly identified with the "great waterlime bed at Rondout, Kingston and Rosendale, N. Y."

Finally we have the name Decker Ferry limestone (White 1882, p. 137; Weller 1903, p. 62) which originally included all but the uppermost 5 to 10 feet of our waterlimes, but which Hartnagel (1905, p. 348-49, 358) used in a narrower value. It would be a small matter to stretch Decker Ferry upwards the few feet needed to include everything up to the base of the Manlius (compare Kay and Chadwick 1933, p. 3, 5, 15), if that were desired, though this would not be as historically accurate as to go back to the original Rondout, the course here chosen.

One point, however, must be made clear. The base of the Manlius at Rondout is not where various writers have put it (above the third cement bed; see Mather 1843, p. 331; Van Ingen and Clark 1903, p. 1183; Hartnagel 1903, p. 1142), but at the base of the "curly bed"—a persistent but highly incompetent paper shale or shaly limestone that curls up like tinsel in the folding of the strata, beneath the massive beds gliding over it. The changes in thicknesses thus involved are, at Rondout:

	Formerly		As amended		Logie's
Manlius	37½		51¾		46
Rondout	23¾	41¼	9½	27	25½
Etc.	17½		17½		
Totals	78¾		78¾		71½

[2] For the future student of these beds, the following notes are given. Small exposures occur from the south edge of the sheet to the first crossroad. At forks of the Y of this road, exposures are good in both directions and north for some rods. Fossiliferous disrupted masses continue north to the Limekiln hill and also make a boulder moraine tailing south to and across route 32 below the corners. The lower beds exposed down past the vineyard on the southwest slope of Limekiln hill should not be overlooked. On the main ridge to the west of this hill nothing has been seen in place north to Mr Wetzler's house, which is a mile south of Schoentag's terminating a private road. On the east side of the limestone ridge just around the north end of it from his house, a good ledge of the Glasco is found resting up against a Normanskill knoll, with extension southward. North across the marsh, in the south end of Schoentag's hill, the Rondout rises rapidly, to make a commanding crag facing east at a high point on this ridge. It declines under cover before the elbow of the farm road on east is reached, but halfway from this to the Glasco road it shoots up very suddenly, under ascending Manlius ledges, and is largely uncovered in a small road-metal pit beside the farm road, with other exposures beyond for a space. Next comes the excellent strip north of Schoentag's past West Wood farm, northwest from which, across a brook, are various fine ledges at different elevations and with diverse dips, as well as others southward up both sides of the brook valley. A quarter mile north, beyond the backset of the hill, there are weaker ledges up the slope at different levels, but these soon pass under cover.

The anticlinal hogback on the north limits of Saugerties at Canoe hill is just behind a modern house. If there are any other exposures on Canoe hill or on Bambach's hill next north they have escaped me. Where the road east from Katsbaan Church hits the limestone ridge and Mr Fera's road forks from it, a climb straight over the hill brings one to the next known exposures, on its east foot. For a half mile north, though not continuously, the Rondout regains something of its self-assertion, with a white limestone bed carrying Halysites in a thin seam of flint that keeps mostly just west of the road under the east front of Shults's hill and forms more or less of a terrace that even crosses the road into an orchard for a few rods, then shows up well in the farmyard beyond. The next exposures are two skin outcrops on the west edge of the Great Vly a few rods north of the Asbury road. Less than a mile north, the Rondout picks up again as a distinct terrace above the Vly and continues at intervals north to the old stone house at the head of the Vly. North of the house it spreads east across vertical ridges of Normanskill into a broad cuesta as far as the cement company's railway cut into their back quarry. It arches back over the knoll north of their engine-stable and does not extend much north of their access road but comes back south on the east side of the Vly above their track until it forms the roof of the tunnel portal. With short covered spaces it continues through to the cemetery above West Camp, being specially well displayed for over a half mile northwest of there to the thumb of this hill and in the road that crosses.

On the east side, at West Camp, the Rondout comes down to road level of 9-W at the first scattered houses north of the store, then is largely covered to the crossroad, which it crosses just above the hairpin turn and is lost again to the West Shore cut south of the cable-bucket line, continuing into the fine section on route 9-W previously mentioned. Thence northward it leads a vagarious life in the faulted and plicated east front of the Kalk berg. Just north of the bucket line a second wedge comes in on the sidling road behind the house west of the railway. This wedge runs along the hill slope and into the big railway cut on the curve to north. Meantime a third one enters above it, crosses above the brick house and also comes to the tracks, at north end of the cut, reappears at the underpass and climbs toward the quarries. A fourth wedge makes the east wall of the southeast Alsen quarry with specially good sections, as are those north along the service railway and in the highway cut opposite the Alsen mill of the Lehigh company. The interbedded limestones are suggestive of Manlius or sometimes of Coeymans, and this is particularly true as one approaches the North American plant where various splits and wedges have mixed the strata badly. Besides the exposures along the road, here, there are important ones down along the West Shore tracks showing beneath the limestone a basal sandstone two or three feet thick that consists of reworked Normanskill and is distinguishable from that only by slightly coarser grain and more calcareous content (ground-up crinoids). These beds run up to the highway, halfway down the winding hill, where the same basal bed may be climbed to and found unconformable with the true Normanskill. Behind (west) and parallel runs another rib of the sandstone (Fuyk) farther up the hill. The easterly one persists, fishhooks over a north-plunging anticline in pretty fashion and returns to the highway where that runs close to the tracks, then arches up from the filling station, goes under the spring and climbs to the top of the roadhill above the red schoolhouse. Meantime the upper rib resumes above it on the steep hillside for a space.

Mrs Young's house is next north of the school. Up the slope behind her house are some of the most picturesque crags of the Fuyk sandstone, again in two strips, the lower one double. These all coalesce north, and at intervals crop out, dropping toward the road at the next filling station but losing thickness and presently becoming practically lost in the talus. No exposure was noted thence, short of the Quarry hill. Just where the upper waterlime bed comes in is not known. From the Cauterskill road exposure around to Moon's spring on the Fuyk farm road, exposures are scant. When the talus of Moon's big cliff is passed, the sandstone again alone makes the ledge and is already very thick, with continuous outcrop up to the big ledge of figure 15. Here again are complicated relations on this steep hill-front, with several strips of the sandstone but most of them badly shattered and traceable only by their debris. The sandstone picks up thinly just north of the Kaaters kill, fails before the thinnest appearance of the Rondout (waterlime) in a small waterfall over a half mile north, then the rock hides to the Cats kill in Austin's glen (figure 58). A thousand feet northeast of the last, the basal contact is again exposed in a small digging by the road under the cliff below the cottages. The beds show near the top of the Austin millroad and in a small quarry just east towards route 23 and poorly in the cut on that highway by the Salisbury House, their last appearance.

[a] Logie's stratigraphic results have been embodied in a pink-print chart sent out to fellow workers. From this and from personal correspondence have been obtained the data accredited to him in these pages. Mr Logie has traced these Silurian beds in detail clear across the State from Lower Canada to New Jersey, making a most important original contribution.

Figure 15 Rondout (Fuyk) sandstone at type locality on West ridge of the Fuyk, west of Catskill, showing the main ledge in the upper (fifth) slice of the imbricated structure. Height of this face more than 10 feet, the sands here replacing all of the Rondout that is present. Note offsetting of cliff on joint faces, and evident but unequal solubility. Looking west of south. Photo: September 1936, E. J. Stein.

Figure 16 Eagle cliff, Austin's glen. Synclinal outlier of Silurian and Devonian limestones (Rondout, Manlius, Coeymans and Kalkberg), Manlius making vertical part of cliff, its talus largely concealing the Rondout. The Cats kill, with island, and old railway grade in foreground. Looking south-southwest. Photo: April 1938, W. J. Schoonmaker.

Figure 17 The Fuyk valley, west of Catskill, viewed from east rim. Cliff is chiefly Manlius limestone, capped by Coeymans and Kalkberg limestones on which the camera stands. Note long talus slope (covering Rondout), clay-filled valley below (Lake Albany level), the distant Mt Potick peaks of the Hooge Berg range (Mount Marion beds) and the nearer wooded ranges of the Kalk berg, of which this ridge is an eastward offset across an eroded anticline (see map). Looking about north. Photo: (winter), R. W. Jones.

Figure 18 Laminated or platten limestones in the lower part of the Manlius at old Cornell "black marble" quarry on northwest side of Quarry hill, Catskill. Note cross-bedding in upper right (compare Brigham's Geology, figure 95), nodular nature of middle right and good major and minor jointing. A "clinkstone." Looking southeast. Photo: April 1923, W. Irving Steele.

Figure 19 Manlius limestones upturned along Rip Van Winkle trail (23-A) just out of Catskill, showing high west dip into the Quarry Hill syncline and slickensided bedding-planes where the layers slipped upon each other in the folding. Doctor Ruedemann indicates a larger fault-plane, not following the bedding, which repeats the lower 10 feet of strata. Looking north (toward quarry of figures 21, 22). Photo: April 1938, W. J. Schoonmaker.

2 MANLIUS (OLNEY) LIMESTONE

The cliffs of the Manlius,[1] formerly called the "Tentaculite"[2] limestone, are dominating features along the front scarp of the Kalk berg wherever these beds approach horizontality and sometimes where they are vertically uptilted. Master-joints often control these cliffs for many rods giving a sheerness of face that defies ascent. The weathered ledges, particularly of the "ribbon" layers, are whiter than those of the overlying limestones, but internally the rock is much darker than those, being very dark blue, fine-grained and dense, breaking with a conchoidal fracture under the hammer. Its fresh color has gained for it locally the name "black marble." Natural joint fragments retain their angles well, indicating resistance to solution in rain water, but the purity of the rock is better demonstrated by its solubility in underground waters, giving rise to extensive systems of caverns.

The Manlius limestone (figures 12, 13, 16-21) is here about fifty feet thick. It consists of some ten recognizable strata, of several contrasting kinds in alternation. The fine lamination of the "ribbon-banded" layers is often accompanied by a columnar jointing due to superposed mud cracks, dividing such beds into hexagonal or polygonal prisms from three to ten or more inches in diameter in a fashion suggestive of a cooled lava sheet. Such a structure is almost unknown elsewhere in limestones (see Kindle, 1914; Branson and Tarr, 1928; Roy, 1929)[3] and only in such thinly banded deposits of fine lime-mud, exposed to the sun and air at ebb tides during deposition. The lowest of these beds weathers to "paper shale," showing well the sun cracks along highway 23-A (figure 19) just beyond the crusher-quarry, is about 4 feet thick and may be traced clear across our area and on to Rondout. Around Catskill a ribboned and columnar bed up to 10 feet thick lies in the middle of the Olney and is the most conspicuous of such layers. Another but thin one occurs near the top (figure 21), again all the way to Rondout where it is thicker.

Very different in aspect are the "Stromatopora beds," of which there are from one to three in each section. They appear rough and knotty from the abundance of small heads of these coral-like organisms[4] and are lighter colored internally and slightly more grainy than the usual Manlius beds, thus more like the succeeding Coeymans. Here the main bed lies above the middle of the Olney, just above the main columnar stratum and is massive with a thickness usually of 10 feet, the fossils mostly of the size of apples. A thinner bed commonly occurs at or near the top of the formation and one of about six feet thickness in the lower part, two or three feet above the paper shales, often dividing into layerlets a few inches thick. At the top of this lower bed, especially on the old mill-road to Austin's glen, is a zone of huge heads (figure 20) from a foot to two feet or more in diameter, some of which are upside down.

These organic reefs eventually tail off laterally into the normal hard blue dense Manlius limestones, varying from thin-bedded to fairly heavy and massive, or even into the ribbon-banded beds. A conspicuous phase of these layers in the old "black marble" quarry on the Quarry hill is a 4-foot zone of somewhat cross-bedded flagstone-like layerlets, very smooth and even (figure 18; illustrated also in figure 95 of Brigham's Textbook of Geology, 1901 edition).

Characteristic of the talus slopes of the Manlius is the jingling sound emitted by the fragments when disturbed under foot. They rattle down like bits of china or glassware, whence the name "clinkstone." Their mode of fracture is also like glass, but not always so brittle; indeed, the heavier layers are often fairly tough. The dense and rather tough nature of the rock has made it favorable for crushing and screening, for track ballast and "gravel," and as it also packs and binds well under the roller or traffic, it has been used extensively for road metal. Crushers using the Manlius have been operated west of Catskill ("Turtle Pond" quarry at Blivenville, figures 21, 22), at Saugerties (Canoe Hill, figure 67) and Glasco (Schoentag's).

Recently, one of the cement companies has attempted the use of the Manlius for Portland cement, in order to get a whiter product than the Becraft gives.

The Manlius fossils are small but pretty, though few in kinds, and cover certain layers abundantly. The species include:

1 the pteropod, *Tentaculites gyracanthus;*[5]

2 the brachiopods, *Spirifer vanuxemi,* and *Brachyprion varistriatum;*

3 the ostracods, *Leperditia alta, Kloedenia notata, Kloedenella trisulcata;*

4 the pelecypod, *Leiopteria aviculoidea;*

5 the gastropods, *Holopea(?) elongata, H. antiqua, Straparollus sinuatus;*

6 the worm tube, *Spirorbis laxus;*

7 the crinoid, *Lasiocrinus scoparius;* also unnamable crinoid stems;

8 the stromatoporoids, *Syringostroma, Stromatopora,* and others;

9 a cephalopod, *"Cyrtoceras" subrectum;*

10 the bryozoan, *Monotrypella(?) arbuscula.*

Figure 20 "Stromatopora" in lower Manlius, broken across on a cross-joint so as to expose the structure, which continues to right of hammer (12 inches). Note nodular, and partly shaly, character of inclosing bed, and fragmental filling of voids on lower left. In place in ledge under talus of Manlius cliff on old Austin millroad entering Austin's glen, Jefferson Heights. This bed carrying the big "heads" is down near road grade for many rods. Looking north-northwest. Photo: April 1938, W. J. Schoonmaker.

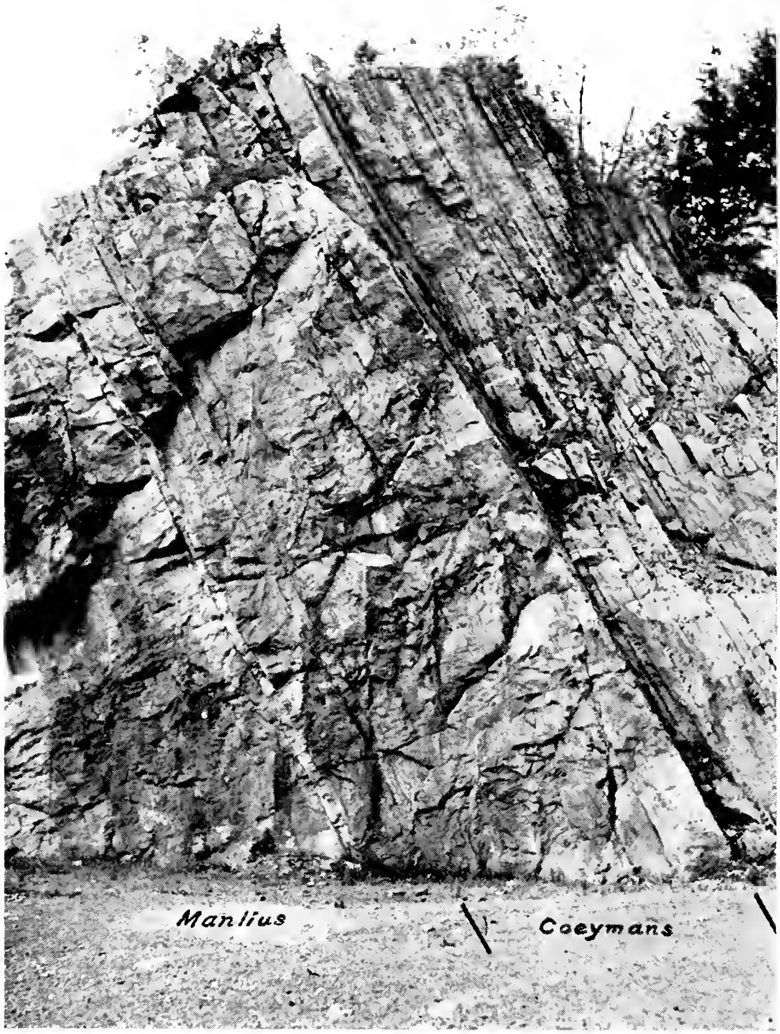


Figure 21 Upturned limestones at south end of Turtle Pond quarry, on Rip Van Winkle trail just west of Catskill. Locality of Kay's measured section (International Congress Guidebook 9A: pages 13-14). Note sharp line between Coeymans and Kalkberg (of old "Lower Pentamerus") but difficult visual separation between Manlius and Coeymans due to reworking and bonding on a disconformity. Looking west of south. Photo: May 1938, W. Storrs Cole.

Supplementary Notes

[1] The original Manlius "waterlime group" in its typical region around Syracuse, N. Y., has been subdivided by later workers into four or more members, of which only the lowest, or Olney limestone, extends into eastern New York according to Mr Logie's tracing (see note 1 under previous subhead). It would be more precise, therefore, to refer to our rock by the name Olney, but it will be difficult to displace the long familiar use of Manlius, and as no other Manlius member is present no confusion will arise.

[2] This name, derived from the abundance of the little pteropod shell, *Tentaculites gyracanthus,* originally supposed to be a sea-urchin spine, is the one used by James Hall in describing the fossils of this formation in our area. Actually, the Tentaculite zone is comprised in the lower half of the Olney, as Logie's chart shows. Southward, the species ranges down into the Rosendale just above the "Wilbur" at Rondout (see Van Ingen and Clark 1903, page 1183).

[3] The outstanding and long familiar occurrence of this phenomenon in the Catskill-Kingston region seems to have been overlooked by these later writers (see Van Ingen and Clark 1903, page 1185 and plate 6). Similar structure is reported by White (1882, p. 77, 144-45, 282) in the Bossardville limestone of northeastern Pennsylvania, strikingly like our Manlius but older than the Rondout. (See also Chadwick 1940.)

[4] The stromatoporoids have been referred variously to the sponges, hydrozoan corals and calcareous algae. Our Manlius forms are poorly preserved in their minute details and have not been studied and described. From cognate formations in the United States and Canada about 30 forms have been named, and of these Marshall Kay (see Chadwick and Kay 1933, page 14) thinks that *Syringostroma barretti* is our most common species, though originally described from the "Lower Pentamerus" (Coeymans) limestone of the Devonian. (See G. H. Girty 1897, p. 296.)

[5] *Tentaculites* is thought by some to be an annelid (worm) tube.

3 COEYMANS LIMESTONE

In the old terminology the "lower Pentamerus limestone" succeeded upon the "Tentaculite" and was followed by the "Catskill or Delthyris shaly limestone." When geographic names (see Clarke and Schuchert, 1899; Clarke, 1900, 1903g)[1] supplanted these old ones, Coeymans and New Scotland townships, both in Albany county to north of our area, were selected for the beds mentioned. But the exact limitations of these strata were nowhere defined with the precision demanded in modern stratigraphy. Hence it came about that both at Catskill and in the Helderberg mountains of Albany county some 50 feet of limestones[2] were looked upon as "lower Pentamerus" (or "Coeymans") by various writers.

A tracing of the layers between these two points has shown, however, that only the lower 15 feet, or less, of the reported 50 at Catskill (figures 16, 17, 21, 22, 67) correspond in lithology and fossils to the 50 feet in the Helderbergs that constituted there the original "Lower Pentamerus," beneath the "Shaly." Since no type section nor precise description of the Coeymans has been given, but that name merely substituted for the old one, and since by lithology and by subsequent description (see Hall, 1859)[3] of its fauna the

New Scotland clearly reaches down to the top of the beds just mentioned, at which point there is a sharp stratigraphic and faunal and lithic break at Catskill, it became necessary to limit the Coeymans to the 15 feet (or less) of such limestone in our area (figure 21). The overlying beds once included in the "Lower Pentamerus" are here referred to the Kalkberg member of the New Scotland, as defined in the next section.

At some points the Coeymans and Manlius form one cliff (figures 16, 17). At others the Coeymans retreats behind the main cliff of Manlius or forms a second and separate ledge. It is easily distinguished from the Manlius by its light color, bluish or sometimes pinkish, and its coarse granular texture, aided by the presence of the smooth, nutshell-like brachiopod *Gypidula coeymanensis* (formerly but erroneously called *Pentamerus galeatus*) and the larger crinoid stems (referable to *Melocrinus* and perhaps also *Lepocrinites*). The beds are massive and knotty, breaking down into irregular hunks.

In the stone crushers the Coeymans goes into the mill with the Manlius and while it is more crumbling its small bulk of admixture does not seriously affect the quality of the product. It is more silicious and a bit more magnesian than the Manlius but with less clay content. The silica present makes itself evident in the tendency to flinty alteration of the shells and crinoid stems, whereas the fossils in the Manlius are calcified rather than silicified.

While the discrimination of the Coeymans from the Kalkberg is an important one, the former could not, because of its thinness, be mapped separately from the latter formation.

The Coeymans fossils are usually few including:

1 the brachiopods, *Gypidula* (*Sieberella*) *coeymanensis, Atrypa reticularis* and *Uncinulus mutabilis;* (*Brachyprion varistriatum,* supposed to range up from the Manlius into the basal two feet of the Coeymans, appears to occur only in slabs of Manlius worked up into the Coeymans base);

2 the honeycomb coral, *Favosites helderbergiae;*

3 the pelecypod, *Actinopteria obliquata;*

4 stems of the crinoid *Melocrinus* and perhaps other genera;

5 the trilobites, *Odontochile micrurus* and *Proetus protuberans.*

Supplementary Notes

[1] The Delthyris limestone generally but not originally included upward to the Oriskany base, thus comprising the Becraft and perhaps the Alsen (see W. W. Mather 1843, p. 325, 343-45, 352). James Hall (1843, p. 144) protested: "The name of Catskill Shaly Limestone, which has been proposed on account of its great development on the Catskill creek, is found to be objectionable, as it at once carries the mind to the Catskill mountains, a very different group of rocks, thus tending to propagate a false impression." But the name Catskill

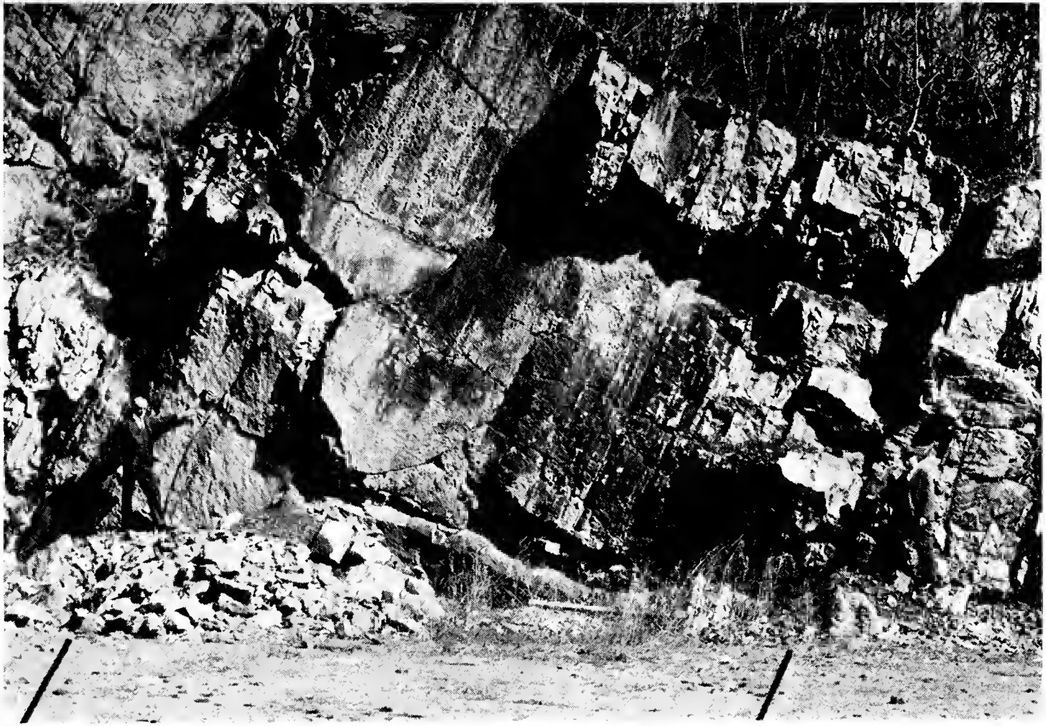


Figure 22 North end of same quarry as figure 21, showing full thickness of Kalkberg limestone between Doctor Ruedemann's hand, right, on sharp Coeymans contact and Chadwick's hand on less evident contact with Catskill shaly limestone. Looking north-northeast. Photo: April 1938, W. J. Schoonmaker.

Figure 23 Lengthwise view of Kalkberg limestone crossing the Cats kill at type exposure in Austin's glen, Jefferson Heights, showing the black chert seams (lower left) that have given the name "Coffin Rocks" to this locality. Note west dip flattening to right into the syncline, and white top of Coeymans limestone uncovered on left; also control of the stream course by parallel master joints (steps in falls). Eagle cliff (figure 16) in distance. Looking west of south. Photo: August 1931, Ashley Robey.

is much more appropriate to the exposures on the Cats kill than it is to those of the misnamed mountains (the Katsberg), to those who know the history of these names in the early days. And the name Catskill shaly limestone remained in the literature as late as 1905 (Clarke, Mus. Bul. 80, p. 5). Because of its correct downward limitation in Austin's glen, we find it convenient to retain it for the typical shaly portion, in the sense in which Delthyris limestone was used by E. Emmons 1846, p. 167-68.

[2] W. M. Davis 1882, p. 23, says "about eighty feet" which includes very exactly all the thick-bedded strata next above the Manlius. Mather's limitation (1843, p. 325, 326, 346-47) gives a thickness of only 41½ feet at the Turtle Pond quarry for the combined Coeymans and Kalkberg, but his "fifty feet" (page 347) are based on the Helderbergs though his description is for Catskill. The name Coeymans is Dutch, for an early settler, and is pronounced coo-ee-mans or kweemans. Geographically it lies intermediate between Catskill and New Scotland.

[3] Hall states plainly (p. 259) that *"Pentamerus galeatus"* (now *Gypidula coeymanensis*) ranges above the Coeymans, saying: "The more perfect specimens are obtained from the Shaly limestone above the Pentamerus limestone." He clearly understood the true stratigraphic relations.

4 KALKBERG LIMESTONE

The reasons for the separation of the Kalkberg (figures 21-25, 67) from the Coeymans have been partly stated under the account of the latter and will be discussed more fully in the next section. The equivalent of these beds in the Helderbergs is a series of thin but highly fossiliferous limestones extensively interbedded with shales like those of the overlying shaly limestone (Catskill member), together with which they constitute the New Scotland limestone, the Delthyris limestone of Emmons 1846 and Hall 1859; but the distinction is easy to make. The silicified fossils that weather loose in great numbers at the Indian Ladder park in the Helderbergs are identical with those that similarly weather out of the hard limestones at Catskill. All of these forms were described by Hall as coming from the Shaly limestone, at both localities, so that we are in full accord with him in separating the Kalkberg from the Coeymans at Catskill. The type locality chosen for the Kalkberg formation or member is where these beds cross the Cats kill at and below the "coffin rocks" (or "flat rocks") in Austin's glen (figures 1, 23). At this point the creek is emerging from the Kalk Berg range. The locality has been a favorite one for collectors since the days of Amos Eaton (Chadwick, 1908).

From 25 to 35 feet in thickness of beds are referred to the Kalkberg at different points in our area (figure 22). These are hard and heavy impure limestones, darker, less granular and more fossiliferous than the Coeymans and carrying (figure 23) seams of black chert (hornstone flint). These seams begin close above its basal contact with the Coeymans, which is a marked bedding-plane, and continue to recur through the first ten or fifteen feet, above which they break up into scattered flints and become almost lacking at the top. Unlike the Coeymans, the Kalkberg gathers a rusty clay crust several millimeters thick upon its weathered surfaces, from which the prettily silicified fossils slowly loosen and accumulate in the talus or in the residual earth in the seams and joints. Sometimes the Kalkberg caps the Coeymans-Manlius cliffs (figure 17), but when tilted it usually forms its own lesser cliff behind that of the Coeymans. Strong jointing and ready solubility along joints and seams give rise to the rectangular blocks so strikingly shown in the "coffin rocks" (figure 23) and elsewhere, besides resulting in the entrances to numerous caverns (figure 24) that extend down, often into the Manlius.

In its upper half the Kalkberg grows more impure, argillaceous, tending to grade into the shaly limestone above it, and becomes still more packed with fossils, especially small kinds and bryozoans. The lime tends to segregate into nodules of purer and more fossiliferous nature embedded in a mesh of more argillaceous and silicious stuff, often with a regularity like that of a tennis net. This characteristic is much more marked in the next overlying 35 feet or so of rock which, though still in heavy beds, weathers so shaly and weak that it has been grouped with the thinner bedded shaly limestones above. It is a feature also of the chert-seamed Alsen limestone higher up, which the Kalkberg thus may often deceptively resemble when it develops similar buffy tones on weathering. This resemblance to the Alsen increases northward and is most marked in the vicinity of the Leeds turnpike (highway 23) at the north edge of the map.

The Kalkberg limestone also goes into the crushers along with the lower beds.

The fairly profuse fauna of the Kalkberg includes hereabouts:

1 the brachiopods, *Bilobites varicus, Dalmanella perelegans, D. concinna, D. planoconvexa, D. quadrans,* and *D. subcarinata, Rhipidomella oblata, Leptaena rhomboidalis, Brachyprion aratum, Strophonella leavenworthana, Anastrophia verneuili, Gypidula* [*Sieberella*] *coeymanensis, Camarotoechia transversa?, Uncinulus nucleolatus, U. pyramidatus,* and *U. abruptus, Eatonia medialis,* and *E. singularis, Atrypina imbricata, Atrypa reticularis, Cyrtina dalmani, Spirifer macropleura,* and *S. cyclopterus, Delthyris perlamellosa, Nucleospira ventricosa, Coelospira concava, Rhynchospira formosa* and *Rh. globosa, Trematospira perforata, Meristella laevis,* and *M. arcuata;*

2 the corals, *Favosites helderbergiae,* and *F. conicus, Enterolasma strictum* and *Caninia roemeri;*

3 stems of the crinoids, *Mariacrinus stoloniferus, Melocrinus* sp., *Cordylocrinus plumosus,* and *Brachyocrinus* (*Myelodactylus*) *nodosarius;*

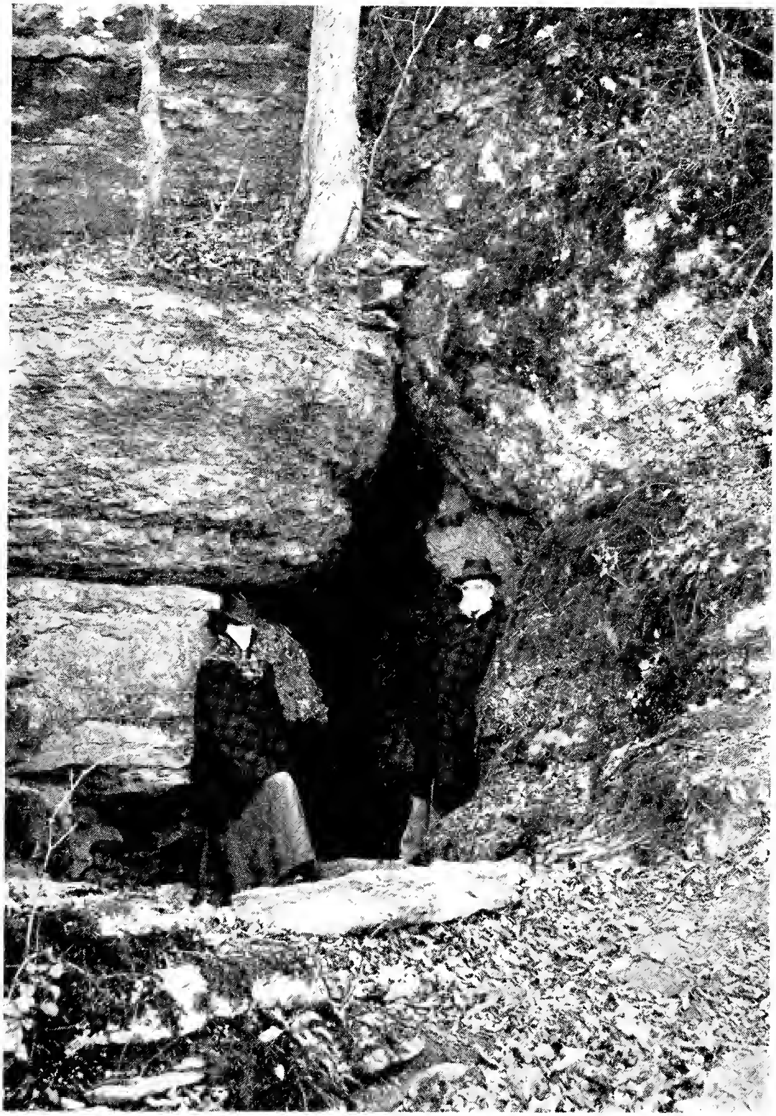


Figure 24 Kalkberg limestone at Austin's cave, west of Salisbury Hotel, Jefferson Heights, in high cliff overlooking the Cats kill as it emerges from Austin's glen. Water enters over (and through) ledge above, escapes far below in Manlius limestone on Austin millroad. Looking east. Photo: November 1902, G. H. C.

Figure 25 Catskill shaly limestone in its type exposure on the Cats kill at mouth of main gorge of Austin's glen, Catskill. Creek escapes diagonally across lower limestones as they roll up on east side of syncline (see figures 1, 23). Manlius (and Coeymans) in foreground; Kalkberg beyond water, to line of talus; then heavy-bedded lower Catskill with more shaly above; Becraft caps knob at left. Looking south of west. Photo: April 1938, W. J. Schoonmaker.

4 the trilobites, *Phacops logani, Goldius pompilius* and *Odontochile* sp.;

5 the sponge, *Hindia inornata;*

6 numerous bryozoans of the genera *Trematopora, Hallopora, Callotrypa, Chilotrypa, Fistulipora, Polypora, Monotrypa* etc.

5 CATSKILL SHALY LIMESTONE

Of the muds of the ancient seas none are more prolific in our region than the "Delthyris shaly limestone" of the old reports, named from its carrying the large *Delthyris* (now *Spirifer*) *macropleura*[1] and other spirifers. It was this rock (figures 1, 12, 22, 25, 26, 69, 78) that Professors Clarke and Schuchert renamed the New Scotland limestone as it is developed in the Helderberg mountains. But it should be noted that the earliest geographic name of this formation was the alternative one of "Catskill shaly," derived from its exposures on that creek in Austin's glen (figures 25, 26). Yet, as we have pointed out, these two names are not strictly synonymous, since the Catskill did not include the Kalkberg member of the New Scotland, but is itself the complementary member of the New Scotland, the Kalkberg being shaly on the Helderbergs but massively bedded at Catskill. Inasmuch as no other name presents itself for this higher member of the New Scotland formation, that of Catskill is here employed as of the greatest appropriateness and of long standing in the literature though in a dual sense.[2]

The highly fossiliferous shaly-looking slabs of the Catskill limestone are strewn about or heaped into stone fences throughout its line of outcrop, veritable treasure houses for the collector. The fossils are, however, in general only impressions or natural molds with the shelly substance dissolved away. Such original calcareous portions of the shells as remain are strikingly white against the dun matrix; there are also black fragments of trilobites or lingulas and similar. The weathered color of the slabs varies from gray to "coffee and cream," the whole effect dull and unattractive, becoming dark and forbidding in the rugged ledges. Fresh cuttings show a dark blue, lusterless and often massively bedded rock, appearing as a true limestone. The total thickness is not easy to determine with accuracy because of faulting or minor crumpling at the places best suited for measurement; it is thought to be approximately 120 feet.

The behavior of the "shaly" limestone under the weather is not the same at different points or at least at different levels within it. In general there are rapid alternations of more shaly and more resistant beds. Some of the latter are like thin recurrences of the

Kalkberg, though the silicified fossils (including many bryozoa) in these layers seem more delicate than in that rock while the chert is lighter in color and less abundant. In the thick-bedded but weak rocks of the basal 35 feet these fossils occur best preserved in the deeply weathered pittings the size of one's fist that result from the solution of the purer limy nodules mentioned under the preceding section on the Kalkberg member. In the north part of the quadrangle these lower beds produce usually a hollow between the Catskill and the Kalkberg ledges; a similar depression often lies between the Catskill and the superjacent Becraft limestone. The middle portion of the Catskill shaly limestone is therefore the more resistant, but still it is less so than the heavy limestones above and below. Yet at points where the strata are on edge the normally weaker shaly Catskill limestone often rises above these buttressing formations to form the backbone of the ridge, whereas the Kalkberg and Becraft subside into subordinate altitudes on the flanks. That this anomaly may result from greater induration of the shaly beds by lateral compression exerted at right angles to the bedding of the upturned layers is suggested by the seeming reduction in thickness of the Catskill limestone at such places.

Under other circumstances of compression, especially in the drag-zones of the overthrust sheets, these shaly limestones have proved quite incompetent and are crumpled, sometimes most intricately. Distortion or fracturing of the fossils is then a frequent consequence. In places, a closely spaced shearing-cleavage obscures the true bedding.

In composition the Catskill shaly is just about half limestone, analyses usually ranging from 30 per cent to 70 per cent of calcium carbonate. The remainder is mostly silica, with some alumina and about 3 per cent of iron oxide. Thus the rock is not suitable for cement, as it might be if clay replaced the silica and iron content. Except for the basal part it is avoided at the stone crushers, so that its chief economic use has been for stone fences and for cheap foundations.

The fossils of the Catskill member of the New Scotland include in part:

1 the gastropods, *Platyceras ventricosum, P. gebhardi, P. trilobatum, P. intermedium?, P. platystomum alveatum, P. retrorsum, P. calantica, P. (Orthonychia) lamellosum, P. spirale* etc., and *Diaphorostoma ventricosum;*

2 the brachiopods, *Spirifer macropleura, Schellwienella woolworthana, Meristella arcuata, Delthyris perlamellosa, Eatonia medialis, Strophonella headleyana, Leptostrophia becki, Leptaena*

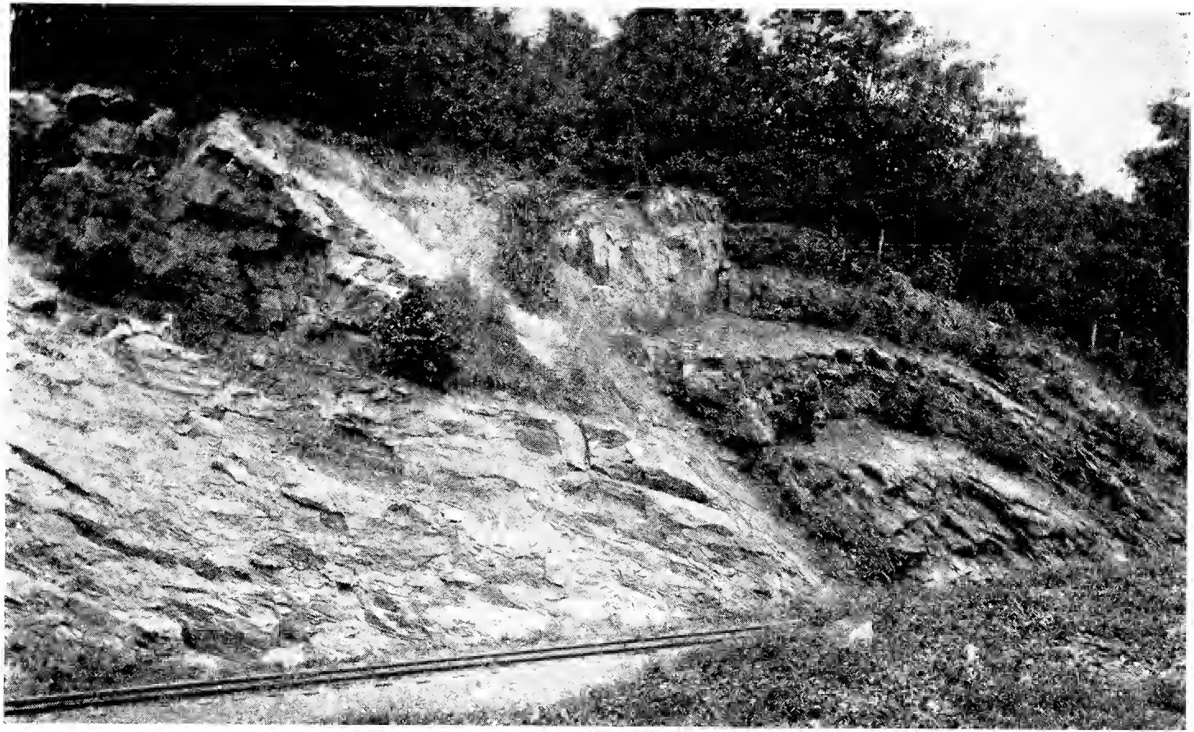


Figure 26 Overthrust fault, with marked "drag," on former Catskill Mountain railway at reverse curve in Austin's glen, Jefferson Heights (north bank of the Cats kill, see figure 1). Massive Becraft limestone at left, dipping east (right); fault surface diagonally up middle from right to left; arching (dragged), strongly cleaved New Scotland (Catskill) shaly limestone on right, also dipping east, belongs below the Becraft. Looking north-northeast along the strike. Photo: August 1912, H. L. Fairchild.

Figure 27 Becraft limestone quarry of George W. Holdridge on Quarry hill, west of Catskill, from which many fine public buildings have been constructed. Massive bed at the top (rear) is known to the trades as "Catskill shell marble." Looking west. Photo supplied by Mr Holdridge.

rhomboidalis, Rhipidomella tubulostriata, Orthostrophia strophomenoides, Pholidops ovata, Lingula rectilatera;

3 the trilobites, *Phacops logani, Odontochile pleuroptyx, Ceratocephala tuberculata;*

4 the pelecypods, *Aviculopecten tenuilamellatus, Actinopteria communis,* and *A. textilis, Pterinea halli;*

5 the cephalopod, *Orthoceras rude;*

6 the pteropod, *Tentaculites elongatus;*

7 the sponges, *Hindia inornata, Receptaculites infundibuliformis* and *Aulacopina(?)* sp.;

8 the crinoids, *Edriocrinus pocilliformis, Aspidocrinus callosus,* and various unidentified stems, the joints of which are numerous in the upper beds;

9 various bryozoans, of which the following are definitely reported from our area, *Fistulipora maculosa, Monotrypella? (Eridotrypa?) densa, Callotrypa macropora, C. striata, C. unispina, Polypora obliqua, Stictopora? granatula;* three others whose horizon is not given may be from the Kalkberg rather than the Catskill, namely *Unitrypa praecursor, Polypora arta, Ptilodictya nebulosa.*

Supplementary Notes

[1] This species recurs in the Alsen limestone, though sparingly, and is thus not so diagnostic of the New Scotland as was once supposed. See note 1 under the Coeymans limestone, for the history of the formation names. Lardner Vanuxem (1842, p. 120) in proposing the name Catskill shaly limestone to include, as he says, the Delthyris shaly limestone and Scutella limestone of the annual reports, explains: "The present name of this rock is taken from Catskill creek, near the town of Madison, Greene county, by the side of the railroad, where for a long distance it is exposed to great advantage for examination. The name is objectionable, but it is no easy matter to find one in the State which will be less so." Madison is now Leeds, the railway a memory.

[2] The name Catskill has become ingrained in geologic literature for the red beds of our mountains, where its correct limitations remain a matter of controversy. Because of the fallacious shift of the name of the creek to these mountains, as previously pointed out, it is unfortunate that it ever gained such currency among geologists. Since the red beds are now subdivisible in their type area, opportunity has been taken to employ herein the more appropriate Dutch and Amerindian terms, Katsberg and Onteora, their designations for the uplands, and to retain Catskill for the limestone whose description precedes that of the red beds in Vanuxem's report, the original publication of the name in both senses.

6 BECRAFT LIMESTONE

Most important economically of our limestones is the "shell marble" of local parlance, the "Scutella or Encrinal limestone" of the old reports,[1] renamed from Becraft's "Mountain" in the rear of the city of Hudson, an interesting outlier of Silurian and Devonian rocks off the northeast corner of our map area. There as on the west side of the river it is the main material for the manufacture of Portland cement. Analyses of the fresh rock run as high as 98 per cent of calcium carbonate, 90 per cent being a general average.

The Becraft (figures 26-29, 65, 68, 69) is a beautiful and durable building stone, as attested by some of the best public buildings in Catskill and elsewhere. It was used also for cyclopean blocks in the construction of the concrete anchors for one of the East River bridges in New York City. It takes a good polish and trims easily to any desired ashlar, but loses its polish too easily on exposure to be useful for monumental work.

The massive but much dissolved ledges of the Becraft limestone are the most conspicuous of any between the Manlius and the Onondaga. Open joints and seams characterize its outcrop, proof of its purity and solubility but making treacherous footing especially after the leaves fall. Yet caverns of any extent are not frequent in it.

Though, like our Helderbergian formations in general, usually somewhat darkened on the weathered surface, the rock is normally very light colored within. It crumbles to a white, sugary powder under the hammer and gives but little sound when struck. In grain it is coarsest of our strata, composed mostly of crinoidal fragments mingled with rather small brachiopods of few kinds and often with many of the larger watchglass-shaped objects formerly called "Scutella" (being mistaken for a genus of sand-dollars), now known as *Aspidocrinus scutelliformis* and considered to be crinoid anchor-plates. These have recrystallized into cleavable calcite of creamy white color, making them conspicuous against the light gray or pinkish tints that predominate in the matrix, to which some soft yellowish tones add warmth on exposure. The general effect is not cold, but fleshlike, enlivened by an abundance of calcite cleavage of all the organic fragments, recrystallized. It is this recrystallization that entitles the Becraft to pass commercially as a marble, though it is not a "metamorphic" rock in the limited sense.

Chert is unusual in the Becraft, yet it has been discovered at a few localities and at different levels in the formation, very sparingly, especially a thin seam at the very base. Exceptionally, the fossils are silicified.

The lower part of the 60 feet of Becraft on our area is thinner bedded (figure 27) than the upper massive stratum and carries seams or partings of bright green to black flinty shale, from one-half to four inches thick. These shale seams sometimes stand out on the weathered joint faces, being evidently less soluble than the limestone. Frequently they are packed with *Atrypa reticularis* and other fossils.

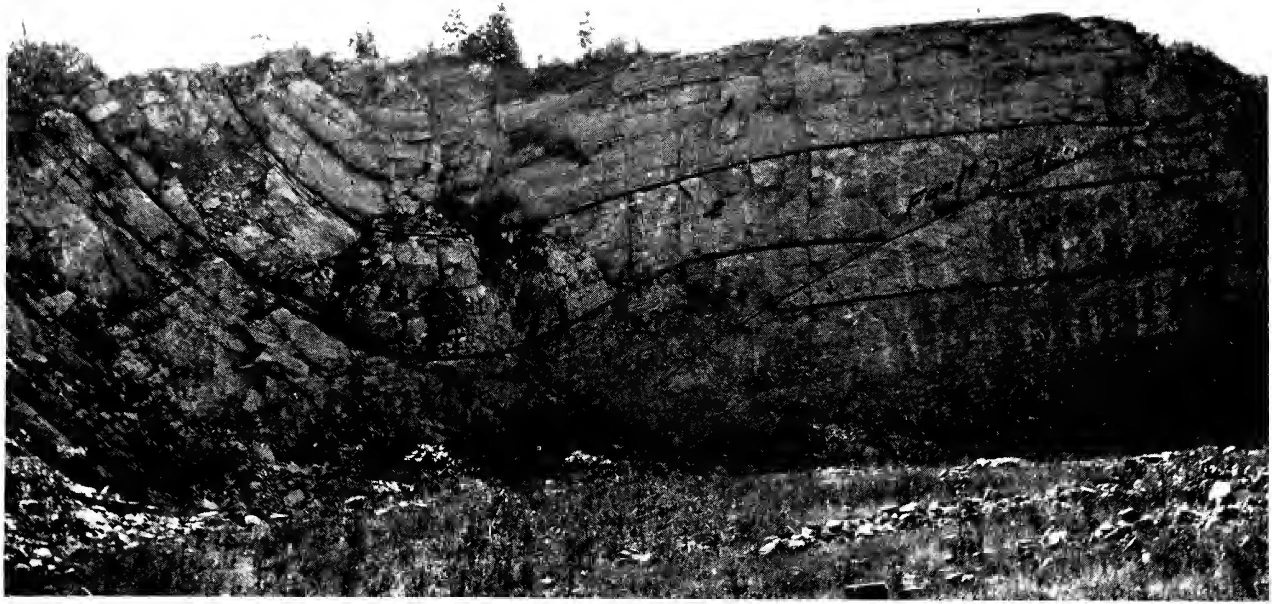


Figure 28 Becraft limestone overlain by Alsen limestone in south end of south Alsen quarry at Alsen. Characteristically unsymmetrical syncline with full thickness of both limestones at type locality of the Alsen. Height of face is 90 feet. Looking south. Photo and retouching by Robert W. Jones.

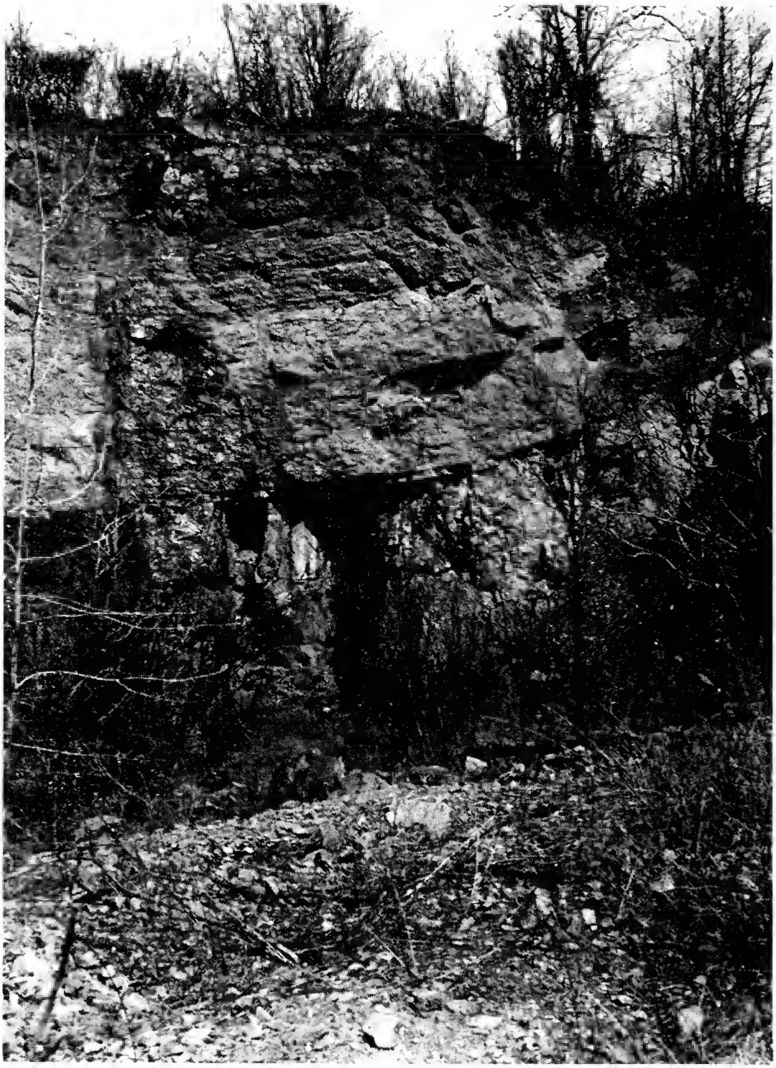


Figure 29 Alsen limestone of type exposure in middle Alsen quarry, Alsen, now property of the Lehigh. North wall of quarry, showing massive upper Becraft limestone up to the overhang, full thickness of Alsen, including banded "yellow" beds at its top, capped by about 15 feet of Glenerie cherts with shales. Looking north. Photo: April 1938, W. J. Schoonmaker.

They help to reduce the lime content of these lower beds to about 80 per cent of calcium carbonate, average analysis.

These shale seams increase and the beds grow thinner downward, so that the transition from the New Scotland (Catskill) below is not very sharp, especially since the summit of the latter becomes crinoidal and carries increasing proportions of thin, but blue and resonant, limestone bands. When attentively examined there is nevertheless no trouble in drawing an exact line.

The fossils of the Becraft limestone are chiefly:

1 the crinoid anchor-plate, *Aspidocrinus scutelliformis,* and stems of *Clonocrinus(?) macropetalus, Cordylocrinus parvus* etc.;

2 the brachiopods, *Spirifer concinnus, Atrypa reticularis, Uncinulus nobilis* and *U. campbellanus, Meristella princeps, Orbiculoidea discus;*

3 the (rare) gastropods, *Strophostylus fitchi, Straparollus decollatus, Salpingostoma profundum, Phanerotrema labrosum;*

4 orthocerate cephalopods, rare and poorly preserved;

5 fistuliporoid and fenestelloid bryozoans, not common.

Supplementary Note

[1] The "limestones of Becraft's mountain" was the first name applied to the Helderbergian rocks in the early annual reports (W. W. Mather's second report, 1838, p. 166). The first subdivision of these was into Pentamerus limestone, shale and Sparry limestone two years later (Mather, 1840, p. 237), while farther on in the same volume the names Delthyris shaly limestone and Scutella limestone were given for the last two (Vanuxem 1840, p. 377), and Mather adopted these names in the following year (fifth report on our district). In 1842 Ebenezer Emmons (p. 429) substituted Encrinal limestone for Scutella but misplaced it above the Oriskany, while Vanuxem (1842, p. 120) merged both the Delthyris and the Scutella in his Catskill shaly limestone and Mather (1843, p. 343) adopted the same grouping but preferred the name Delthyris for the combination. Hall, however, (1843, p. 145) continued to keep the Encrinal (Scutella) distinct from the Delthyris and added an Upper Pentamerus limestone above the former. Thus the present Becraft, or "upper limestone of Becraft mountain," has been known as Sparry, Scutella, Encrinal, Catskill in part, Delthyris in part, and Upper Pentamerus (at least in part). (See Darton 1894, p. 398, 406, pl. I; Hall 1893, p. 11).

7 ALSEN LIMESTONE

The Alsen succeeds the Becraft much in the same way that the Kalkberg follows the Coeymans, with incoming of black chert seams and a general reduction in purity and in size of grain. Its resemblance to the Kalkberg limestone has already been remarked. Seldom, however, does it form such cliffs as does that limestone. Usually it either caps the Becraft ledges or retires behind them into obscurity. Seldom, too, does its real thickness of 20 feet or more impress one in the natural exposures. The cement quarries reveal it better (figures 28, 29, 65, 68, 69) and they furnish its type locality (see

Grabau, 1919, p. 470). The Alsen was formerly made a basal portion of the Port Ewen formation, into which it tends to grade upward much as the Kalkberg does into Catskill shaly. The character of the fossil remains in the two is also parallel—silicified in the Alsen, as molds in the Port Ewen. They are 45 feet thick at Leeds.

The basal layer is finer grained and more resonant than the Becraft, but still usually of a light flesh color. This color quickly changes in succeeding beds to a blue, becoming still more dense and finer grained toward the top. A subargillaceous meshwork appears, like that in the Kalkberg and especially the basal Catskill but more conspicuous, inclosing the nodules of purer lime. Weathering often brings out much buffy coloring. The fossils are mostly silicified, as in the Kalkberg, and often weather free, but are more apt to be affected by a ring-growth of the silica that destroys the finer surface markings. The almost constant presence of *Spirifer concinnus,* and the frequency of *Monotrypa tabulata* and the large circular apertures of *Platyceras obesum,* are among the best means of distinguishing the Alsen from the Kalkberg in areas of faulting where the succession is obscured.

The calcium carbonate content drops to about 85 per cent in the Alsen, with considerable increase in silica and a little more magnesium. The beds, though less suitable for cement and troublesome in the grinder because of the flint, are not wholly rejected, however.

Because of its former inclusion in either the Becraft or the Port Ewen, or partly in both, the faunal lists of the Alsen became mixed with those until it was specially restudied by the writer. (See Davis, 1883, p. 391; Clarke, 1900, p. 73; Grabau, 1903, p. 1062-67; Van Ingen and Clark, 1903, p. 1192-97; Shimer, 1905, p. 183-84, 262-68; Grabau, 1906, p. 154-57; Chadwick, 1907.) Its separation from the Port Ewen and Becraft serves a useful purpose, but in our area it can not be discriminated on the scale of our map from the Port Ewen and is included in one color with that rock.

The fauna of the Alsen limestone includes:

1 the bryozoans, *Monotrypa tabulata, Fistulipora maculosa* and many other forms;

2 the gastropod, *Platyceras obesum;*

3 the brachiopods, *Rhipidomella oblata, Spirifer concinnus, S. cyclopterus* and *S. macropleura, Atrypa reticularis* (a thickened gerontic form is usual), *Delthyris perlamellosa, Schizophoria multistriata, Schellwienella woolworthana, Leptaena rhomboidalis, Brachyprion schuchertanum, Eatonia peculiaris, Nucleospira ventricosa, Uncinulus nobilis, Trematospira perforata, Rhynchospira globosa?,*

Cyrtina varia, Meristella princeps, Lingula rectilatera, also rarely *Spirifer macropleura;* perhaps *Beachia suessana* of the Oriskany fauna;

4 the corals, *Vermipora serpuloides, Enterolasma strictum, Caninia roemeri, Pleurodictyum lenticulare, Favosites helderbergiae* and *F. conicus;*

5 crinoid stems, especially of *Clonocrinus(?) macropetalus;*

6 the sponge, *Hindia inornata.*

Many of these have come up from the New Scotland, some from the Becraft. Only a few are new.

8 PORT EWEN BEDS

In the Rondout region, south of our area, the Alsen limestone lies at the base of a thick mass, somewhat resembling the New Scotland (Catskill), which passed as "upper or recurrent Shaly" until renamed geographically.[1] Port Ewen village lies just south of Rondout, and the exposures are in the long West Shore railway cut three-fourths of a mile above Port Ewen station. The succession of Becraft, Alsen, Port Ewen around Kingston and Rondout is like that of Coeymans, Kalkberg, Catskill shaly in the lithic changes involved, though there is in general less likelihood of confounding the Port Ewen with the Catskill limestone than the Alsen with the Kalkberg. It is much less fossiliferous than the Catskill shaly.

The 150 feet[2] of Port Ewen that succeed the Alsen around Rondout diminish rapidly northward. As they enter our area from the south they have dropped to a few feet and become more assimilated to the Alsen member. Northward from West Camp they are scarcely noticeable in outcrop. The quarries and road cuttings show, however, that there lingers a thin representative of these beds at most points, darker and more argillaceous than the Alsen, weathering yellower and more banded, lacking chert. From about 15 feet at Alsen (figure 29) the thickness falls to only seven or eight feet where it crosses the Cats kill in the upper part of Austin's glen at the north edge of our map. At several points on the quadrangle, even in the south part, it appears to be wholly absent.

The Port Ewen is less fossiliferous than the Alsen, though there is not much change in the species and, except to recognize the Alsen as a basal phase, the separation is a doubtful one, the lithic change being gradual and the line probably drawn at different levels at different points. The type Port Ewen is lithically rather like the Esopus, and like that rock it contains profuse tubular burrows at certain levels, but it differs essentially in being definitely limestone of the Helderbergian sea. The fresh color is somber, the weathered surfaces of the higher beds when present are more often gray than buff. Good exposures have been made along the new Palenville-Catskill road (route 23-A) at the extreme summit of the Blivenville hill and at intervals beyond, in which the Alsen lithology extends up to the base of the Glenerie beds and no typical Port Ewen is seen; yet the higher beds lack chert, have fossils as molds, more clay content, darker color, species indicative of the Port Ewen and probably correlate with layers next above the Alsen at Rondout as well as with those assigned to the upper Alsen in Austin's glen (thus accounting for the excessive thickness of 37½ feet of Alsen there). Phosphatic nodules at the top indicate an erosional break between the Port Ewen (respectively Alsen) and the Glenerie. Such nodules occur elsewhere at this horizon, especially on the upper or old stage road south of Schoentag's about 1.8 miles southwest of the Glasco docks as measured on the map, and here they top the small thickness of Alsen limestone with the Port Ewen wholly pinched out.

While the Port Ewen has some affinities with the Oriskany group and shows some faunal gradation, especially from Kingston southwestwardly, its divorce from the Alsen and from the Helderbergian generally does violence to the facts. There is no satisfactory break from the top of the Port Ewen down to the Coeymans base (the hiatus that was postulated by Grabau below the Port Ewen being actually above it), wherefore it seems wisest to retain all these beds in the Helderbergian where they originally resided.

In the northern part of our area, the Port Ewen remnants carry about 75 per cent of calcium carbonate and 15 per cent to 20 per cent of silica. But southward, the lime content must drop even lower than that of the Catskill shaly; no analyses are at hand.

The following list of fossils is based chiefly on collections made in the Rondout region, south of our map, though all the species named may be expected to occur on our quadrangle. These include:

1 the bryozoans, *Monotrypa tabulata* and *Fistulipora ponderosa;*

2 the brachiopods, *Eatonia peculiaris* and *E. medialis, Spirifer cyclopterus,* and *S. concinnus, Rhipidomella oblata, Dalmanella plano-convexa, Leptaena rhomboidalis, Leptostrophia becki, Reticularia modesta, Coelospira concava, Delthyris perlamellosa, Pholidops ovata* and rarely *Spirifer macropleura;*

3 the corals, *Duncanella rudis, Pleurodictyum lenticulare;*

4 the sponge, *Hindia inornata;*

5 the pteropod, *Tentaculites elongatus;*

Figure 30 Glenerie limestone in type exposure at old quarry on east side of route 9-W a quarter mile north of Glenerie Mills, four miles below Saugerties. Shows about 30 feet thickness (the Rev. C. E. Brown gives measure), much of which is packed with silicified fossils here and along highway. Looking northeast. Photo: April 1928, G. H. C.

Figure 31 Glenerie cherts, with interbedded shales, on Rip Van Winkle trail opposite Ellsworth Jones's house, two miles west-southwest of Catskill, (compare figure 29). Note easterly dip into Quarry Hill syncline. Looking north. Photo: October 1927, G. H. C.

6 the pelecypod, *Cypricardinia lamellosa;*

7 the trilobites, *Homalonotus vanuxemi, Phacops logani, Odontochile pleuroptyx, Ceratocephala tuberculata;*

8 "fucoidal markings" or tubular worm burrows.

Supplementary Notes

[1] Overlooked by earlier writers or confused by them with the New Scotland, the "Upper Shaly" was first differentiated by W. M. Davis in 1883 (pages 390-91), a date coinciding with the opening of the West Shore Railroad which has a long cut through these beds on the south side of the Rondout creek. In their great revision of 1899, Clarke and Schuchert called them the Kingston beds, a preoccupied name (in Canada) later changed by Clarke (1903, p. 21) to Port Ewen.

[2] The reported figures (see W. M. Davis 1883, p. 390; N. H. Darton 1894, table opposite p. 396, p. 407, 491, 498, 517; J. M. Clarke 1900, p. 73; Van Ingen and Clark 1903, p. 1194), when the Alsen is deducted, range from 100 to 200 feet in the Rondout region, with the more startling difference of 40 to 180 feet at Whiteport (Darton p. 407, Van Ingen and Clark p. 1195). Some of the divergences are due to faulting and internal mashing at the various exposures. The writer's own field work would indicate that about 100 feet comes nearer the truth from East Kingston southwestward to New Jersey.

9 GLENERIE LIMESTONE AND CHERT

Buff browns are the characteristic weathering colors of the Glenerie Oriskany beds, but the fresh exposures are very blue to nearly black, often fading to a neutral gray where weathering has just begun. These colors are more constant than the rock composition, as that ranges from limestone to solid chert beds, to soft shale and to conglomerates. This variability, together with the thinness, marks the shorewardly onlapping nature of the Glenerie beds and emphasizes the importance of the time-break at their base—a line formerly chosen (and to which we may return) as the base of the Devonian system. Southward, they thicken greatly into limestones (figure 30); northward in the Helderbergs they grade over into two or three feet of sandstone, there correlated with the coarse Oriskany white sandstone of central New York, whose type locality is southwest of Utica. This very thin sandstone layer in the Helderbergs is packed with the characteristic coarse brachiopod shells or their molds[1] and is decidedly flinty, giving glassy surfaces when glaciated. As it comes southward it soon loses any character of sandstone, becoming a chert or cherty limestone (figures 29, 31, 68). Throughout this change it keeps most of the diagnostic brachiopod fossils of the typical Oriskany, the coarse forms that would survive wave buffeting on the beach. But added to these are now smaller species germane to the limestone reefs and ranging up from below, with some new forms, constituting a much more profuse fauna and giving rise to the impression that the Glenerie limestones were older (lower) than the typical Oriskany sandstone.

On the Cats kill below Leeds, just as these strata enter our quadrangle, they roll out flat in the creek bed, exhibiting highly fossiliferous cherty seams with many species that are holdovers from the underlying Helderbergian formations and only subordinate numbers of the typical large Oriskany forms. Nine feet of beds are here referred to the Glenerie, resting on the seven-foot Port Ewen shaly stratum. They pass directly beneath the Esopus shale of the big cliff (Darton, 1894, plate 2 op. p. 402) formed by that rock at the former Leeds Mills, which is so conspicuous from route 23. At low water all contacts and the entire succession from the Alsen to the Esopus and then through the Schoharie to the Onondaga can be studied here, care being taken to recognize some small thrusts in the Glenerie and Esopus. The only equally good exposures of the Glenerie contacts are on the Esopus creek at the Oak Ledges, Saugerties or in the cement quarries.

Southward from Leeds (Austin's glen) the Glenerie beds are much masked under strips of alluvium or swamp as far as Van Luven's lake, though search reveals some natural exposures. The fresh cuttings on the new Palenville-Catskill highway (23-A) have supplied excellent sections (figure 31) and brought to light shaly phases interbedded with and bottoming the cherts, as well as one thin zone of pebbles. Fossils, including some species not yet described, are abundant in these cuts but not easy to collect. A pebble zone occurs also just at the north edge of our quadrangle in the Glenerie beds at the "natural dam" in Austin's glen and one or two such layers in the cement quarries.

Southward from Van Luven's lake the Glenerie assumes a physiographic importance it has not had north of there, capping and protecting the cement limestones (Alsen and Becraft) in the various fault-blocks of the West Camp syncline. It is the "black rock" dreaded by the quarrymen as exceedingly difficult to drill. In the deep railway cut of the Alpha company at the south end of this ridge, the Glenerie is seen to be at least 20 feet thick, nearly all black chert.

But it is from Saugerties southward that the rock takes on its most interesting character through the incoming, at the top, of highly fossiliferous limestone beds. This locality, made famous by the collections of the late Reverend Thomas Cole jr of Saugerties, furnishes our name for the formation, from the old Glenerie white-lead mills on the Esopus creek that still stand unused at Glenerie falls of the map. The type exposure is a small old quarry (figure 30) on the east side of highway (9-W), north of the mill, but the collecting grounds extend north nearly to the bridge leading to Mt Marion[2] and have furnished a wealth of fossils so beautifully silicified as to rival those well known to paleontologists from the Oriskany of Cumberland, Md. Across the creek is the type Esopus shale (figure 32).

A comparison of the map areas covered by the Glenerie here with its diminishing prominence northward to the Cats kill is instructive. Farther south it thickens more and more, while a small-pebble conglomerate comes in below it, at Rondout, which is still of Oriskany age. The aspect of this Connelly conglomerate is that of a transgressing deposit, an interpretation strengthened by its disappearance northward, along with most of the Port Ewen (from top down), the incoming there of pebbles at higher levels which have become basal Oriskany, and the occurrence of phosphatic nodules beneath the basal contact. The Connelly has not been detected in our map area.

Nowhere within the Catskill quadrangle is there any exposure to which one could apply the name "Oriskany sandstone." Failure of several acute observers to recognize the Oriskanian here was due to this absence of this sandy phase associated with the name in their minds. But the belief that the beds here present are earlier in age than the typical Oriskany because of their large admixture of holdover Helderbergian species seems to lack cogency. (Ulrich and Schuchert 1902, p. 653 have only upper Oriskany in eastern New York.) As pointed out by Doctor Clarke (1900, p. 72) and Professor Shimer (1905, p. 190), the calcareous facies of the rock provides a sufficient explanation of the faunal difference. On the other hand, it is equally true that the presence in both localities of *Spirifer arenosus* and its associates by no means proves that the two rocks are necessarily continuous and contemporaneous deposits. The Oriskany sand is just such a beach deposit as we have in our Rondout at Alsen and like that it must have formed rapidly and be the equivalent of but a few feet of limestone. But *Spirifer arenosus* ranges through 300 feet of beds in Maryland. Until more information is at hand, therefore, it seems best to continue the local designation, Glenerie, and to include under it in one formation all the local lithic variations.

Analysis of the Glenerie beds in the Quarry Hill syncline shows about 60 per cent of calcium carbonate, over 20 per cent of silica and about 6 per cent each of alumina and of magnesium carbonate. Some portions, however, run much higher in silica than in lime.

The Glenerie fauna includes in part:

1 the brachiopods, *Spirifer murchisoni* and *S. arenosus, Lepto-*

coelia flabellites (robust variety approaching *L. acutiplicata*), *Palaeoglossa spatiosa?*, *Leptostrophia oriskania* and *L. magnifica*, *Rhipidomella musculosa*, *Plethorhyncha pleiopleura* and *P. barrandii?*, *Centronella sinuata*, *Eatonia peculiaris* and *E. sinuata*, *Coelospira concava*, *Meristella lentiformis*, *Reticularia saffordi*, *Chonetes hudsonicus*, *Schellwienella becraftensis*, *Brachyprion majus*, *Anoplia nucleata*, *Hipparionyx proximus*, *Leptaena rhomboidalis ventricosa*, *Rensselaeria ovoides*, *Pholidops*, *Merista lata* etc.;

2 the gastropods, *Diaphorostoma desmatum* and *D. ventricosum*, *Platyceras gebhardi*, etc.;

3 the trilobites, *Synphoria stemmata*, *Homalonotus vanuxemi*, *Phacops logani*;

4 the pteropod, *Tentaculites elongatus*;

5 the crinoids, *Edriocrinus sacculus*, *Ancyrocrinus quinquepartitus* and unidentified stem segments;

6 the worm tubes, *Autodetus beecheri* and *Cornulites?*; and the burrow, *Taonurus cauda-galli*; also branching burrows ("fucoids");

7 the coral, *Enterolasma strictum?*;

8 small ostracods similar to those from Maryland;

9 a few bryozoans (*Monotrypella?*, a fenestelloid etc.).

Supplementary Notes

[1] See A. W. Grabau 1906, p. 157-68, R. Ruedemann 1930, p. 56-58. The latter reports (p. 57) that this bed is interrupted on the outcrop for a space in the southern Helderbergs.

[2] First mentioned by W. W. Mather (1843, p. 335) and later by W. M. Davis, and N. H. Darton (1894, p. 405, 497), the fuller accounts are given by J. M. Clarke, 1900, p. 74-75 (fossil list) and by Van Ingen and Clark 1903, p. 1201-3 with the most complete list of species on p. 1203 that has been published, 94 in all, 56 of which are republished by A. W. Grabau, 1906, p. 305.

10 ESOPUS SHALE

The inadequacy of our petrographic terms for sedimentary rocks is nowhere better evinced than by the efforts to name this rock. "Cocktail (or Cauda-galli) grit" expresses its true character no better than the present substitute, Esopus "shale." Shale it is not, and grit it is not. "Siltyte" would be more appropriate, yet still would fail to convey a precise impression of this almost unstratified, strongly vertically cleaved and gravelly-crumbling mass of uniform, barren, dark-gray stuff, two hundred fifty to three hundred feet thick in our area.

Where undercut along the strike and cleavage planes, as on the Cats kill at the north margin of our map (figure 78) and on the Esopus creek (figures 32, 33) at the Glasco-Mt Marion bridge (which is the "type locality") the Esopus "grit" forms smooth banks

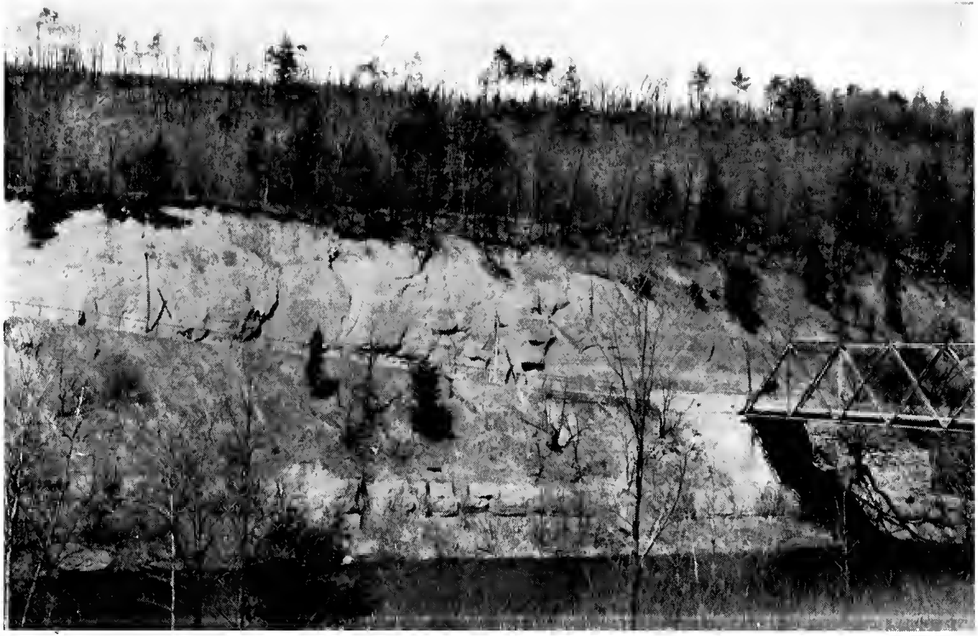


Figure 32 Esopus shale on west bank of Esopus creek at type locality, Sauer's bridge, three miles south of Saugerties, on route 9-W. Note vertical cleavage and lack of visible stratification except in hard bed at base. Camera stands on Glenerie limestone. Looking northwest. Photo: April 1928, G. H. C.

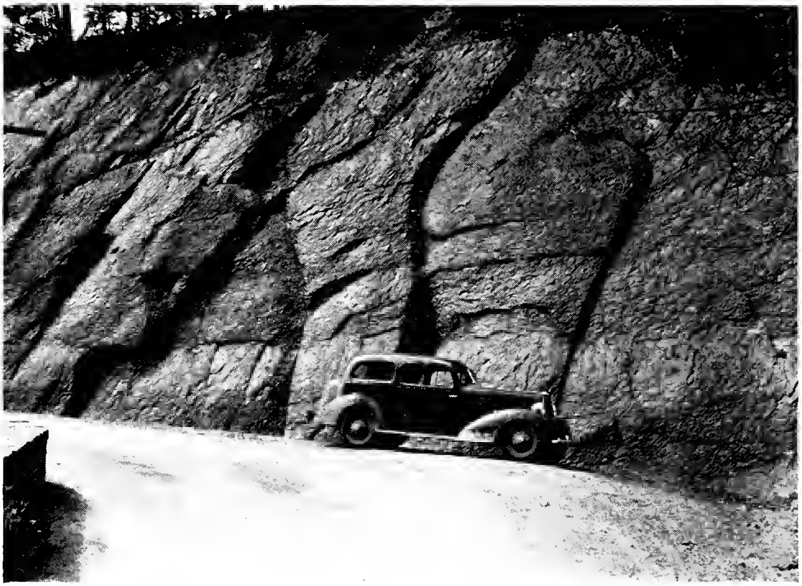


Figure 33 Detail of cleavage in Esopus shale of type section (figure 32). Only faint color bands represent the stratification. Dip is away from camera. Looking west. Photo: April 1938, W. J. Schoonmaker.

Figure 34 Schoharie shaly limestone (top beds) in low anticline on route 32 just west of Saugerties, near junction with Old King's road. Silicious nodules make rows of whiter spots. Looking northeast. Photo: September 1936, G. H. C.

of light gray aspect, with the surface covered by small cubical bits so as to resemble a huge pile of finely crushed stone.[1] But where cut transversely, as in the high "wheel" cliff at Leeds Mills just north of our area or on the Esopus creek below the West Shore Railroad bridge (Glenerie falls), the rock stands out in dark forbidding crags with very resistant appearance and a steep or vertical false bedding due to the pronounced cleavage.

On the uplands it gives rounded hills with fair soil, usually cultivated or at least cleared for pasture, whereas usually the limestones that emerge from beneath it and often the Schoharie above it are left in timber. When the Esopus is not cleared it carries an oak forest with trailing arbutus, mountain laurel, wintergreen and other sand-loving plants, or a second growth of juniper, whereas the limestone ridges support evergreens (hemlock, pine, spruce), maples, sassafras and dogwood more abundantly and the lime-loving ferns.

The general absence of stratification has an exception in the lower 40 feet, in which there are at intervals prominent layers about a foot thick that sometimes prove to be cherty. On the Esopus creek these beds are very silicious (figure 32), so resistant as to make a strong rib of rock lengthwise of the stream at the Mt Marion bridge, where Darton has called them "Oriskany"; but they shoot well over the Glenerie limestones. Some fossils, however, continue upward into this basal portion, especially the robust variety of *Leptocoelia* that flourished in the Glenerie. Rounded flint nodules of several inches occur at definite levels. This fossiliferous and stratified lower portion may eventually require a distinctive name. The most interesting collections have been made about a mile east of Leeds.

The most abundant and characteristic fossil of the Esopus is the spiral worm-burrow, *Spirophyton* or *Taonurus caudagalli,* which increases in prominence toward the top of the formation.

The full list of species, mostly from the lower 40 feet, is:

1 the burrow, *Taonurus caudagalli,* and a tubular burrow (*Buthotrephis*?) exactly like that in the Port Ewen beds;

2 the brachiopods, *Leptocoelia flabellites* (variety?), *Chonostrophia complanata, Orbiculoidea* sp., perhaps *Ambocoelia* sp.(?);

3 a gastropod, *Platyceras* sp.;

4 a goniatite with closely spaced septa, about as simple as *Agoniatites,* from the railway cuts north of the Kingston tunnel.

All this material was given to Dr J. M. Clarke for study but became mislaid.

Supplementary Note

[1] See N. H. Darton 1894, plate 3 opposite p. 510, for this cliff, and plate 2 opposite p. 402 for the cliff at Leeds. Since the latter cliff is 120 feet high, and the nearly vertical mass at the right also belongs to the Esopus, it is easy in this view to measure 250 feet thickness, excluding about 10 feet of (thrust duplicated) Glenerie beds in the core of the arch. The 40 feet of more stratified Esopus next above the Glenerie are well shown in the picture. The cliff at Glenerie at its highest point, the boardinghouse not far north of the falls, is 200 feet high, to which dip will add at least another hundred; so that on this south part of the map the thickness must reach 300 feet. Darton (1894, p. 403) named this rock Esopus "slate", a term by no means as inappropriate as the others, from, he says, "the Esopus settlement" (now Kingston) "and the Esopus creek"; but since the complete section is exposed only on the latter, we must look upon it as the real type section and locality.

11 SCHOHARIE SHALE

The 60 to 80 feet or more of beds mapped as Schoharie were formerly included by all writers in the preceding formation, the Cauda-galli or Esopus. Discovery of characteristic Schoharie grit fossils in them at Becraft's mountain led Doctor Clarke (1900, p. 13-15) to observe the lithic differences and to give these beds proper recognition. Similar conclusions had been earlier reached on the west side of the river by E. R. Beardsley, R. W. Jones and the writer, but not published until later; in fact, there had been a growing general conviction among all field workers of a valid lithic and faunal distinction from the Esopus, of stratigraphic continuity of these shaly lime-mudrocks with the thin bed of true sandrock in the Helderbergs known as the Schoharie "grit" from its outcrop on the hills above Schoharie Court House in Schoharie county and of the presence hereabouts of many of the distinguishing fossils of that stratum. Thereafter, this recognition became unanimous.

These beds are harder, more calcareous and browner on weathering than the underlying Esopus and they break into much larger pieces than that rock. This is well illustrated in the arching surface of the Schoharie on which stands the old stone church in Leeds, on route 23 just north of our map, a surface that for the regularity of its minor jointing looks like a brick pavement.

Some of the smoothly arched anticlinal hills of this formation, just unroofed of their limestone cover, are cleared and cultivated, but more often the inclined or vertical beds give ragged ledges and rugged ridges still in timber. The Schoharie is in fact a highly resistant rock and it has a marked physiographic effect in contrast with the subdued Esopus topography. At many points the Esopus forms only a broad vale or meadow between upturned ridges of Schoharie on one side and subjacent limestones on the other. It is only here and there, in anticlines, that the Esopus stands higher and the Schoharie sinks back down the flanks of the hill.

To give a meaningful lithologic name to the Schoharie is even more difficult than it is for the Esopus. Less shaly than that, it is in no sense a "grit" as at Schoharie, but instead it is in our region and southward a fine-grained impure limestone or calcareous mudrock for which "marlyte" might do if the lime content were higher (figure 34). Nevertheless, the rare limestone plants such as the walking fern, purple cliff brake and ebony spleenwort find footing upon it quite as readily as on the purer limestones.

The Schoharie is the third of such rocks in our series. Its characteristic "coffee-and-cream" fragments, usually crudely shaly but often with bulging centers, are rather closely imitated by the lower Glenerie at many points and again by certain layers in the New Scotland (Catskill shaly). These resemblances are sufficiently close to demand caution in faulted areas, though usually the fossil contents will announce which rock is outcropping. No places have been found where the Glenerie is in fault contact with the Schoharie, however, though the intervening Esopus is sometimes wholly under cover of alluvium; so that such difficulties are between the Glenerie and New Scotland and do not affect the Schoharie, which lies to the west of those except in the Streeke syncline. Were fossils in the Schoharie as numerous as in the New Scotland, doubtless it likewise would have been called a "shaly limestone."

These fossil contents are, indeed, rather limited to the uppermost portion and are none too abundant there, while the lower part is increasingly more impure and more like the Esopus. The exact line between these formations is marked by glauconite, with abrupt cessation of the "cocktail" (*Taonurus*) markings and substitution of an obscure branching tubular burrow(?). Stratification becomes more distinct, with often a thin limestone band not far above the base of the Schoharie (figure 64). The physiographic line is usually a definite depression in the topography, or a terrace quoin. The middle and higher portions of the Schoharie are readily known, even the topmost part which becomes heavy-bedded like the Onondaga above it (figure 35), from which too it is separated by glauconite and distinguished by color and slaty cleavage.

The fossils of the Schoharie shale hereabouts, chiefly from the top, are:

1 the brachiopods, *Atrypa impressa, Spirifer macrus, Strophonella ampla, Schellwienella pandora, Delthyris raricosta, Stropheodonta demissa, Dalmanella peloris, Chonetes hemisphericus, Reticularia fim-*

briata, Leptaena rhomboidalis, Orbiculoidea sp., *Lingula ceryx?;* (Clarke lists also *Coelospira* cf. *camilla, Chonetes* cf. *arcuatus*);

2 the trilobites, *Synphoria anchiops, Calymene calypso;* (Clarke adds *Phacops* cf. *bombifrons*);

3 the cephalopod, *Orthoceras zeus;*

4 the gastropods, *Orthonychia* cf. *arcuata, Platyceras* sp.;

5 the sponge-boring, *Clionolithes radicans;*

6 bryozoans, *Monotrypa* etc.

From the top bed at Becraft's mountain (which Grabau 1903, p. 1070, took to be basal Onondaga) Doctor Clarke reports also (1900, p. 14) the following:

1 the brachiopods, *Spirifer varicosus, Atrypa reticularis* "large and rotund" (*?A. impressa*);

2 the trilobite, *Odontocephalus selenurus;*

6 the bryozoan, *Fistulipora* (or *Stromatopora*), incrusting;

7 the corals, *Chonophyllum, Zaphrentis, Favosites* (branching).

12 ONONDAGA LIMESTONE

The great "Corniferous" or "Upper Helderberg" limestone marks a return to coral-reef conditions after the long interval of the "grits" and is the last limestone formation in eastern New York. Split Rock in Onondaga county is the type locality for the present name, Onondaga limestone,[1] but there have been other uses of the name Onondaga. Our Onondaga limestone (figures 35-39) forms conspicuous ledges characterizeed by an abundance of "black" chert seams in a rock that though dark internally weathers strikingly "white" and by massively jointed cliffs and blocks that are easily recognizable even when glacially transported far from the outcrop. Chert is, however, practically missing from the top 12 feet or so and in the basal four to eight feet. Fossils are usually plentiful, especially rather large silicified horn corals, honeycomb and organpipe corals in the cherty middle layers.

The probable thickness of this massive limestone in our area is about 60 feet, as Darton gives it (1894, plate 1 opposite page 396, and pages 491, 496), but good opportunities for measurement are lacking since the summit contact is known at but one point (figure 40). Resistant as the Onondaga seems at most exposures, forming very picturesque ledges, it is surprisingly weak at others and retreats far down the back slope of the Schoharie or wholly disappears under alluvium. Indeed, where the larger streams cross it the Schoharie usually makes the fall while the Onondaga goes under water behind the fall. These anomalies may be due either to its greater

Figure 35 Contact of Onondaga limestone on Schoharie limestone at Webber farm, one-half mile west of Cauterskill, on north side of the Kaaters kill. Hiram Wilcox marks top of Schoharie at spring issuing from bottom of syncline, the layers rising again beyond the tree. Looking east. Photo: September 1911, G. H. C.

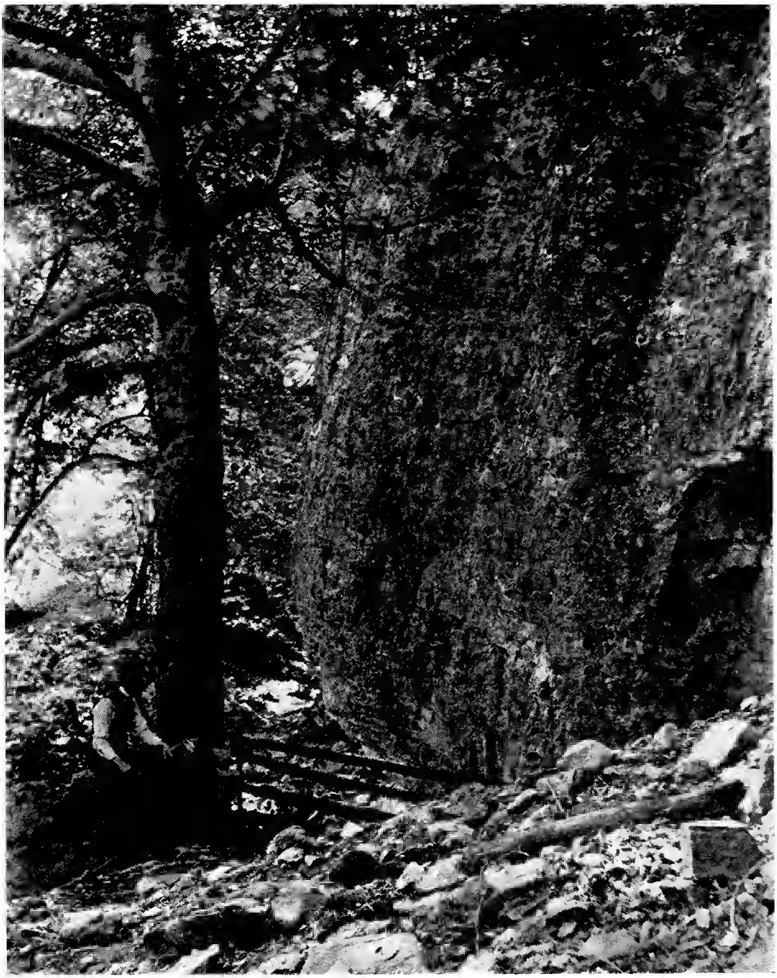


Figure 36 Onondaga limestone at same locality as figure 35, showing unusual thickness of the massive chert-free lower portion. Path to cave goes up right foreground. Looking west toward spring. Photo: September 1911, G. H. C.

Figure 37 Onondaga limestone arch at Quatawichna-ach, on the Kaaters kill, four and one-half miles southwest of Catskill. Beds very near top of the Onondaga, as Bakoven shale occurs just downstream. Right background is Timmerman's hill of the Hooge Berg range (Mount Marion beds). Looking southwest, below bridge. Photo: September 1936, G. H. C.

Figure 38 Detail of same beds as figure 37, under the bridge, showing the chert seams, and the cavernous character which takes the normal flow of the stream underground and gave it the Indian name ("place where water all goes in a hole"). Looking south. Photo: September 1936, G. H. C.

Figure 39 Limekiln on Onondaga limestone outcrop at Katsbaan corners on route 32 three miles north from Saugerties. This stood on south side of the road behind filling station west of the corners, but has been torn down. Looking southwest. Photo: April 1928, G. H. C.

solubility or to the fact that its open jointing made easy its plucking away by the ice sheet. In confirmation its huge squarish boulders are widely distributed eastward and southward by the glacier, even to the river shore, and appear at the most unexpected places, with their rare ferns. The Onondaga has more true outliers than the other formations, perhaps for the same reason.

The purity of the Onondaga limestone matrix caused it to be much in demand for quicklime. Many old kilns (figure 39) mark its outcrop; others have been torn down. It has also been used for a building stone, as in the Webber bridge on route 23-A. Its purity and its jointing again have been favorable to subterranean solution, resulting in some very impressive looking caverns.

Within our area the fauna of the Onondaga limestone has not been adequately investigated. The more easily recognized forms that it affords here are these:

1 the corals, *Synaptophyllum simcoense, Striatopora cavernosa* and *Favosites emmonsi?;*

2 the brachiopods, *Atrypa aspera* and *A. reticularis, Schellwienella pandora, Spirifer duodenarius, Leptaena rhomboidalis, Strophonella ampla, Stropheodonta demissa?, Delthyris raricosta, Chonetes lineatus?, Schizophoria propinqua;*

3 the gastropods, *Platyceras dumosum, Diaphorostoma turbinatum;*

4 the trilobites, *Odontocephalus selenurus, Phacops cristata;*

5 various bryozoans;

6 the fish tooth, *Onychodus sigmoides.*

Supplementary Note

[1] The applications of the name Onondaga, and the appellatives of the Onondaga limestone, have had a checkered history. With reference to what we now call the Salina series of Silurian age in central New York, Vanuxem in 1839 (page 249) used the expression "Saliferous group of Onondaga," which was repeated by Hall (page 290) in the same report. But on page 293, Hall varies this to "Onondaga saliferous group," thus to the technically minded first validating it as a stratigraphic term. Lower on the very same page (and again on page 309) Hall introduces "Onondaga limestone" for only a thin lower portion of the rock to the whole of which the name is now applied. For the major portion of our Onondaga he follows Vanuxem (page 275) in employing the latter's newly introduced name "Seneca limestone" (Hall, pages 293, 310), distinguishing it by its darker color from the "gray sparry crinoidal" Onondaga limestone below, with which he says it "in some instances alternates" (page 310). "Onondaga limestone" was first applied to the whole mass by Conrad in 1842 or Emmons in 1846, but does not seem to have had currency in this sense until used by Hall on the McGee map of 1894, apparently there including also the Schoharie beneath.

Instead, the widely accepted term was at first Corniferous and later Upper Helderberg limestone, while Onondaga continued to designate the Silurian salt-bearing series. The name "Corniferous" (or at first "Cornitiferous") refers to the content of hornstone chert and was introduced by Amos Eaton as early as 1823, and defined in corrected spelling by him in 1839 (American Journal of Science, 36, page 61). The name was taken up by John Gebhard jr and accepted by Mather in 1840 (page 237) but ignored by Hall (page 452) in the same report; he used Onondaga (perhaps in the present sense?, pages 418, 427), while Vanuxem (page 378) inserts it between the Onondaga and Seneca limestones, and thereafter in these early reports and the final volumes, one or both of these members were separated from it. (Emmons 1842, page 429, uses "Helderberg limestone" instead.)

"Upper Helderberg" was a term apparently originated by Hall in 1851 (Foster and Whitney's report, volume 2, page 163) in a breaking up of the old Helderberg Division and included the "grits" as well as the limestone, but it eventually settled down pretty much to the limestone (L. Lincklaen 1861, F. J. H. Merrill 1898), and had long acceptance.

Meantime the duplicate use of "Onondaga salt group" continued in full favor in these reports and all four final volumes of the survey and thereafter, there being no alternative term until J. D. Dana coined Salina in 1863. In Dana's last edition (1895, page 552) he still uses Onondaga period to comprise the Salina group and the Waterlime group (inclusive of Manlius) and retains the name Corniferous for our Devonian limestone. Seneca was appropriated by Clarke and Schuchert (1899, page 877) for their Senecan period of the Upper Devonian. To restore these names now to their value as of first publication would entail endless confusion. (See Darton, 1894, p. 401.)

13 BAKOVEN BLACK SHALE

Our knowledge of this rock in our area is derived from five small exposures; the rest of the way its outcrop is buried under Pleistocene clays and glacial deposits along the line of the Bakoven valley which its weakness has produced. This is the Marcellus valley of W. M. Davis (1882, page 29), for the Bakoven is of Marcellus age and was long supposed to represent the entire Marcellus of central and western New York.[1] This valley (figures 3, 74) marks the back line of the Kalk Berg range and lies between the last of the limestones (the Onondaga) and the high range of the "Hamilton" sandstones, the Hooge berg, now known to be also of Marcellus age.

The best and long famous exposure of the black shales (figure 40) is on the Kaaters kill at the Webber bridge of the Catskill-Palenville road (route 23-A). Approximately 75 feet of the shale and its thin calcareous layers are here revealed, resting directly on the Onondaga limestone summit; but the upper portion of the section is much crumpled, so that only 54 feet can be accurately measured (to the mouth of the first gully) nor is there any way of knowing how much more lies between it and the Mount Marion formation on the opposite side of the clay-filled Bakoven valley. Another but very small exposure, wholly isolated, is visible at low water about a half mile upstream, nearly opposite the old stone house[2] of the Abeels, and furnished interesting fossils from what may also be the Cherry Valley member. The beds here dip east (about 7° to 8°), opposite to the previous dip.

Another small exposure of the lower beds, much ice-crumpled, is on the east bank of the Kaaters kill at the 60-foot contour crossing below Quatawichna-ach.

The summit contact is seen at the "coal mine" below the falls at

Figure 40 Bakoven black shale at type exposure, overlying Onondaga limestone (tip shows at left) on upstream side of Webber bridge over Kaaters kill, Rip Van Winkle trail, four miles from Catskill. The shale extends to the top of the bank, and far to right (down dip); about 50 feet thickness shown in view. Looking east-southeast. Photo: April 1938, W. J. Schoonmaker.

Figure 41 "Hard beds" of lower Mount Marion formation in cut at sharp bend of Rip Van Winkle trail four and one-half miles (by road) west of Catskill. Incipient cleavage (close jointing) due to steepening of west dip on this east front of the Hooge berg, (see figure 3, taken one-half mile northeast). Dip is to left, 25° west. Looking north-northeast. Photo: April 1928, G. H. C.

Wesley Houck's farm, a half mile southwest of the bridge over the Kaaters kill at the Quatawichna-ach, but unfortunately the Mount Marion "brown" sandstones have here ridden up eastward over the shales, crushing and crumpling these and obscuring the normal relations. The drag zone in the top of the "black" shales is from three to five feet thick, with so much slickensiding of the shales as to have given the impression of anthracite coal. A tunnel was therefore drifted into the hillside, extending 50 feet northward along the contact, but of course no coal was found. Nevertheless some of the shale here and also at the Webber bridge is sufficiently bituminous to yield a flame when put upon a hot fire, but the appearance and odor of "oil" sometimes obtained upon fresh fracture is chiefly due to sulphur compounds of no commercial value. A little natural gas, however, was struck in the Marcellus (Bakoven) black shale by a waterwell drilling near Veteran.

About 35 feet of the Bakoven beds are seen in the brook at Houck's "mine." A few rods east, lower layers appear in the Kaaters kill, similar to those at the Abeel house. Dip calculations suggest that the total thickness of the Bakoven represented at Houck's may be about 100 feet, with about the same amount more to reach the Onondaga on the east of the Kaaters kill, or 200 feet in all. But if there is a roll in the strata here as at Abeels and if the zone there and here seen in the creek is the Cherry Valley member, then the total drops to 140 feet. Only some deep well records can solve this problem.

The basal one inch, in contact with the Onondaga at the Webber bridge exposure (sometimes covered by debris), is a calcarenyte of tiny crinoidal fragments, black in color like the shale and containing also comminuted fish remains with an occasional brachiopod shell seemingly reworked from the limestone beneath. The basal contact here shows this bed bonded into solution pittings in the limestone, indicating a distinct break and disconformity.

The fossils found in the Bakoven beds in our area, besides the lost specimens of goniatites, include:

1 the diagnostic brachiopod of the Marcellus, *Leiorhynchus limitare; Leptaena rhomboidalis,* also in the basal film, *Atrypa aspera;*

2 the pteropods, *Tentaculites gracilistriatus, Styliolina fissurella;*

3 a crustacean, *Estheria* (new species?);

4 fragments of plant stipes, roots, and Aphlebia(?);

5 the plant spore-case, *Protosalvinia huronensis;*

6 the fish tooth, *Onychodus hopkinsi;*

7 a possible arthropod podite.

Supplementary Notes

[1] It is not yet certain just how much of the Marcellus is here black shale. A concretionary zone at 35 feet (not 50 feet) above the base furnished to Marshall Kay and his students small umbilicate cephalopods (*Agoniatites* or *Anarcestes?*; unfortunately lost before identified) that suggest the equivalence of this zone to the Cherry Valley limestone member. If that is correct (and it is in keeping with the thickness and variability of the beds below this zone), then we have here 35 feet of the Union Springs member, possibly 6 feet referable to the Cherry Valley limestone member, and hardly enough additional thickness to account for all of the Chittenango member of the lower or typical Marcellus. See Chadwick and Kay 1933, p. 6; in which guidebook the name Chittenango is used by Kay for all these, prior to publication of Bakoven by Chadwick (1933, p. 480, 483).

[2] This house, visible from the highway (23-A) was the scene of one of Brandt's raids.

14 MOUNT MARION BEDS

Short of the mountains themselves, Mt Marion (figure 2) is the highest point in our map on the west side of the Hudson. In form and expression it is characteristic of the entire Hooge Berg range, which consists of the same sandstones and shales. Steep easterly fronts, often with a naked summit ledge, and long back-slopes (figure 3) are the outstanding features due to these west-dipping strata which rise into peaks 600 feet above sea level (754 feet on Mt Marion) and must exceed 800 feet in thickness (figures 41-45). They are the Hamilton beds of former writers, named from Hamilton in Madison county, but they are now known to represent but a part of the Hamilton group and to belong in its lowest or Marcellus division (see Grabau, 1917, p. 954, for definition of name; Cooper, 1930, p. 234, 1933, p. 200, for correlation with Marcellus). They seem to correspond roughly with the Cardiff or upper Marcellus of central New York, but have here passed shoreward into the brachiopod facies that the higher Hamilton beds have in their typical exposures there. This is the highest formation in the section to hold marine fossils for the whole length of our map area, those that succeed it being generally of continental origin, but it is allied with those beds above in being the first of the great delta deposits here seen.

The fossils of the Mount Marion beds are those diagnostic of the Hamilton group (in its limited sense, exclusive of the Marcellus) in central New York, but they here extend down into beds of similar lithic character that eastward from there have replaced the black Marcellus (mostly Cardiff) shale of the more western areas. In this we have the inauguration of those deceptive changes in facies, landwardly, upon the great delta deposits forming across New York State from the close of Onondaga time onward through the rest of the Devonian, of which we shall see more presently and which have

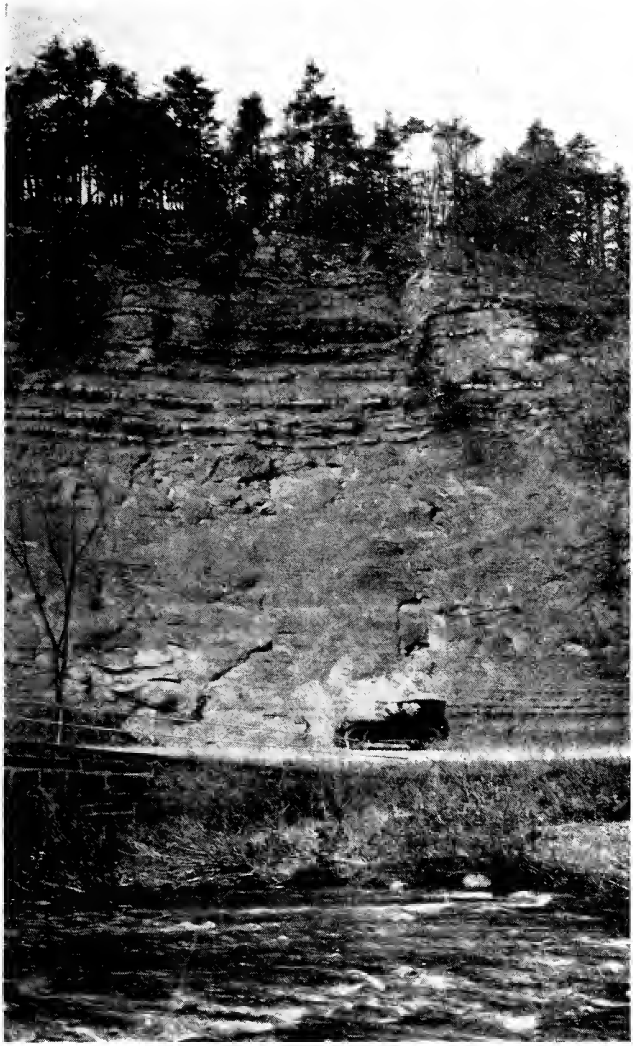


Figure 42 Mount Marion beds, middle portion, at bridge over Platte kill one mile west of Mt Marion railroad station on road to Highwoods and Daisy. Type exposure. Fine talus dug for road "gravel." Low dip away from camera. Looking west-southwest. Photo: April 1928, G. H. C.

Figure 43 Mount Marion beds, upper portion at High Falls of the Kaaters kill, eight miles from either Saugerties or Catskill. In summer flood, showing two heavy sandstone layers, with gentle west dip, that make the falls, and weaker layers in cliff above. Looking north. Photo: July 1928, G. H. C.

in the past so seriously misled us in the correlation of these beds. By actual field tracing, the Mount Marion beds have been proved by Doctor Cooper to be not "Hamilton" in the limited sense, as they were called from their appearance and fossils, but Marcellus, which in its typical expression as black shales they do not in the least resemble.

The name applied to these strata was given at the time when the Hamilton age of also the overlying Ashokan flagstones was first beginning to be recognized, so that a distinctive term became necessary. But it was little realized then that even the Ashokan is low in the Hamilton group instead of being its top. We owe much to the careful and discriminating field work of Dr G. Arthur Cooper.

No satisfactory subdivision of the Mount Marion formation has yet been attained, though such a subdivision (and correlation with the members distinguished farther west in the Cardiff) will doubtless be worked out in time. The lower layers for a thickness of perhaps 100 feet are nearly homogeneous, fine-grained, argillaceous, barren sandstone, whose bedding planes are often obscured by a strong vertical cleavage (figure 41) and which tend to break up into blocky pieces. The fresh color of this rock is bluish gray, becoming a tan or coffee-brown in the exposure. Fossils are practically absent from this portion, which is well seen at Miner falls, five-eighths mile west-southwest of Asbury, and at Mr Houck's "coal mine" three miles farther north. Another exposure is at the four corners one-half mile west of Mount Marion station and in the Platte kill immediately adjoining. It is just below this point that the Platte kill begins to flow across the alluvial flats that gave it its name (see note 12 on p. 19). Here, a single very fine specimen of *Palaeoneilo fecunda* was found in the blocky shale fragments in the road gutter. This member may represent the Chittenango portion of the Mount Marion, if such there be.

Three-fourths mile farther west on this road, toward Unionville, just over on the Kaaterskill quadrangle, is a high bank (figure 42) of the main mass of the Mount Marion formation, continuous with the Mt Marion hill itself on the north and extending along the west bank of the Platte kill at the iron bridge. Nearly 150 feet of beds are here exposed (the lower third showing downstream) though all are largely inaccessible in the steep face. The upper third of this exposure and the lowest 10 feet are full of sandstone intercalations up to a foot or more in thickness, but the general mass is an arenaceous or argillaceous shale. At the base of the middle third, by the roadside at the bridge, is a harder bench carrying many specimens of

Spirifer granulosus, besides *S. audaculus, Leptostrophia perplana* and an *Orthoceras.* The blocky blue shales above this afford on careful examination many species, chiefly pelecypods. In an hour's collecting, Professor Prosser (1899, page 294) secured 28 species from this cliff; the writer in about the same length of time obtained mostly additional forms. Another *Spirifer* bed lies in the water under the bridge. The forms collected here indicate a horizon not lower than the Bridgewater member of the upper Marcellus. These beds must lie about midway in the Mount Marion formation. In the creek bed at the lower end is a layer with large "staghorn" corals.

A zone intervening between the two just described seems to be represented along the northeast base of the mount itself, where the most common form in the massy dark blue shales is the small coral *Ceratopora.* A *Cyathophyllum* (*C. nanum?*), the goniatite *Tornoceras uniangulare,* a large frilled form of *Atrypa reticularis* like those from Independence, Iowa, and a variety (new?) of *Schellwienella pandora* were also obtained from these shales and thin interbedded sandstone, but fossils are rare. This zone is probably lower Bridgewater.

The higher part of the Mount Marion formation is seen at High falls (figures 43, 44) on the Kaaters kill, where rather heavier sandstones predominate for some distance upstream, but sandy blue shales form the gorge below the crest of the fall. It is these harder layers that make the ledges topping Mt Marion, Mt Potick (just over on Coxsackie quadrangle to north) and other hills of the Hooge Berg escarpment and their position suggests that they are in the Solsville sandstone member with the more shaly Pecksport overlying them and terminating the Mount Marion formation. The shales beneath the falls carry nests of *Chonetes coronatus* and about 30 other species, mostly very rare (see C. S. Prosser 1899, page 279), whereas the sandstones are often well filled with *Spirifer granulosus* and other forms.

The full list observed here in the sandstones is:

1 "fishes," *Cephalaspis?* and other ostracoderm? plates;

2 cephalopod, *Orthoceras exile;*

3 pteropod, *Tentaculites;*

4 gastropod, *Diaphorostoma;*

5 pelecypods, *Grammysia circularis, Modiomorpha* cf. *alta, Nucula bellistriata, Palaeoneilo* (or *Nucula lirata?*), and various aviculoids;

6 brachiopods, *Spirifer granulosus, S. pennatus, S. audaculus, S. acuminatus, Delthyris consobrina?, Camarotoechia congregata, C. prolifica, Chonetes coronatus, Stropheodonta concava?, Leptostrophia junia?, Schellwienella chemungensis* (*pandora?*);

Figure 44 Mount Marion upper beds just above High Falls, showing hanging tributary in distance, below falls. The gentle west dip causes the Kaaters kill to migrate west, undercutting the cliff along joint faces and making a gorge with only one wall. Jointing of fossiliferous sandstone bed well shown on left. Looking southwest from highway bridge. Photo: July 1928, G. H. C.

Figure 45 "Storm rollers" in topmost (marine) beds of Mount Marion formation on old road just west of new alignment, Unionville. There are two such cuts near together, in the roller beds, and the nonmarine layers begin a few rods west, at road three-corners. Note west dip. Looking about south. Photo: September 1936, G. H. C.

7 bryozoans;

8 crinoid, *Ancyrocrinus bulbosus,* also columns and brachials;

9 coral, *Pleurodictyum* cf. *dividuum?;*

10 worm burrows, *Taonurus velum,* and interlacing linear burrows not necessarily of worms.

From these higher beds, far up on the south slope of Mt Marion itself, came the marvellous trove of the starfish *Devonaster eucharis* described by Dr J. M. Clarke in 1912 (page 44). More than 400 specimens were recovered from less than a square rod of sandstone (see Clarke, 1912*a,* p. 115-18, pl. 14-16, for fuller account).

Still higher, close to the summit of the formation, besides abundant shells of *Camarotoechia* and *Chonetes vicinus,* the pteropod *Tentaculites bellulus* forms a widespread layer an inch or more in thickness in what may be the Pecksport member. In the topmost beds above High falls, south of the highway (and also on the road northward), are seen the curious so-called "concretionary" masses better known as "storm-rollers" and always found to mark nearshore conditions and impending transition to continental deposits, made on the land. The finest display of these on our area is, however, in the two road cuts (figure 45) through rock noses at Unionville, between the new and the former road junction. These are worth careful inspection, in the effort to understand and explain how such structures could be formed, for no unimpeachable explanation has yet been suggested. They are not concretions, at least, as all now admit.

The Mount Marion fauna constitutes a long list for any one formation in our region, rivalled only by the New Scotland. The following are known:

1 the "fish," *Cephalaspis?* (plate), and other ostracoderm? plates;

2 the annelid burrow, *Taonurus velum;* and other burrows;

3 the cephalopods, *Tornoceras uniangulare, Orthoceras exile, O. subulatum, Geisonoceras?* sp., *Spyroceras crotalum;*

4 the pteropods, *Tentaculites bellulus, Conularia aff. undulata;*

5 the gastropods, *Bucanopsis lyra, B. leda, B.* sp., *Trepospira rotalia?, Bembexia sulcomarginata, Diaphorostoma lineatum, Platyceras carinatum?;*

6 the pelecypods, *Modiella pygmaea, Elymella nuculoides, Palaeosolen siliquoideus?, Cypricardinia indenta, Orthonota undulata, O.(?) parvula, Prothyris lanceolata, Schizodus appressus, Paracyclas lirata, Buchiola retrostriata, Sphenotus truncatus, S. subtortuosus?, Grammysia bisulcata, G. magna, G. circularis, G. alveata, G. constricta, Nyassa arguta, N. recta, Palaeoneilo constricta, P. plana, P. fecunda, P. emarginata, Nuculites triqueter, N. oblongatus, N. cuneatus?,*

Nucula bellistriata, N. varicosa, N. corbuliformis, Cypricardella tenuistriata, Modiomorpha concentrica, M. mytiloides, M. macilenta?, M. cf. *alta, Goniophora hamiltonensis, Plethomytilus oviformis, Leiopteria dekayi, Actinodesma erectum, Limoptera obsoleta, Actinopteria boydi, Aviculopecten princeps;*

7 the starfish, *Devonaster eucharis;*

8 the crinoid "root," *Ancyrocrinus bulbosus,* crinoid brachials and columnals;

9 the brachiopods, *Reticularia fimbriata, Delthyris consobrina?, Spirifer pennatus, S. audaculus, S. granulosus, S. acuminatus, Athyris* cf. *spiriferoides, Atrypa reticularis* variety, *Tropidoleptus carinatus, Camarotoechia congregata, C. prolifica, C. sappho, Strophalosia truncata?, Chonetes coronatus, C. vicinus, C. scitulus, C. lepidus, C. setiger, Leptostrophia perplana, L. junia?, Stropheodonta concava?, Schellwienella pandora, Schizophoria impressa, Rhipidomella vanuxemi, Lingulodiscina* sp., *Dignomia alveata, Lingula densa, L. compta;*

10 bryozoans not identified;

11 the corals, *Ceratopora distorta, C. dichotoma?, Eridophyllum?* sp., *Cyathophyllum nanum?, Cystiphyllum* sp., *Zaphrentis* sp., *Pleurodictyum dividuum?;*

12 the boring sponge, *Clionolithes radicans?;*

And very rarely, carbonized plant stems or stipes; also simpler forms (rootlets?) that have been called "Psilophyton."

15 ASHOKAN FLAGSTONES

The old flagstone quarries (see Dickinson, 1903, map on pl. 2 and p. 17-34) extend along the west flank of the Hooge berg from Dutch Settlement (Ruby) northwards, by Highwoods, Fish Creek (Vanaken Mills), Unionville (Centerville, Veteran), Quarryville and Great Falls (High Falls) to the Catskill-Lawrenceville road on Bethel ridge and the "Five-Mile Woods" at the north limit of the quadrangles. The successful quarries have, in general, been kept near to the main roads and to the outlets eastward through the Hooge Berg range, and their absence in the vicinity of the Catskill-Palenville road (route 23-A) has been due to the morainal overburden that here conceals rock for some distance. A higher belt of flagstone quarries lies to the west, in the red beds, extending up almost to the summit of Plattekill mountain, as described beyond.

The change from the nonlaminated and generally less resistant sandstones of the Mount Marion formation, with their marine fossils, to the laminated arkosic "bluestones" or graywacke flags (figure 46) that carry only fragments of land plants, is a marked zone, indicating a change in the conditions of deposition. Although there are quarries also in the uppermost Mount Marion at Ruby, Highwoods and Unionville, the quarrymen recognize the difference in character of the beds and do not put the stone to the same uses. The interbedded shales change from blue to olive and more blocky, weathering reddish or brown so as to be suggestive lithically of the Upper Devonian "Chemung" facies beds in central and western New York, though lacking the fossils. These shales and flags constitute the first of the "continental" sediments in our area, and they differ from the overlying formation (the Kiskatom) only in showing no red shales. In fact, there is reason to believe that the line of division based on the local incoming of the red color is not a constant one across our area, but that the reds keep appearing lower down toward the north, especially where the line veers so suddenly eastward north of Kiskatom.

The converse of this is the retreat of this line southwestward from Highwoods to Zena and then to west of West Hurley (the relocated village) just off our map. The typical Ashokan flags lie south-southwest from West Hurley, around the east end of the Ashokan reservoir and in strike with the western part of this widened belt at Zena. Unless there are rolls in the strata that our field work has failed to discover, the typical Ashokan must be wholly or in large part represented by red-beds from Highwoods north, and what we are here calling the "Ashokan" throughout the same stretch must correspond to marine Hamilton beds above the Mount Marion at Stony Hollow and Bristol Church southeast of West Hurley, which are in strike with the eastern part of the flags at Ruby and with our "Ashokan" belt at Highwoods. The fossils in these beds at Bristol Church include, in addition to 14 species of the Mount Marion fauna, also the following not yet known in the Mount Marion (see Prosser, 1899, p. 296-97): (1) the trilobite, *Cryphaeus boothi;* (2) the pelecypods, *Palaeoneilo maxima, Prothyris planulata, Cypricardella complanata;* (3) the brachiopods, *Cyrtina hamiltonensis, Schellwienella chemungensis, Rhipidomella penelope?, Orbiculoidea* sp. "Storm-rollers" are conspicuous in this section.

Pebbly beds near or at the base of the flagstone series occur at Ruby and also on the road along the west side of Timmerman's hill, a half mile south of route 23-A, perhaps elsewhere. Darton (1894, page 494) reports "thin streaks of quartz conglomerate . . . at several localities interbedded among the flags, notably in the lower beds of the Jocky Hill region." Jockey Hill lies just south of the Saw kill, off our map, but in the same basal portion of the flags. These pebbles are suggestive of a disconformity between the Mount Marion and our

"Ashokan," (see Chadwick, 1927, p. 160). On the other hand, the behavior of the flagstone belt on the map, between Kiskatom and Vedder's hill, suggests that the continental flaggy facies may there invade the upper Mount Marion of farther south, at the same time that the Kiskatom reds invade the flags from above.

In short, the mapping of both upper and lower limits of the "Ashokan" flags has, for the time being, been necessarily done on lithologic features, which so often have proved misleading in these delta deposits with their facial changes; this mapping must therefore be accepted with caution, as also the use of the name Ashokan for the belt as depicted except at its southwest expansion.

The perplexity felt by writers over the identification of these strata is mirrored in the variety of names and correlations that have been employed.[1] In the dismemberment of the original Catskill Mountain series, which had included all our rocks above the Onondaga limestone, they at first passed as "Chemung," or else as "Portage." As early as 1894, however, Mr Darton (page 494) assigned them to the Hamilton; but in 1899 (pages 290-94) Professor Prosser identified them with the Sherburne sandstones of the Chenango valley in central New York, on the basis of supposed continuous field tracing and mapping. Returning to the belief in their Hamilton age, Doctor Grabau gave them in 1917 (page 954) the local name of Ashokan flagstones from the exposures and quarries around the Ashokan reservoir, especially those opened for stone for the Ashokan dam at Olive Bridge. It has remained for Doctor Cooper to show that these flagstones are lower instead of upper Hamilton, far below the Chemung (which actually does not reach our mountains' tops except possibly the summit of Slide far southwest of our area).

The thickness of the "Ashokan" flagstones in the belt from Highwoods to Kiskatom appears to be about 300 feet. At Zena, on the south, it is probably much thicker, approaching the 500 feet of the type section just over the edge of the map, and this by upward extension at the expense of the red Kiskatom. At the north edge of our map it seems to be thinner—in fact, has but little expression on the Cats kill, with no flag quarries north of Vedder's hill, but appears to lose itself in the downwardly encroaching reds near Puffer's corners (above Leeds, on route 23) where the highest marine fossils (spirifers) have but small thickness of flags between them and a heavy mass of reds. These uppermost marine sandstones are themselves very flaggy and nearly barren of fossils, in the Valje Kilje just under the highway, which now covers the exposures once visible beneath the old railway bridge.

The question of the exact age of our "Ashokan" is an interesting one, to which Doctor Cooper has not yet given us the answer. There is a chance that it may still be uppermost Marcellus (Cardiff) as Cooper concludes (1934, p. 5) "from thicknesses alone," namely Solsville and Pecksport (which we had thought to recognize in the upper Mount Marion). Other considerations suggest that it may be lower Skaneateles (Mottville, Delphi, perhaps Pompey, members), or that this may be the age of the type Ashokan if distinct from ours. That our belt may be partly each, Cardiff below and Skaneateles above, is hinted by a marked break or possible disconformity in these beds exposed by the roadside on the west of the Kaaters kill a mile or so north of High Falls, but any attempt to trace and map this break would be futile as there is no difference in character of the beds above and below it. Fossils do not help us. In the upper beds a half mile northwest of Quarryville one thin stratum of coarse sandstone in the roadway is filled with vertical burrows of the "worm" (phoronid?) *Scolithus,* indistinguishable in appearance from the familiar Scolithus beds of the Portage sandstones in western New York. In a brownish shale seam an inch thick in one of the eastern quarries near the base of the flags, a mile north of Quarryville, a tiny ostracod was obtained, a smooth form of no diagnostic value, but no other fossils save plentiful plant fragments. All these plants are of widespread Hamilton forms and give no aid in detailed correlation, though they are common everywhere in the flag series but mostly not so well preserved as in the upper Kiskatom and higher red-beds flags. Either they have been carried farther from their haunts, or they were less advanced and more fragile kinds; they seem in general to have been smaller.

Difficulty was experienced in mapping the basal limit of the flags on the west flank of the Hooge Berg peak at south end of Vedder's hill. The slope is strewn, far up, with loose masses of these beds, disrupted by the ice sheet. The expected (physiographic) boundary would follow the brook at the western base of this hill, where our line is drawn.

The only Ashokan fossils to be expected in our area are:

1 stipes of such plants as *Archaeopteris, Archaeosigillaria* and other forms listed under the Kiskatom flora, and rootlets(?) called "Psilophyton";

2 the (phoronid?) burrow, *Scolithus verticalis;*

3 the coiled burrow(?) described by Mather 1843, page 319, and named *Planolites clarkii* by Prosser 1899, pages 149-50, plate 6;

4 occasional ostracods.

Supplementary Note

[1] They are a part of division number "5. Grey grits and bluish shales, among which are the flag stones," of the Catskill Mountain series of Mather 1840, page 227, of which he states (page 232): "The stratum of flag stone is from 700 to 1,000 feet above the Helderberg limestone series." In Mather's detailed section in 1841, page 81, they constitute only No. 121 "Gray slaty grit, laminae of deposition distinct," whereas his overlying beds of "Gray slaty grit," No. 116-20, unknown to him actually contain and overlie red shales on the line of his section and are therefore mapped in our Kiskatom formation. It is these very beds, however, that may be the true Ashokan flagstones as above explained. In this table, Mather assigns no age, but by putting them next above the "Ithaca" of No. 122 leaves us to infer from his list on page 77 that they belong to the "3. Chemung group of Professor Vanuxem." On page 83 he says that this No. 122 "Ithaca to Marcellus" is probably 1,000 feet thick, and since (page 81) it constitutes a single "terrace" it is clear that it is the Mount Marion and Bakoven, not inclusive of any of the flagstone series. The same tabulated section, with the numbers of these beds raised by ten, is given by Mather in 1843, page 305, where No. 131 is our Ashokan, and the same comments apply. (See also pages 317-19). In Mather's six cross-sections on plates 45 and 46 (of 1843) we have a choice between "Ithica (sic) and Chemung group" on three of the sections and "Portage and Chemung groups" on the others, for the strata between his Erie division (Hamilton) and the red Catskill division.

Nevertheless, on the geological map of 1842 (and 1844) accompanying these final reports, the lower flagstone belt is included in the color for the Hamilton Group, while the Portage and Chemung color occupies practically the position of the Kiskatom red-beds. Mather's sections showing Portage and Chemung are copied.

Emmons in 1846, page 192 and plate xxi section 5, makes them "Chemung group" and lying directly upon the Hamilton, a succession accepted by Hall in 1859 (see pages 48, 51). In 1861, however, Ledyard Lincklaen referred them (page 68) to the Portage Group, in which he was followed by Hall in 1868, page 31. But in 1873 (page 7) and 1878, page 129, Hall put the "bluestone of the Hudson valley" into the Hamilton, a view that was apparently held by Professor Prosser as late as 1894 (page 56), was definitely that of Darton in 1894, as above noted (see pages 491, 494), who says they (his "Lower Flag series") are "in the main of the upper Hamilton group," and they were so mapped on the McGee map of 1894.

But in 1899, as noted, Prosser in his largely reactionary work, blinding his eyes to the significance of the facts he recorded, put these beds into the "Sherburne" of Genesee age (whose real equivalents are up around the Mountain House) on lithologic grounds, showing them on his map as "Ithaca and Sherburne" but naming only Sherburne in the text (pages 276-81, 289-98) with the explanation (pages 313-14) that the Ithaca had become red-beds included with the "Oneonta."

In spite of this, the Merrill map of 1901 labels them "Ithaca," though there is a chance that this was intended to cover the Sherburne as in Clarke 1903, page 24. Grabau in 1906, page 303, called them Sherburne, but renamed them as we have seen, in 1917, and corrected their assignment. See also Grabau 1919, pages 468-70. Like other aboriginal names, A-sho-kan really carries no accent, or an equal accent on all syllables, though the present tendency is to accent -sho-.

In their type area, south of ours, the Ashokan flagstones are given a thickness of 500 feet (Darton, 1894, page 491, also 494, misprinted "Upper Flag series") and are said to contain "several thin, discontinuous streaks of light greenish and reddish shales" in their upper part. Eastward increase of these reds on our area would put such strata into our Kiskatom, as before suggested. It is clear that our 300 feet of flags below the reds can include but a part, if any, of the type Ashokan.

Figure 46 "Ashokan" flagstones at waterfilled old quarry southwest of Quarryville, furnishing only land-plant fossils. Shows low westerly dip and good jointing, with blocky shale seams. Looking northwest. Photo: April 1928, G. H. C.

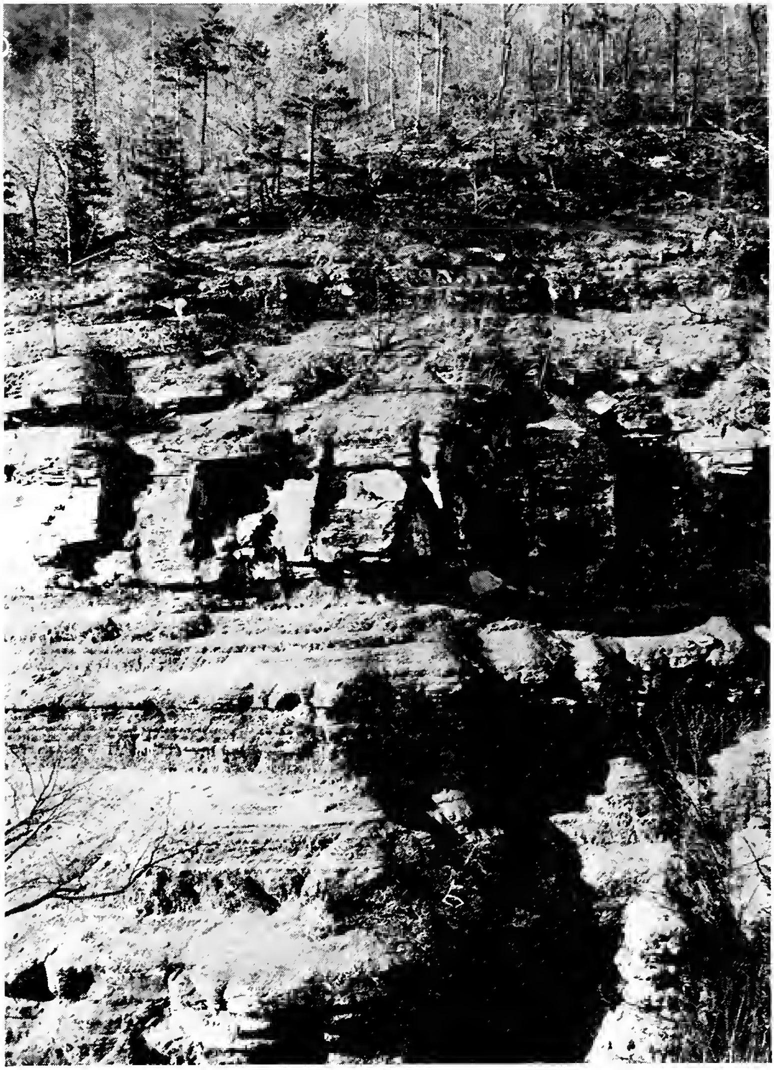


Figure 47 Kiskatom red-beds at the "High Rocks," a postglacial chasm of the Kaaters kill in Kaaterskill clove, as seen from the Rip Van Winkle trail a mile west of Palenville. Middle beds (of about Ludlowville age). West dip about 3°. Shales are red. Looking north. Photo: April 1938, W. J. Schoonmaker.

16 KISKATOM RED-BEDS

The mile and a half in thickness of red-beds (figures 8, 9, 47, 77) that succeeds upon the "Ashokan" flagstones was formerly considered as wholly of Upper Devonian age and more or less indivisible, though occasionally someone glimpsed the idea that it might extend down into the Hamilton (Middle Devonian). As it constituted both the supporting plateau and the peaks and ranges of the Catskill mountains, it went under the comprehensive and ill-defined name of "Catskill formation" or Catskill group,[1] of which it must of course contain the typical expression.

Recent studies have demonstrated beyond controversy that these red-beds are not all of one age, and that they are subdivisible into members (formations) that may be traced continuously into definite members of the marine stratigraphic succession farther west in New York. The beds here termed the Kiskatom reds, with a thickness of certainly 2300 feet, prove to be of Middle Devonian, Hamilton, age.[2] They are, at least approximately, the beds formerly taken here to be the Oneonta, of Naples age (lower "Portage"), though early mapped as "Chemung."[3] Moreover, they are the beds to which the name "Catskill" was first applied among these Upper and Middle Devonian red strata.

The Kiskatom beds do not reach quite up to the rim of the Catskill plateau, while a fair portion of their thickness extends outward from the mountain foot into the Hudson valley (figure 77). Very characteristic of the Kiskatom belt, as indeed of all strata from the Mount Marion up, is the development of a succession of terraces, facing eastward in more or less vertical cliffs, with straight long fronts following master-joints, and with low westward dips beneath the next such terrace. Even on the steep mountain sides a light snowfall brings out the steplike flights of ledges (figure 5; compare frontispiece of Chadwick: Bulletin 307). These cliff or ledge faces have undoubtedly been much accentuated by glacial scrubbing and plucking and they run lengthwise of the ice flow. Each is commonly capped by sandstones or flags as gray as those of the Ashokan but often of coarser grain and more notably cross-bedded. Some of the sandstone is red, however, and banks of bright red shale nearly always bottom the cliffs.

A heavy bed of red shale in the lower part of the formation was formerly quarried in a large way on the east of Cairo Roundtop, north of our map, for the manufacture of vitrified paving brick in the now abandoned plant at Catskill village (all traces of which are fast disappearing). Quarries have been opened in the sandstones, especially the flaggy ones, at many levels, both in the more easily reached ledges of the valley and in the almost inaccessible ones on the steep front of the mountain plateau. Almost none of these are in operation today. In these quarries, particularly those far up on Palenville Overlook, beds of a few inches filled with fossil plants occur and sometimes afford good material for study. The best collecting is usually in the quarry dumps. Fish remains must also exist, as they have been found in the neighboring Kaaterskill clove. On the quarry road up Palenville Overlook, at an elevation of about 1200 feet above sea, a large block was found containing a dozen or more well preserved and large specimens of the freshwater mussel shell, *Archanodon catskillensis*. The adjoining quarry yields a profusion of plant remains, including stems, straplike leaves and fruit cones.

Besides the land plants and the mussel already mentioned, and the "fish beds" reported by Sherwood (1878, page 347) in the lower part of the clove, the shales show many "fucoidal" markings due to burrowing worms of the ancient mud flats. In areas both north and south of our map, a zone in the lower part of our Kiskatom (but there just underlying the locally lowest reds) carries the little phyllopod crustacean *Estheria membranacea* and two tiny species of ostracods called "Beyrichia." (See Prosser, 1899, p. 257-59, 268; Clarke, 1901, p. 107, pl. 4).[4] The horizon of this zone should be well up in the reds near Palenville and is not likely to be discovered in such facies, probably passing farther west deep under cover in the mountains.

The cornstone layer reported by Mather (1841, page 81, No. 119; 1843, page 305, No. 129) as "Limestone, brecciated and conglomerate, two feet," has been found by me in or near the base of the Kiskatom beds a short distance northwest of Kiskatom (corners), and at that time looked upon as marking a possible disconformity in the bottom of the then supposed "Oneonta," (see Chadwick 1927, p. 160).[5] But cornstones occur at various levels in these continental strata, being thus without proved stratigraphic significance except that they are usually near the ancient shore line.

The fossils of the Kiskatom red-beds (see Mus. Bul. 307, page 91) have been listed for their whole geographic extent as follows:

1 the land plants, *Archaeosigillaria vanuxemi?, Sigillaria(?) gilboensis, Archaeocalamites inornatus?, Archaeopteris hallana, A. minor, A. obtusa, Eospermatopteris textilis, E. erianus, Rhachiopteroides punctatus, Psilophyton princeps;* the spore case, *Protosalvinia huronensis;*

2 the fresh-water pelecypod, *Archanodon catskillensis* (or new species?);

3 the "worm burrow"(?), *Planolites clarkii;*

4 the phyllopod crustacean, *Estheria membranacea;*

5 ostracod crustaceans, *"Beyrichia"* sp. (two kinds);

6 the "fishes," *Bothriolepis minor?, Dinichthys* cf. *tuberculatus, D. pustulosus, Sauripterus taylori(??), Holoptychius americanus?.*

Supplementary Notes

[1] It was only as it gained currency that this name became ill-defined in the minds of writers, widely extended over any beds of similar color in the higher Devonian and bandied about in its home ground. The original definition was the most clean-cut of any formational description that appeared in the early writings and is a model to follow today. The history of this name "Catskill" is given at great length in N. Y. S. Mus. Bul. 307 (Chadwick, 1936) in order to relieve this present report of a prolix discussion.

[2] As far back as 1885, Hall (p. 517-18) considered (see also his tabulation) that the Oneonta reds embraced down into the upper Hamilton, which is not true, however, for the typical Oneonta. In 1900 (p. 594), H. S. Williams said that in eastern New York "as low as the horizon of the Hamilton fauna the sedimentation assumes the arenaceous and sometimes the reddish character of the typical Catskill rocks." In 1902 (p. 420): "The Catskill formation begins at the horizon of the Hamilton in the eastern sections." And in 1910 (p. 285), he says of Catskill sedimentation: "In eastern New York it began while the Hamilton marine fauna was still present and cut it off, bringing in estuarine conditions with a brackish water and land fauna and flora."

The differentiation of these Hamilton red beds, with proposal of the name Kiskatom, was made by Chadwick in 1932, p. 7, as reprinted in Chadwick 1936, p. 72. This was further amplified in Chadwick 1932(*a*), p. 12, 77; 1933, p. 86-87; Chadwick and Kay 1933, p. 4, 6-7; Chadwick 1933(*a*), all; 1933(*b*), p. 102-3; G. A. Cooper 1934, p. 5; Chadwick 1934, p. 11; 1935, p. 134 figure; 1935(*a*), p. 822; (*b*), p. 857; Chadwick 1936 (use index). The name is pronounced kis'ka-tom.'

[3] The Kiskatom and Kaaterskill constitute the original "Catskill division" of Mather 1843, p. 299-316, technically preceded by Vanuxem's "Catskill group" of 1842, p. 186-94, also p. 16, which we now know does not correspond or even overlap with Mather's Catskill. On the 1842 (1844) geological map, however, essentially the whole Kiskatom is mapped as "Chemung" and the Catskill color is confined to the higher rocks that Mather had assigned (p. 303) to the "Coal formation" (Pottsville conglomerate). Ashburner 1888 also maps here a belt of "Chemung." Hall in 1863 (p. 108; see also 1862, p. 381) definitely assigned these red beds "below the elevation of the Mountain House" to the Chemung. In general, though, the name Catskill stuck to these beds as well as the overlying ones in spite of some recognition of supposed Chemung equivalency. But in 1885 (p. 518), Hall decided that the Chemung had thinned to nothing in the Catskill front, assigned these lower reds to the "Oneonta" and asserted a mixed upper Hamilton and "Portage" age for them. The name "Oneonta" then adhered to them until that of Kiskatom was proposed (1932).

[4] This zone has been traced by me over a considerable area east of Oak Hill and has been found by Doctor Ruedemann as far north as Rensselaerville, at the falls. It recurs with exactly the same expression and contents near the aeration plant at the Ashokan dam, but there has reddish beds below it in what might be considered the top of the Ashokan according to Prosser's mapping. *Estheria membranacea*? was collected by me also in the old summit cut of the Delhi and Andes Railway grade in the western Catskills, a very much higher stratigraphic position.

[5] See Chadwick 1927, p. 160. Mather (1841, p. 83; 1843, p. 307) says that this bed "is found over a great area in the Catskill mountain region, although rarely more than one foot thick," and that "it is a good reference stratum."

He further states (*ibidem*, and 1840, p. 228; 1843, p. 314) that it carries small quantities of metallic ores "in various parts of Greene, Ulster, Sullivan and Delaware counties, but the stratum was nowhere more than eighteen inches thick. It was generally a calcareous conglomerate or breccia, formed of small masses of limestone, imbedded in a reddish or brownish paste of the underlying shale bed.* / *This stratum, when exposed to the weather, becomes more or less porous and cellular, from the solvent action of the water upon the calcareous ingredient. Considerable quantities of it are seen scattered over the fields and it has acquired the name of *firestone* in some of these counties, in consequence of its resisting the effects of common fires, not cracking to pieces." Cornstones in the red beds are reported also by Vanuxem 1842, p. 186. The distribution reported shows that they are at no one constant level. The source of the lime that they contain is an interesting problem.

17 KAATERSKILL SANDSTONES

Rimming the steep trench of the Kaaterskill clove in heavy ledges (figure 50), making both the Kaaterskill and Haines' falls and extending thence to the Mountain House and beyond to the nearer ledges on North mountain (Artist's rock, Prospect rock), is a group of three sandstones or flagstones (figure 48) of the usual "Catskill" type, gray to reddish in color and often with some white quartz pebbles. Red shales up to 50 feet thick are interlarded (figure 49). The series terminates upwards against a heavy (pebble or cobble) conglomerate that may bear slightly unconformable relations to it. To this series of beds, with a provisional thickness downward of about 250 to 300 feet, Dr Bradford Willard has given the highly appropriate name of Kaaterskill sandstones. It is our present belief that these strata are of the age of the Tully limestone of central New York. (See Willard, in Chadwick, 1936, p. 74.)

These beds, with the conglomerate overlying them, rim also the Plattekill clove and in fact they are the rimrock of the whole eastern front of the plateau, capping the quoin of the steep drop into the Hudson valley on all the spurs. Tracing of them across the southern stretch, from Overlook mountain westward, is not so easy and may not have been done correctly. The suggestion of unconformity is found in both of the cloves, the vertical interval between the conglomerate and the rimrock appearing to increase westward towards their heads. Although the mapping has been done on the base of the conglomerate, it is possible that this increment belongs with the Onteora rather than with the Kaaterskill. In view both of the now demonstrated relation of the Tully to the Hamilton, as Middle Devonian, and of the uncertainty as to the division line locally, the Kaaterskill is mapped by us along with the Kiskatom, just as Mather united these.

The fossils of the Kaaterskill have not been studied. Plants are present, of course, but poorly preserved. In my boyhood I found near the Laurel House, loose below the level of the conglomerate, but did not retain, an aviculoid shell (probably an Actinopteria) that may

Figure 48 Kaaterskill (Tully?) sandstones at the famous Kaaterskill falls, showing full amount of short post-glacial gorge. Remnants of winter ice. Note great irregularity of bedding and rapid alternation from thick red shale to massive gray sandstones. Looking north of east. Photo: April 1915, G. H. C.

Figure 49 Thin bed of red shale, high enough for path, beneath middle Kaaterskill sandstone at the Kaaterskill falls. Shows roof spalling and the irregular contact of the gray sandstone upon the red shale. The sags of the sandstone are pebbly. Vertical drip-marks in the rotting shales. Looking north. The roof projects about 70 feet! Photo: April 1919, Atwood G. DeCoster.

have come from the outcrop. Inasmuch as both the Tully and the overlying Sherburne ("Ithaca") are filled with marine fossils no farther away than Hardenburgh falls, Gilboa and the Manor Kill valley (see Cooper 1933, p. 541, 544; 1934, p. 7, 8; not likely true Ithaca), some stray shells may yet be found here in the most unlikely looking rocks at these horizons. Similarly, pelecypods and even brachiopods have been discovered in the midst of the Kiskatom red-beds and in typical flaggy to pebbly "Catskill" sandstones as far east as Durham and Cornwallville, on the quadrangle next north. The search is worth making.

18 ONTEORA RED-BEDS

Rough tracing of the base of the Upper Devonian around the north end of the Catskill mountains from Gilboa (in the Schoharie valley) via the Manor kill, together with expected thickness increase in the Hamilton beds, has led to the recognition of the "puddingstone" conglomerate or "third ledge" above the Catskill Mountain House as the probable commencement of Upper Devonian sedimentation here. This is the point that Mather in 1843 (page 303), mistaking the puddingstone for the Pottsville conglomerate at the base of the Coal Measures, made the top of his original Catskill division. It is the point selected by Hall in 1863, page 108,[1] for the bottom, instead of the top, of the Catskill group, the reds below being correlated with the marine Chemung. In 1885 (page 518), having decided that the Chemung failed to reach the Catskill front, Hall made it the line between the Catskill above and the Oneonta below. The former was presently correlated, in turn, with the Chemung, (Darton 1893). The successive shifts in the supposed ages of the beds above and below this line may be tabulated thus:

Mather 1843	*Hall* 1862-63	*Hall* 1885	*Darton* 1893	*Chadwick* 1934-36
Pottsville	Catskill	Catskill	(Chemung) note	Genesee (Onteora)
Catskill	Chemung	Oneonta	(Portage)	Tully (Kiskatom)

Thus these writers picked here what seems to be the most marked lithologic break in the stratigraphic succession across this interval. But this was not the tracing of Darton (1893, page 207), who brought his Chemung around below the "red shale bed 25 to 30 feet in thickness" next under the Mountain House ledge, and carried its base about 250 feet lower, or about 490 feet lower than the conglomerate. From Sutton's gap southward along the Catskill front Darton's "Chemung" was, however, actually uppermost Hamilton (upper Moscow); therefore his bringing it just under the Kaaterskill (Tully) beds checks almost exactly with our own tracing, in this same stretch. Darton's line, 340 feet below the Mountain House, was adopted on the 1894 and 1901 geological maps of the State.

From the base of the conglomerate up to the base of the heavy Stony Clove sandstones there is a vertical interval of about 1100 to 1200 feet, and from the base of the Stony Clove beds to the base of the white Slide Mountain conglomerate there is an interval of about 3000 feet. To these two subdivisions of the "Catskill" of Hall and later writers have more recently been applied the early names for these mountains, the aboriginal name of Onteora (figures 50, 52, 59) to the lower division, the Dutch name of Katsberg to the higher one. Regardless of what happens to the much disputed name Catskill, a misnomer for the mountains in any event, these earlier and more correct names are available for its stratic members (see Chadwick, 1936; 1933, p. 482-83, for history of these).

The Onteora red-beds differ little from the Kiskatom red-beds except for the incoming of substantial conglomerates, especially at base[2] (figure 51), and the somewhat larger proportion of sandstone and the lesser amount of shale. So far as known the shale is always red, containing none of the occasional blue-gray (marine?) or even the green layers that occur in the Kiskatom. Quarriable flagstones continue upward throughout the Onteora, (see H. T. Dickinson 1903, plate 2, map), and have been worked to the summit of Plattekill mountain.

The 1150 feet (more or less) assigned to the Onteora formation is not as much thickness as would be expected here for the equivalents of the combined Sherburne (Genesee) and Oneonta (Ithaca) formations, if these beds thicken eastward as do the other members in this delta deposit. Possible alternative correlations will be discussed under the Stony Clove sandstones. It will be well, nevertheless, to consider at this time the nature of the contact between Middle and Upper Devonian across New York State. From Central New York to Lake Erie this contact exhibits a markedly disconformable relation; the underlying Tully limestone is cut out westward and then parts of the upper Hamilton are pared away, while the overlying Genesee loses eventually all of its thick bottom member (Geneseo black shale) and thus the middle Genesee (Genundewa limestone) comes to rest on a level some distance down in the Moscow shale of the Hamilton. Eastwardly the Tully persists and thickens into sandstones (Gilboa, Kaaterskill), but according to Doctor Cooper the 300 feet of Geneseo and Sherburne at Ithaca (after thickening in the intervening territory) have dropped to 206 feet of Sherburne in the Susquehanna

Figure 50 Kaaterskill sandstone rimming Kaaterskill clove on north side at Sunset rock (seen from east side). Doctor Alling on brink. Kaaterskill clove below, with the corresponding ledge on far side at left. Haines' falls, where this layer crosses at head of the clove, concealed behind tree in middle. East peak of East Jewett range in background, with Parker (Onteora) mountain to right, and Colonel's Chair of Hunter mountain faint to left. Looking west-northwest. Photo: April 1919, A. G. DeCoster.

Figure 51. Twilight Park conglomerate in Twilight Park, one-half mile southeast of Haines' corners, Haines' Falls. The steps have been built up through a natural joint crack. Looking southeast. Photo: April 1938, W. J. Schoonmaker.

valley. In that case, the entire Sherburne might disappear from the section before reaching the Catskill front; whereupon the Onteora would consist wholly of the Oneonta and this would fit closely to the expected thickness here of that formation alone. But the small wedge of sandstones that seem to intervene between the Kaaterskill and the conglomerate at the upper ends of the two cloves might be the feather edge of the Sherburne.

From the new road cut west of Beach's corners, in the northwest corner of our map, came the block of rock with excellently preserved stems of the early tree, *Archaeosigillaria primaeva* ("fossil snakes") that now supports the bronze tablet at the Catskill end of the Rip Van Winkle bridge. This plant was originally described from the "Genesee" beds of Pennsylvania, of nearly the same age as our Onteora beds that furnished this block. Rather finely preserved plant material has also been obtained from the quarries on the east end of Mt Zoar at East Windham, about seven and one-half miles northeast by north from Beach's corners, which are at a lower level in the Onteora and presumably are Genesee (Sherburne) in age. There is still much work to be done in collecting and studying the flora and fauna of the Onteora beds. The list that follows represents all that has been published on the entire area occupied by both Onteora and Katsberg divisions with also all land plants found drifted into their marine equivalents. Complete separation of the lists from these two formations is not possible at this time on account of indefiniteness of locality and horizon on a number of the reported finds. Those found *only* in the Genesee (Sherburne) portion of the Onteora are starred. (See Mus. Bul. 307, page 91.)

There may be expected in the Onteora and Katsberg beds:

1 the land plants, *Archaeosigillaria primaeva, A. vanuxemi, A.? gaspiana, A.? simplicitas, *Cyclostigma affine, *Archaeocalamites inornatus, Protosalvinia huronensis* (spore cases), *Archaeopteris jacksoni, A. halliana, A. obtusa, Asterochlaena noveboracensis, *Cladoxylon mirabile, Eospermatopteris* sp., *Psilophyton princeps, P. robustum, *Rhachiopteris tenuistriata, *Rhodea pinnata, Rhachiopteroides punctatus, Cordaites clarkii, Dadoxylon* sp., *Hormoxylon erianum;*

2 the "fishes," *Holoptychius americanus, H. halli, Sagenodus fleischeri, Holonema rugosum, Dinichthys pustulosus, D.* cf. *tuberculatus, D.* cf. *curtus, Onchus rectus, Bothriolepis nitida, B. minor, Cephalaspis* sp.; (a part of these are true fishes);

3 the huge eurypterid, *Stylonurus excelsior;*

4 the phyllopod crustacean, *Estheria membranacea?;*

5 the freshwater mussel, *Archanodon catskillensis.*

Supplementary Note

[1] In 1862 (p. 380) Hall said: "I am inclined to believe that until we ascend the slopes of the Catskill mountains and rise to an elevation of at least 2000 feet above tidewater, we find no rocks of newer age than the Chemung group." And in 1863 (p. 108): "The term 'Catskill group . . .' . . . is not at all applicable to any beds in the Catskill mountains below the elevation of the Mountain House."

[2] This is The Twilight Park conglomerate of Prosser (1899, p. 238-84).

19 STONY CLOVE SANDSTONES

The deep and constricted pass of the Stony clove is walled on both sides with precipices of gray sandstones (figure 76) coarsely flaggy and without noticeable trace of red color through a thickness of eight or nine hundred feet. These beds (figures 52-55, 71, 76) have a marked physiographic effect. Viewing the Catskills from the Rip Van Winkle bridge or for some miles around it, the outlines of the mountains are seen to be mostly rounded. Four or five peaks furnish conspicuous exceptions: Indian head (figure 4) with its three south-facing cliffs that make chin, nose and eyebrows, Kaaterskill High peak and its companion Roundtop (figure 5) again with south cliffs on summits that give sawtooth profiles, similarly Stoppel point and finally the sharp south drop on the dome of Blackhead (figure 6). In each case these mountains are capped and these cliffs are formed by the Stony Clove member, though it has taken us a century to recognize this simple fact. Now that the idea of perfect horizontality of strata in our mountains has given place to perception of the actual dips, it is easy to follow these beds with the eye (figure 54) southeastward from the Stony clove along the escarpment of the central range till they cap Indian head but shoot over the top of Plattekill mountain, and similarly to pick them up eastward on the East Jewett range and the summit of the High Peak-Roundtop range (figure 52), northward in the Colonel's Chair of Hunter mountain.

Opportunity was lacking for adequate field tracing, but because of their color, lithology, proper expected thickness and general position in the succession, the Stony Clove sandstones have been taken to be the continuation of the Kattel gray flagstones of the region eastward from Franklin, Delaware county, New York, the beds that Darton correctly traced as "Chemung" on through to Delhi while they carried fossils, then missed the dip and stepped down off them before reaching Prattsville. The possibility that the Stony Clove beds may really be the next lower formation, the Oneonta, and so belong with the Onteora, is discussed under the Katsberg member beyond. For purposes of mapping it is easier to draw the line at their base than

Figure 52 North slope of High peak and Roundtop (Mt Lincoln) above the Kaaterskill clove (which, a thousand feet deep, lies hidden in front) on which slope lies type section of the Onteora red-beds. Peaks capped by Stony Clove sandstones. Visibly west dip. From near road corners one and one-half miles east of Haines' Falls, looking south-southwest. Photo: April 1938, W. J. Schoonmaker.

Figure 53 Stony Clove sandstones on east ("south") side of the Stony clove and making the full height of the steep slope (lower part covered by talus in the view but exposed in rear of camera). (See figure 76.) Looking northeast. Photo: Novemebr 1936, E. J. Stein.

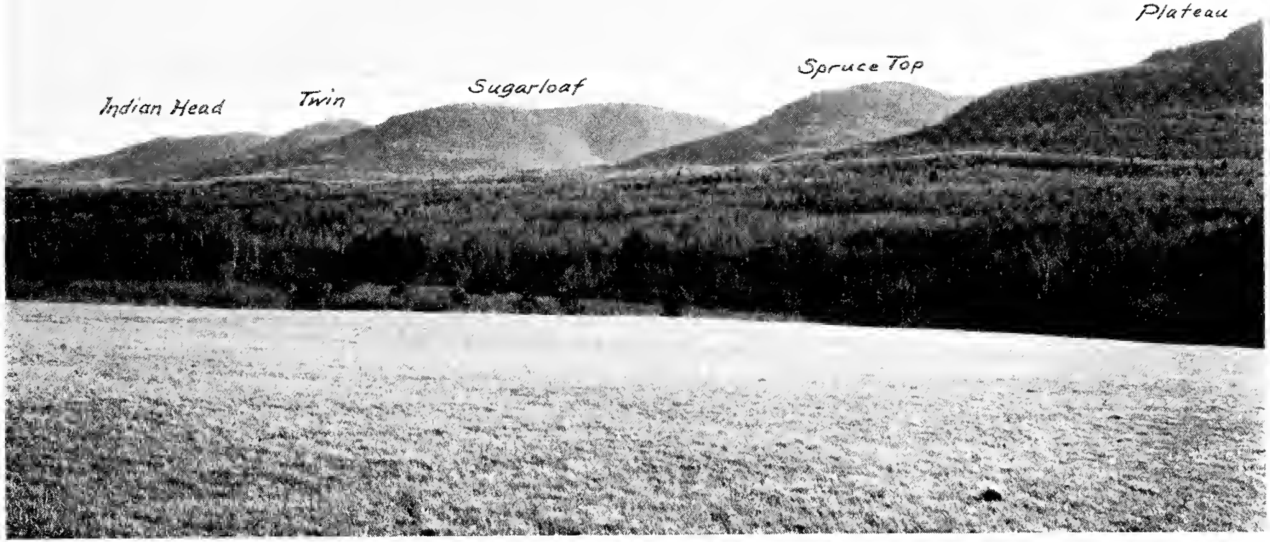


Figure 54 Stony Clove gray sandstones (underlaid by Onteora, overlaid by Katsberg red-beds) making steps in the smooth slopes of the peaks of central range of the Catskill mountains, and rising slowly left (southeast) into the summit of Indian Head mountain. Spruce Top is only a spur of Plateau. Looking south-southeast up south fork of Schoharie kill toward Elka Park (center) from Rip Van Winkle trail about two miles west of Tannersville. Photo: November 1936, E. J. Stein.

Figure 55 Katsberg red-beds making the great dome of Hunter mountain (4025 feet). Near spur on right (out of perspective) terraced by Stony Clove sandstones forming the pediment of the mountain. Amphitheater developed by arborescent drainage simulating a circ but without circ characters. Asterisk marks position of fire tower, too faint to appear in the half-tone. View west-southwest from start of route 214 near junction with Rip Van Winkle trail two miles east of Hunter. Photo: April 1938, W. J. Schoonmaker.

at the somewhat indefinite summit, and thus to include them in the Katsberg as its basal member, expressive of our present understanding of their relations.

In the quadrangles westward, a zone of high-grade flagstone quarries appears to follow the Stony Clove outcrop and to tie this in with the Kattel flags, but in our area the beds seem to be too coarse for economic use and are not worked, as far as I have ascertained.

Little is known of the fossils of the Stony Clove sandstones. Some of the plants in the list given for Onteora and Katsberg should be present.

20 KATSBERG RED-BEDS

The highest layers on our area are those on the summit of Hunter mountain (figure 55), our highest peak and the second highest of all the Catskills. Here, in the trough of the gentle syncline, there are about 1250 feet of beds on top of the Stony Clove sandstones which are unquestionable Katsberg, but these beds fall at least 800 feet short of reaching the summit of the formation as it is seen on Slide mountain, 15 miles southwesterly. (See map figure 4 in Mus. Bul. 307.) The white-looking and pebbly beds on the top of Hunter belong to the Wittenberg conglomerate member of the upper Katsberg, a remnant of which also caps Plateau mountain and has helped to preserve its crest. These "white" beds are in the Pocono facies and have been called "Pocono" by writers[1] but are older than the Pocono beds of the Pocono mountains in northeastern Pennsylvania.

Although the Katsberg formation is here called "red-beds" (which it actually is farther west), there is very little red in it on our area. This absence of abundant red color from the higher part of the Catskills has troubled many observers, and it has been one of the reasons for their thinking that later rocks here supervened upon the Catskill. The explanation will be brought up in a later chapter. But it is nevertheless true that some red shales do occur, especially just above the Stony Clove member, and that there are large thicknesses of them again in the upper beds of the Katsberg that are missing on Hunter but present in the top part of Slide mountain. The percentage of red shale in the successive members of the red-beds series is found to diminish progressively upwards, the Kiskatom containing the most red color and the Katsberg the least, so far as the local expression of these beds is concerned.

Gray to "white" sandstones or flagstones, in thicker and thinner layers, therefore make up most of the Katsberg on our area, with small amounts of red shale and red or reddish sandstones. Quartz pebbles are common, especially in the "white" layers. Fossils are few, chiefly poorly preserved land plants. The list of expected forms is that already given under the Onteora member.

In our present understanding of the Katsberg as including the Stony Clove sandstone for its basal member, the formation has a thickness where complete of about 3000 feet. The portion above the Stony Clove member is lacking in good flags. Its sandstones are heavy, coarse, likely to be pebbly and sometimes reddish. They are comparatively inaccessible and have not been quarried. The Katsberg forms a large part of the central range, especially the part north of figure 54.

The question of correlation, twice mooted previously in these pages, can not be settled without further field work to northwest and west. The method of expected thickening (at the rate of 1½ per cent per mile to southeast, compounded) that has proved so useful for predicting in western and central New York seems to confirm the Kattel age of the Stony Clove and the Oneonta age of most of our Onteora, with wedging out of the Sherburne. This is brought out in figure 56.

In viewing this figure it is necessary to keep in mind that the sections are not drawn to a uniform scale, but each is enlarged to what it would be expected to increase to by the time that the beds reached the Catskill mountains of our area. The rate of increase is figured at 1½ per cent per mile for the Upper Devonian and 1 per cent per mile for the Middle Devonian except at Ithaca; there the 1½ per cent is used for the Middle Devonian also in order to offset the sudden swell in the Cardiff east of there. In the Oneonta column two sets of measurements are used: on the right, 600 feet of Sherburne and 500 feet of Oneonta; on the left, 206 feet of Sherburne (Cooper's figure) and 700 feet of Oneonta (expectation from Ithaca would be 770 feet of Oneonta and 440 feet of Sherburne). On the basis of these two sets of measurements, two interpretations become possible for the beds above the Tully and are shown by solid line for the one presented in our text and in broken line for that suggested as alternative.

It will be seen that the general correspondences of expected to actual thickness at Catskill section are fairly close but that if the Kattel becomes the Stony Clove (solid lines), using Cooper's figure for the Sherburne, then the latter should actually wedge out at the east as we have previously considered likely. On the other hand, if we believe (broken lines) that the Sherburne makes the whole of the Onteora up to the Stony Clove beds and that these are the Oneonta, we are confronted with the difficulties higher up, first that

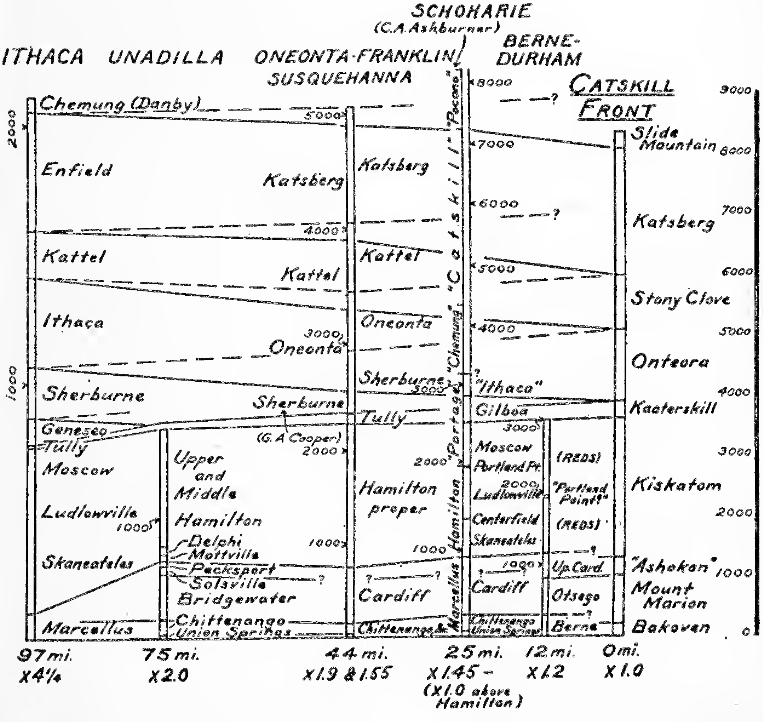


Figure 56 Alternative correlations in the Upper Devonian (Senecan) beds of the Catskill Mountains as suggested by the principle of uniform thickening eastward. Distances obtained by projection upon a line N. 45° W. In Senecan beds 1½ per cent per mile increment used and also for Hamilton at Ithaca; otherwise 1 per cent in Hamilton. The chart does not actually demonstrate any correlations, especially in the Hamilton, and serves merely as a *point d'appui.*

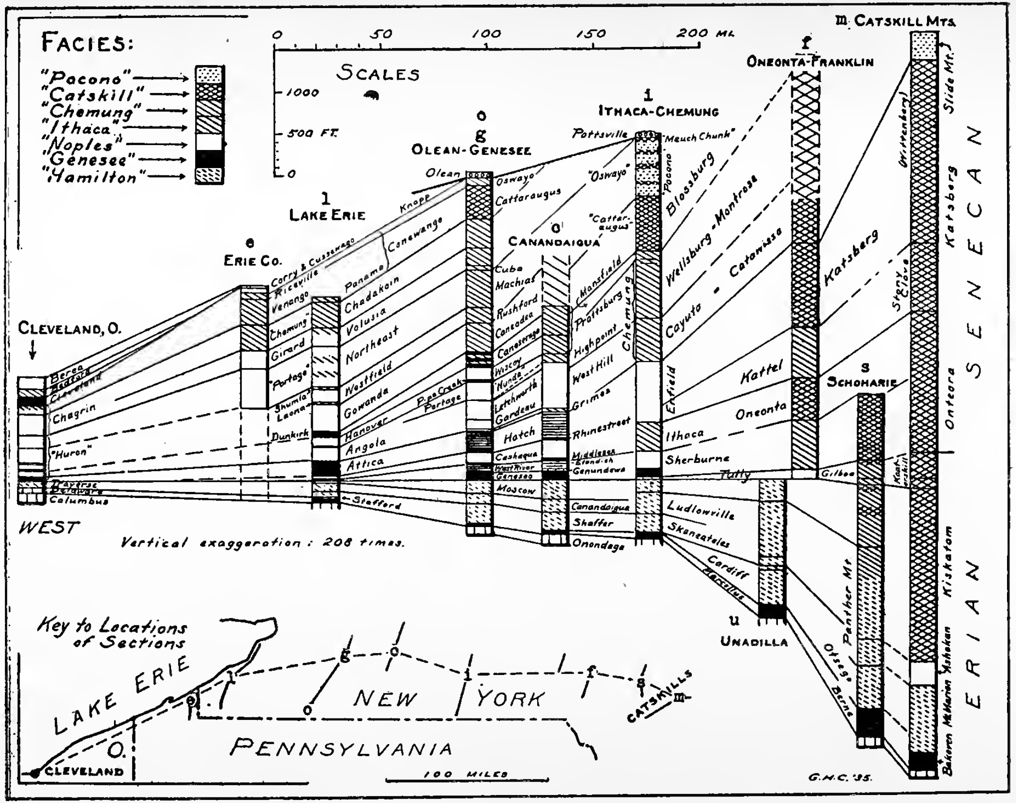


Figure 57 A chart showing progressive thickening and facies changes from west to east in the sediments of the "Catskill delta." Reproduced without revision from New York State Museum Bulletin 307, page 99.

there is there no recognizable Kattel equivalent and second that the disconformable relations are merely shifted up to the Enfield-Chemung contact. Nevertheless, a small break is known at that contact in western New York, cutting out the Grimes sandstone. Therefore the chart still leaves us with the question open.

The Schoharie section (from Cooper) has been checked against Ashburner's old measurements through his "Portage" and then continued upward on his actual figures without enlargement, because of geographic convergence of the section to ours. His 1000 feet of "Pocono" is of course too much.

Supplementary Note

[1] It will be recalled that Mather (1843, p. 295, 303) and Emmons (1846, p. 195, 367) hesitated whether the (Pottsville) conglomerate of the base of the Coal Measures occupied our mountain tops. Their remarks seem, however, to have been taken by Lincklaen in 1861 (p. 70-71) to refer to the Pocono which (identified by its being succeeded by the "Umbral" or Mauch Chunk) he now makes "the base of the great Carboniferous system" and this is in agreement with Hall in 1859 (p. 52-53) who referred the Catskill also to the "great Carboniferous limestones" (Mississippian period). In 1883 (p. 65), Hall speaks of "the Catskill, including the upper member or Pocono sandstone," in which he was preceded by J. P. Lesley in 1882 (p. x): "The peaks are what remain of the overlying Subcarboniferous, Pocono formation." (See also Ashburner 1888, p. 954; Lesley 1892, p. 1567; who assign 1000 feet at top of our mountains to the Pocono.)

FACIES CHANGES ON THE RED-BEDS DELTA

It was formerly supposed that the Upper Devonian strata of New York consisted of four successive formations each with a characteristic lithology and fauna or flora, namely, the *Genesee* black shale, the *Portage* olive shales and thin sandstones or flagstones, the *Chemung* brown-weathering sandy shales and sandstones and the *Catskill* red shales and interbedded sandstones or heavy flagstones. To these in Pennsylvania and also, some thought, in the Catskill summits was added a fifth deposit (Devonian or Mississippian as the author might choose), the *Pocono* "white" sandstones and conglomerates. Although lateral transitions of these five kinds of deposits into one another were repeatedly observed and reported in the literature, they were still relied upon for correlation and believed to be of five distinct ages, in the order above given, with the Genesee the oldest. From central New York westward into Ohio there were many sections where these five types of beds could be found succeeding one another upwards in proper succession and this was taken as conclusive evidence.

But there early began to be doubt as to the red-beds, the "Catskill." It became evident that this type of deposit, at least, interfingered with and passed laterally into marine beds ("Chemung") of contemporary age and even into marine beds as old as the "Portage" east of Ithaca (the Oneonta red-beds). (See Hall 1862.) Half a century ago the discovery was announced that the "Chemung" beds overlying these Oneonta reds were the changed eastward extension of the pre-Chemung Enfield beds (name not then proposed) of the Ithaca section, there classed as "Portage." (See H. S. Williams 1886.) Just previous had come the soon-forgotten proof that the true Portage sandstones are of Chemung age (see John M. Clarke 1884, pages 21-22, and 1885, page 67) which startled the conservatives when reasserted on fuller evidence recently. (See Chadwick 1935, page 343.) Even before that, the lateral passage of "Catskill" reds into "Pocono" ("whites") had been noted. (See H. M. Chance 1880, page 114.) The great thinning of all these deposits westward, and the passing of "Portage" beds into black ("Genesee") shales in Ohio, had also gained general acceptance.

Long continued field work eventually showed that all five of these types of sediments were laid down contemporaneously on a great land delta and its underwater (marine) extension westward. The coarse "white" beds called Pocono were those far up toward the delta head. The red muds did not lodge much there but were swept on down and spread out between the flaggy sands of the main delta surface to make the "Catskill." What continued out under water lost its red color by organic reduction of the red ferric oxide in a shallow and warm "littoral" zone where life was abundant, and this part constitutes the "Chemung." Finer stuffs floated in suspension into deeper colder waters farther from shore, where frail things lived in the chill depths, and this is our "Portage" sediment. At the most remote point, organic material was the main accretion—the black "Genesee." (See the chart, figure 57.)

The apparent superposition of these deposits came about through the building of the delta westward, just as the Mississippi has built all the way from Illinois down and out into the Gulf. Inevitably, then, each zone, with its own type or "facies" of sediment and of life-forms, gradually overlapped westward the next outward zone, until the latest "Pocono" far overreached the earliest "Genesee." For these matters took many millions of years and meantime life was changing, evolving, so that only a few of the most hardy forms carry through, in sediments of like facies, but being abundant these were supposed to prove age identity until the whole faunas of the beds at different points were analyzed and the very significant age differences made evident. (See Chadwick 1935*a*.)

FORMATIONAL CONTACTS

The outstanding general feature of our Silurian and Devonian rocks is their parallelism, their maintenance of uniform thicknesses across the entire area. Continuity of deposition is the natural inference—a quiet and stable sea, receiving formation after formation without break in the record. But there are certain exceptions already noted, especially in the Rondout and Glenerie beds, at local base respectively of the Silurian and (possibly) the Devonian. More searching examination of the formational contacts reveals evidence that deposition was not thus uninterrupted. Sharp changes in lithology (often also in fossils) can not well occur without disturbance of the conditioning factors (climate, currents, lands and seas) that doubtless was never so "sudden" as it appears. Time was lost, the record broken.

Much longer known is the break between these rocks and the Ordovician rocks beneath them, which will be described first.

THE BASAL UNCONFORMITY

Mention has been made (page 45) of the encroachment of the Silurian sea upon an eroded land surface of the older rocks. The returning sea brought late Silurian beds to rest upon early Ordovician ones in the Hudson valley, whereas in central and western New York a great thickness of other rocks intervenes, the section is nearly complete and the line between Ordovician and Silurian strata barely discernible in the midst of red beds (Queenston-Medina). The formations present (between Watertown and Syracuse, for example) but lacking in our region at the Normanskill-Rondout contact are as follows:

	Maximum thickness in New York
Cobleskill limestone (probably)	10
Bertie waterlimes	60
Camillus shale	400
Syracuse salt and shale	100
Vernon shales	500
Lockport limestones	170
Rochester shale	100
Clinton beds	150
Oneida conglomerate	50
Medina sandstone	120
(Total Silurian missing: 1660 feet)	
Queenston red shale	1200
Oswego sandstone	100
Lorraine shales and sandstones	900
Utica shales and limestones	800
Trenton limestones	350
Black River limestones	150
(Total Ordovician missing: 3500 feet)[1]	
Total thickness	5160

The loss of these beds eastward is by a double procedure: The upper and middle Ordovician strata are gradually bevelled away as far east as the vicinity of Rome, N. Y., where they are slightly upturned and cut off more rapidly for a space, steadily thence eastward to the Helderberg front. The Silurian beds, on the contrary, fail from bottom up, as they come east, losing first the lower and then the middle members. The loss of the Ordovician rocks is thus clearly by erosion and removal of strata once present; that of the Silurian, by failure to lap on against a land whose shore line was gradually shifted eastward as the sea transgressed. Naturally, erosion continued to operate longest in the part last to be submerged, the east.

Coming around the Helderberg salient, the Manlius rests directly upon rocks of Utica (Frankfort) age, though both east and west the topmost beds of the Ordovician are of the still older (Trenton) Schenectady formation. But southeast even lower beds then appear, as the overthrust mass of the Normanskill (Chazy) shales and grits passes under the Rondout-Manlius cliff. That is the relationship past Catskill and Saugerties to Kingston.

The chronological dimension of the break, hereabouts, is thus conspicuous, large. Much must have happened during it: (1) deposition of the higher Ordovician beds, now gone, to a thickness we can only guess at but certainly over 2800 feet (all of Black River, Schenectady and Indian Ladder beds) plus perhaps fully as much again; (2) overthrusting upon these and folding of the Normanskill and older beds (exposed east of the Hudson), with great metamorphism farther east; (3) subsequent erosion of an unknown thickness of these overthrust strata, estimable in many thousands of feet since it reaches down to zones of severe metamorphism; (4) the slow return, meanwhile, of the Silurian epicontinental sea from the west.

We should therefore expect rather than discount (T. H. Clark 1921, Bost. Soc. Nat. Hist., Proc. 36 No. 3: 135-63) field evidence of this erosional contact, of such long time lapse.[2] Nor is this evidence hard to find (see figures 58, 13) when the contact is followed through continuously from Kingston across the Catskill quadrangle. Indeed, striking large-scale demonstration of the unconformity is given by the topographic map as a whole. Though in the south third of the sheet there is no appreciable lack of parallelism of the Ordovician strike-ridges, either east or west of the Hudson with those of the Silurian-Devonian rocks, the case is different from Malden and Katsbaan northward as the later rocks swerve more and more

Figure 58 Ordovician-Silurian contact, dry bed of Cats kill in Austin's glen, Catskill, at lower end of main gorge. Sandy Rondout layer (below boy) dipping left and away from camera, on Normanskill shale and sandstone diverging on dip to right at angle of nearly 10°. Boy stands on hackly waterlime. White ledge of Manlius in background. Looking northwest. Photo: drought of August 1912. H. L. Fairchild.

towards the northeast. Here the Ordovician ridges not merely fail to swerve with them but even run a bit more strictly north, thus increasing the convergence of their trend with that of the Kalk Berg range.

Ice movement has tended rather to obliterate than to accentuate this northward convergence of the Ordovician strike, amounting to an angle of about 15 degrees before approximate parallelism is resumed around Catskill and thence northward through the Coxsackie quadrangle.

Moreover, although throughout our area Doctor Ruedemann finds only one formation, the Normanskill, in contact with the Silurian, yet of that very thick formation different portions are at the contact. The seeming conformability (Davis 1883, page 322) at one easily visited spot, Cauterskill road exposure, north end of Quarry hill, is scarcely matched at any other. The actual contact is visible at the following localities:

1 Austin's glen. The exposure at low water in the Cats kill (figures 58, 1) shows divergence of nearly 10 degrees in the view, but because the face of the fall is not on the strike of the Normanskill the actual angular discordance is larger, about 15 degrees (Chadwick 1913). While sandstones underlie this contact, in the water, yet at less than two rods away, in the shore, a mass of soft shale is the underlying rock (figure 13).

A second contact is seen about a thousand feet northeast of the preceding. Around the point of the anticlinal hill (figure 1) and beyond clay and Normanskill knolls is a Manlius cliff facing the creek and surmounted by three cottages. The farm road at its foot has exposed the basal Rondout bed resting on Normanskill shales (with thin sandstones) and dipping to the east about 15 degrees more than these beds beneath, about under the middle cottage.

On the west of the creek, both in line with the first exposure and in the slopes of Eagle cliff (figure 16) as seen from the north in winter, the suggestion of discordance, with the Normanskill more closely folded than the limestones, is marked. Returning to the east side, up the old Austin millroad near its top the Rondout buff waterlime bed crosses at a moderate west dip and passes up into the hillside under cover. But just beyond, and striking directly under where it should be, the Normanskill shales and thin sands are vertical to slightly overturned. Below the road, however, they roll out into what looked to Davis (1883: 322 and figure 58) like parallelism with the limestones.[3] On the summit above, halfway over to route 23, lies a small quarry in which the relations seem conformable but rather obscure.

2 Cauterskill-Leeds road. A small brook cascading over the limestone where the Rondout is less than two feet thick, about three-quarters of a mile southwest of the preceding and not far west of the road, shows a strike contact in which it is not so easy to demonstrate unconformity.

3 Quarry hill and Fuyk. From the Cauterskill road exposure already mentioned, tracing of the beds around southwest into the Fuyk shows divergence of the heavy grits away from the contact and unlike layers beneath the Rondout at different points. There is a near-contact where Moon's farm road is first crossed. South of Moon's house, as the old road climbs up the Fuyk sandstone outcrop (where Gates's army once climbed it), Normanskill beds are seen beneath that with somewhat larger east dip and converging strike southward. Here the lower beds of the Fuyk sandstone are shaly and consist of reworked Normanskill arkose, but are unlike that in being coarser grained and carrying lime, enough to support colonies of the lime-loving walking fern.

4 Red (Brick) School. On the road sidling up the hill from route 9-W are plentiful Normanskill exposures, and the Fuyk sandstone cliff crosses at the top. Just short of this, on west side, the fossiliferous limestone is poorly shown, below the high main ledge, but with abundant fossils in the rotted stuff and soil, and just under it at road level are Normanskill sandstones (some shales also) much disturbed and cleaved but dipping 80 degrees east. Rotting of the rocks and overgrowth of vegetation obscures the relations until someone digs them out afresh. Especially puzzling is a seeming lateral replacement of the limestone in a rod or two south by heavy quartz sandstone, still showing fossils on fresh fracture. As there is a quirk in these beds immediately, offsetting them across the road, a small fault may be suspected, or even a slid block.

5 North American plant. On route 9-W one-quarter mile north of the road summit at entrance (west) to the North American quarries, or one-tenth mile south of the low point in the highway just after it turns from the West Shore railway, the Rondout beds on edge make a wall up on the west side to which one may clamber and find a contact with Normanskill beds that are more largely exposed northward. The face of the wall is the corroded under-surface of the sandy fossiliferous limestone, but there comes in just under this (20 feet above the road) two feet of heavy sandstone lithically so like the Normanskill arkoses (from which it has been reworked) as to deceive easily into the idea of conformability here. A second look, however, shows four to five feet of true Normanskill sandstone

(finer grained) and shale dipping west about 45 degrees into these vertical strata.[4]

On the continuation of the same outcrop south nearly two-tenths of a mile, in the West Shore Railroad cut, this deceptive basal bed is again exposed, showing about one and one-half feet, under the fossiliferous limestone, again all vertical and followed by nearly 12 feet of Fuyk sandstone, the rest covered. The base is also covered and no Normanskill shows, but like the similar stuff at the Fuyk it is easy to distinguish this basal Rondout sandstone from that by its lime content and coarser average grain.

6 West Camp. On the road crossing the limestone syncline, a half mile north of the historic West Camp church, in the south bank of the road on its west-side ascent, the Normanskill appears to be vertical, though this might be considered cleavage, as it passes under the rather good section of the Rondout limestones here exposed. In any case its strike differs, being about north-south, while the Rondout is striking west by north and dipping northward, not more than 30 degrees.

On the east-side descent of this road, toward Cementon, 14 rods above the hairpin turn, Rondout limestones on the north side dip about 40 degrees westward, on Normanskill shale and shaly sandstone dipping about 80 degrees eastward, thus meeting at an angle of about 60 degrees.

The west brow of this hill, on the thumb a thousand feet northwest of the former locality, has a good scarp of Rondout limestone looking far down upon the house at end of the stub road, and beneath this ledge (with its low northeast dip) is a ledge of Normanskill that dips east 40 degrees and continues south while the limestones wheel off to southeast.

The best instance of large scale difference in attitude in our region is the one just north of the cemetery and pond, easily reached by a short road from behind the church. Vertical Normanskill ribs strike north between cemetery and pond (and farther west), presently overlaid by gently east-dipping waterlimes at the extreme south tip of the limestone syncline. Standing on the knoll in the pear orchard northwest of the pond, one can look down a northeast-sloping surface of about two acres, eroded across these upedged Ordovician strata, against the Rondout scarp. This is a bit of the old land surface over which the Silurian sea transgressed in Rondout time, recently resurrected for us by glacial stripping away of the Silurian mantle.

7 Great Vly. Normanskill beds, mostly on edge, are displayed for half a mile at north end of the Great Vly while on both sides and

crossing over these are flat-lying Rondout limestones. Recent broad-gauging of their service track by the Lehigh company has freshened the contact at the west portal of their long tunnel (there are two tunnels). This contact had become obscured at the time of Professor Schuchert's visit. Here a measured 14 feet of Rondout (with about as much more above mostly covered) dipping east not over 15 degrees rests directly upon Normanskill shale flanked by a heavy mass of the grits, all dipping due east 80 degrees, making an angular discordance of fully 65 degrees.

Such relations obtain all the way up this east wall of the Vly for its two miles from the West Camp localities, though actual contact has not been seen except here and, again, at the "back" quarry entrance cut of the same railway as described and figured by Schuchert and Longwell (1932, pages 313, 314). They give the respective dips as east 5° south 30°-55° for the lower strata, and north 55° west 20° for those above the contact. Occurrence of thin harder seams at intervals of a few inches in the shaly Normanskill on west side of the cut (opposite the illustrations) has given the eroded edges a feebly washboard surface into which the Rondout base fits, with tendency for fossils to accumulate in the very shallow troughs (as at Rondout, N. Y.). There is no soil band, yet the large "worm" burrows that show on the under surface of the Rondout (see Schuchert's account) must have been largely excavated into softened shales beneath the contact. So far, no included fragments of the Ordovician have been found here in the Rondout. The nearly perfect planation of the Normanskill looks like wave-work, long-continued, and the smooth rounding of the harder ribs shows that the Normanskill was thoroughly indurated before the waves attacked it.

Although thrust-faulting is conspicuous in this same cut, all visitors agree that this faulting fails to involve the actual contact at any exposed point, just as it so failed in Austin's glen, showing how well the unrelated formations were bonded together along an interlocking contact. Yet they separate on weathering.

Over the knoll east of this cut, looking down upon the locomotive shed, the lower Rondout arches gently while upedged Normanskill runs end-on to within three rods of it. A short distance southeastward, or 200 feet east of the shed, the upturned Normanskill is thinly veneered by 15° east-dipping Rondout. On the west limb, southwest from the cut, there is a widening terrace of gently west-dipping Rondout, soon reaching back three or four hundred feet to the abandoned highway and finally terminating north of the old stone house near the head of the swamp. As it thus falls back west to the roadway, on a 10°-20° west dip, 60° east-dipping Normanskill ribs emerge from beneath it, as also along its east front, and continue southwards. Practical contact may be seen close east of the road about 250 feet north of the stone house, and the two rocks are in close proximity for a quarter mile south to beyond where the road turns west across the ridge. In the exposure east of that gap, an excessive thickness of Rondout seems to be represented.

8 Shults's hill. Although now grassed over, the contact behind the garage at the Shults farmhouse three-fourths mile west of West Camp is still suggestively shown in the physiography, close by the public road. Here and north to the next farmhouse the limestone scarp is at its greatest divergence from the Normanskill ridges. The latter, with steep westerly dips, trend 10° west of north in a long succession bassetting up to the road on its east side, while the Rondout with northwesterly dip lies diagonally (N. 35° E.) across them, keeping mostly on the west side of the highway. Under this scarp, 250 feet north of the Shults garage and 70 feet west of the road, the shaly sandstone is exposed only 4 feet under the 13½ feet of Rondout here visible. At the garage, a five-foot grit bed dipping north 45° crosses the road, from the barn, and is exposed to within 25 feet of the Rondout, its ridge continuing to within 15 feet under the lawn end-on toward the limestone, which here dips northwest about 65 degrees.

9 Schoentag's. No actual contacts are known around Glasco, but the suggestions there present are included in this enumeration in order to embrace the south part of the quadrangle. In the vale of the ruptured anticline a quarter mile west of West Wood farm and an equal distance north of Schoentag's (both on route 9-W), the Normanskill is barely and doubtfully exposed close to the basal ("Wilbur"?) limestone of the Rondout on the west side of the pasture in the vale, but removal of sod and earth beneath this limestone might reveal it. The south prong of the hill south of Schoentag's, seven-eighths mile south of the road corners at the hotel, has a fine ledge of Glasco limestone climbing its east brow northward, with scattered Normanskill exposures below it (at and) near the south end. Here a grit ledge, dipping west 35 or 40 degrees and 10 feet lower than the Glasco, converges slowly northwards for about a hundred feet on the similarly west-dipping limestone until the lower waterlimes cut it off.

10 Becraft's mountain. The exposures of the unconformable contact here have been most lately described by Schuchert and Longwell (1932, p. 317-20) and by Doctor Ruedemann.

Supplementary Notes

[1] This thickness will be greatly increased if we take, instead, the clastic equivalents in the Mohawk valley of the Utica and Trenton, namely:

Frankfort beds (Deer River part)	350 feet
Holland Patent (with lower Frankfort)	800 feet
Loyal Creek	300 feet
Nowadaga	400 feet
Schenectady	2000 feet
Limestones	50 feet
Total Utica to Black River	3900 feet

[2] The latest review of the field facts is that of Schuchert and Longwell 1932, but containing some slight inaccuracies due to the hurried nature of their visit. See Davis 1883, 1883*a*, 1883*b*; Grabau 1903; Van Ingen and Clark 1903; Chadwick 1913. Davis 1883*a*, p. 318-21, summarizes the old accounts.

[3] Professor Davis's view was nevertheless modified on his 1910 excursion to this region, in which the writer participated.

[4] Given as horizontal in error by Schuchert and Longwell 1932, p. 313.

THE SUB-ORISKANY UNCONFORMITY

As the gap between the Ordovician and the Silurian formations closes up westward, across New York, there opens above it a different one, between the Silurian and Devonian deposits, that in western New York brings the Onondaga limestone down to rest directly upon a bed lower even than the Rondout (Chrysler), namely upon the Cobleskill (Akron) dolomyte. In this hiatus there are therefore missing the following formations present in our section:

Schoharie shaly limestone
Esopus shale
Glenerie limestone
Port Ewen and Alsen limestones
Becraft limestone
Catskill shaly limestone
Kalkberg limestone
Coeymans limestone
Manlius (Olney) limestone
Rondout limestones

Tracing it east from the Genesee river, this hiatus is found to be compounded of smaller breaks: (1) between the Onondaga and Oriskany, cutting out the Schoharie and Esopus; (2) between the Oriskany sandstone and the Bishop Brook (Coeymans?) limestone of the Helderbergian, cutting out the Port Ewen-Alsen, Becraft and Catskill members; (3) between the Coeymans and the Manlius. North of Manlius village, all three of these breaks may be seen in a vertical space of only eight feet.

Of these three, the upper one fades out in our area, the lower one will be considered beyond, but the middle one is of major importance. The noncontinuity and variable thickness of the Port Ewen limestone, together with its sudden swelling to more than one hundred feet, south of our quadrangle, have been mentioned in the description of that formation. There is also a thickening of the Glenerie (Oriskany) beds southward, with incoming of the Connelly quartz-pebble conglomerate beneath them, around Kingston, besides pebble zones (not always basal) in the Glenerie cherts of our own area. Northward, in the Helderberg salient, the Oriskany sandstone, continuous with and equivalent to our Glenerie chert, rests on a corroded surface down in the Becraft, all Alsen and Port Ewen being cut out, though there is some return of these into the section at Schoharie.

Locally significant of this break at many exposures is the concentration of fossils and the occurrence of abundant dark nodules supposedly phosphatic on whatever happens to be the top surface of the eroded Port Ewen or Alsen. One of the best of such surfaces, followed by "black" shale that might be a soil bed, is well exposed on route 23-A (Rip Van Winkle trail) less than a mile outside Catskill, just north of and passing under the Glenerie beds (figure 31) at Ellsworth Jones's house. The same thing (with the shale bed) may be seen in the west wall of the northwest quarry at the North American plant close to where the pipeline is notched through it. It may be seen again on top of the east wall of the present Alpha quarry, especially at the high point near the south end. The nodules in the top of the limestone have been noted as far south as along the old stage road (upper road) a mile and a half south of Schoentag's. Nor are the nodules confined to the extreme top; they sometimes occur also a few inches lower, and the whole of this few-inch band is particularly yellowed and otherwise suggestive of subaerial weathering. It is quite possible that we are dealing with an old land surface.

Such a land surface is unquestionably buried by the Oriskany in western New York (see John M. Clarke 1907, N. Y. S. Mus. Bul. 107, pages 293-94), where the Oriskany sands infiltrate to depths of 20 feet or more the dissolved fissures and joint cracks of the subjacent Akron and Bertie limestones. Sometimes the Onondaga lime-sand does the same, as at Oaks Corners northwest of Geneva, N. Y.

At this break early workers drew the Devonian base and to it as the true tectonic division-line present thought is returning. It is the hemera of the volcanic outbursts (called "middle Devonic") in New England and beyond. It is the time of the earlier Acadian orogeny (mountain folding) in Gaspé and elsewhere. With increasing recognition of the essentially Silurian aspect of the Helderbergian faunas, as knowledge of the Rondout and Keyser faunas has grown, and after restudy of the European Hercynian, some of our best authorities are putting the Helderbergian back into the Silurian where the earlier workers had it. For the opponents of this view there is still a good break below the Coeymans, now to be described.

THE COEYMANS-MANLIUS CONTACT

Recognition of an erosion interval between the Cayugan and Helderbergian has been tardy. The Manlius ("Tentaculite") limestone was early included in the old Helderberg (later Lower Helderberg) group, and as late as 1906 (see Grabau, Museum Bulletin 92) Ulrich and others were talking about "Manlius transition beds" in east-central New York and the Helderberg region. Inevitably, if such transitions or interbeddings actually occur as true depositional features, the separation of Manlius from Helderbergian breaks down. If, however, the appearance is due to extensive reworking of top Manlius into the Coeymans, as slabs and masses caught up or interfiltrated, the size of the break appreciably grows.

But that is exactly the situation that we have found and Mr Logie has confirmed. Wherever the Manlius-Coeymans contact can be reached on the Helderberg front it has proved to be irregular, undulating, but bonded and obscure until the hammer locates it by the lithology, and for at least two or three feet above it are many Manlius slabs, up to a yard or more in length, carrying of course the Manlius fossils and thus appearing to be interbedded with the Coeymans calcarenyte with its crinoidal and other organic debris. On a visit to this contact some years ago near New Salem, Mr Hartnagel and I found in it among the limestone pebbles a quartz pebble a half-inch in size. Before the later quarrying operations at the Turtle Pond quarry (figures 21, 22) west of Catskill, several geologists saw there a glacially polished edge of the basal Coeymans exhibiting the structure perfectly, near the north end. Even yet the worn Manlius slabs in the Coeymans can be found, especially at the south end of the quarry (figure 21) by close observation, and also in Austin's glen, giving rise to the oft-repeated statement that Manlius fossils are there found living on into the base of the "Lower Pentamerus" limestone.

According to Logie's studies, several feet of beds at top of the Manlius come and go on this erosion plane, around Catskill and Saugerties. But more significant is the cutting out eastward and complete absence in the Hudson valley of the upper three out of the four members of the Manlius found at Syracuse. We have here only the lowest division of the formation, namely the Olney limestone.

LESSER BREAKS

Blasting the Schoharie formation for the new route 23-A a short distance east of the Old King's road crossing three miles west of Catskill, the workmen brought to light a considerable concentration of glauconite grains in its top few inches. This has since been recognized at other localities in the same horizon. A little glauconite has been found also in the top of the Esopus shale at Katsbaan church, in the rear of the building. Since this mineral is considered an index of disconformity, we have in it evidence that the Oriskany-Onondaga gap (page 150) is not fully closed even in our region.

Repairs at the Webber bridge, on route 23-A, have covered up the evidence there beautifully displayed on a glacially polished surface of the Onondaga limestone of unconformity with the black Bakoven shale above it. Corrosion hollows in the top of the "white" limestone were filled with the black limesand (calcarenyte) that initiates the Bakoven shale, mottling the polished surface. This relation can still be made out by the creekside (figure 40) but not so well. Doctor Cooper's work seems to confirm this proof that no contemporaneous overlap can exist between the Ulsterian and Hamiltonian strata as was claimed. Small brownish phosphatic nodules and reworked *Atrypae* from the limestone beneath, in which they abound, occur at the contact, in the calcarenyte (a mere skin), as well as teeth of *Onychodus*.

The emergence and beginning of "continental" sedimentation of our region should be marked by some evidence of shallowing and withdrawal of the sea. Such seems to be afforded, not merely here but all across New York State, by the remarkable masses known as "storm-rollers" (figure 45) occurring at or near the top of the marine beds (here the Mount Marion formation) and even in the basal part of the nonmarine Ashokan beds above. Subspherical masses of sandstone usually a foot to a yard in diameter, surrounded sometimes by sand and sometimes by shale, are tumbled in, this way and that. They are certainly not "concretions" as they were formerly called. Their outside may be dusted all over with fossil shells (brachiopods) like cracker crumbs on a croquette, giving the impression that they were rolled along the beach when soft. Nevertheless, proof of such wave-rolling has not been found convincing to many geologists and a better explanation may have to be found. Rollers occur in the top Mount Marion beds just east of Unionville corners, as figured; two-tenths mile southwest of the bridge at High Falls, and almost continuously for half a mile along the road from High Falls over Timmerman's hill; on the road from Quarryville to Mt Airy and south to near Unionville; on the road from Mt Marion to Daisy about a quarter mile above the bridge (figure 42) over the Platte kill. North of route 23-A they appear to be confined to the beds above the marine summit, which seems confirmatory of the idea of downward encroachment of the flagstone facies ("Ashokan") northward.

Pebble layers are to be expected in the land-made deposits and they begin with or even just before the Ashokan. Half a mile south from route 23-A, on the Timmerman's Hill road above mentioned, is a pebble-bed containing bright-colored quartzes rather than the usual local shale or sandstone pebbles. A cornstone stratum supposedly at the base of the Kiskatom red-beds in the vicinity of Kiskatom and northwards appears to be the "limestone, brecciated and conglomerate" recorded by Mather (1843, page 305, No. 129, pages 307, 314 and footnote) and called by him a firestone. A similar zone occurs in the midst of the flagstones at the break north of High falls mentioned on page 115.

The probable wedging out of the Genesee beds on the Catskill front has been discussed, page 136 and previous, page 122.

The undulatory contact of the Manlius on the Rondout, shown in figure 11, is probably of no consequence, being greatly exaggerated on the scale of the diagram.

Attention should be called to the question of northward disappearance of the highly fossiliferous upper Glenerie limestones, as though wedged out of the section. This is puzzling, since the very close affiliations of the whole Glenerie and Esopus seem to negate any such break between them, but its solution must be left to the future.

STRUCTURAL FEATURES

DEPOSITIONAL STRUCTURES

Any mention of "structure" in our region naturally brings first to mind the conspicuous rock folds and the faults for which this region is distinguished. Long antecedent to these deformations, however, were the structures put into the rocks as they were forming. Primary among these is stratification or bedding (figures 47, 72, and many other figures), usually very evident in our strata, but in the Esopus shale there is a surprising suppression of visible bedding (figures 32, 33) so that the subsequent cleavage planes are easily mistaken for bedding planes. Primary also is the distinction into different kinds of rock, either by chemical composition, as limestone (figures 21, 36), chert (figures 31, 23, 38), and sandstone (figures 8, 15), or by size of grain, as conglomerate (figure 51), coquinite (figure 27)

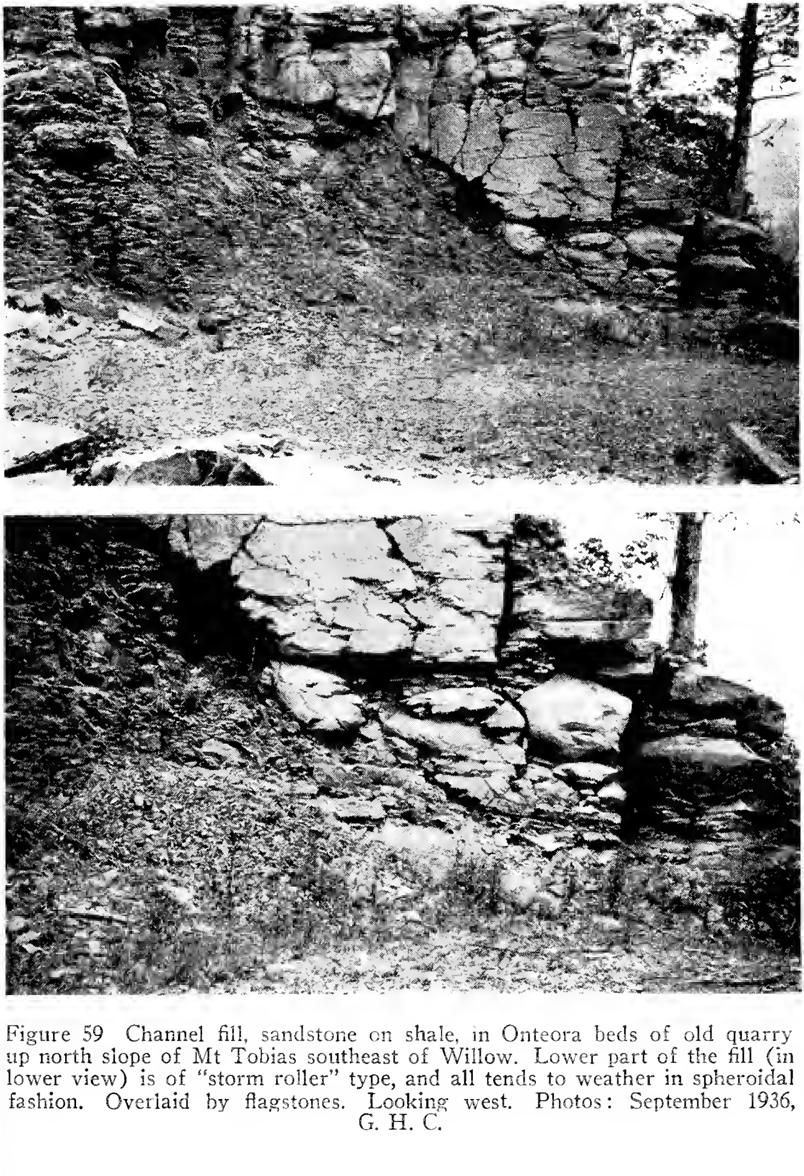


Figure 59 Channel fill, sandstone on shale, in Onteora beds of old quarry up north slope of Mt Tobias southeast of Willow. Lower part of the fill (in lower view) is of "storm roller" type, and all tends to weather in spheroidal fashion. Overlaid by flagstones. Looking west. Photos: September 1936, G. H. C.

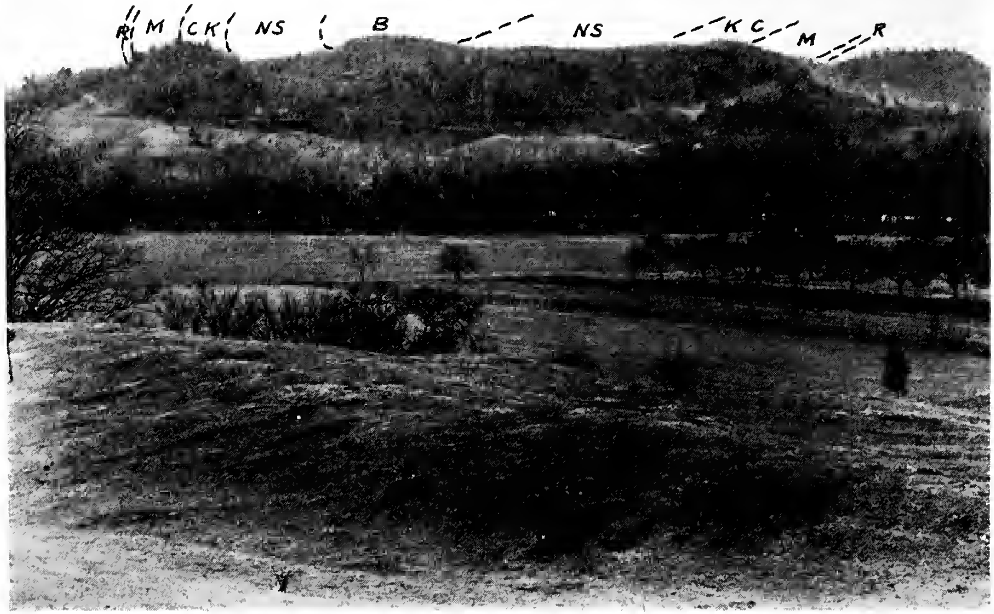


Figure 60 Unsymmetrical syncline of the Quarry hill, west of Catskill seen from west foot of Lake Albany delta of the Cats kill in Jefferson Heights. "R": Rondout; "M": Manlius; "C": Coeymans; "K": Kalkberg; "NS": Catskill shaly; "B": Becraft, limestones. To avoid confusing, downfaulted block of RMCK at right is not labelled. Landslid clay in foreground. Looking south-southwest down the plunge of the syncline. Photo: April 1938, W. J. Schoonmaker.

and shale (figure 40) or clay (figure 72), as well as many so-called sandstones (figure 61) especially those alternating with shales (figures 42, 43, 44). Fossils (figure 20) are original structures, though often subsequently much changed, and so are the ripple marks, sun cracks (mud cracks) and "worm"-burrows.

Irregularities of stratification may take the form of cross-bedding (figure 18), flow-and-plunge or reefy structure, "storm-rollers" or "stone-rollers" (figure 45), channel scour-and-fill (figures 49, 59), disconformities (figure 21) and unconformities (figure 58), though the last involves deformation preceding it.

DEFORMATIONAL STRUCTURES

The transition from original to subsequent structures is bridged by such things as concretions (including the septaria found in the black Bakoven shale and the phosphatic nodules at certain contacts already named), which occur more commonly in the Mount Marion beds (figure 42), and flint seams (figure 38), both of which represent a concentration of foreign materials that may have started contemporaneously and progressed afterwards.

The simplest, probably the latest, of the strictly subsequent structures are the ubiquitous joints (figures 46, 15, 23, 51), at times giving rise to keystone faults (compare figures 71, 76).

This brings us to the deformative structures proper, or those produced by the mountain-making (orogenic) processes, namely:

1 Rock folds. The "miniature" rock folds of the Kalk Berg belt form one of the most entrancing features of our region. Because of their resemblance, in small, to the mountain folds of Pennsylvania and Virginia, Davis (1882) has rightly called the Kalk berg the "little mountains," for they alone of the hills of our area west of the Hudson have typical mountain structure, whereas our mountains (Catskills) are essentially a dissected plateau of upraised flat-lying strata. Davis has used the portion of the Kalk berg directly west of Catskill (Quarry hill and Fuyk, figure 60) also in illustration of his six physiographic types in regions of folded rocks.

It is strange that this beautiful and diagrammatic folding should have had so little notice from earlier writers (see Davis 1883), but Mather wrote (1843) before the appearance of the works of the brothers Rogers describing the huge folds in Pennsylvania and the Virginias. He has many illustrations of tilted rocks and several references to "lines of dislocation and uplift," by which he seems to mean faulting. Sometimes, as at Glenerie falls, his interpretations of structure are incorrect. To Davis and to Darton we owe the first real knowledge of our structural features.

The up-archings of the beds are called anticlines (figure 61), the down-sags are the synclines (figures 28, 68), while a dip in one direction only constitutes a monocline (homocline), as in the Hooge berg (figures 41, 3), but most monoclines (uniclines) are one limb of a syncline (figures 21, 30). A constant feature of our folds is that they are unsymmetrical, leaning to the west in the direction of the push so that the west dips are steeper than the east dips (figures 60, 13, 28, 68), and exceptions to this are very uncommon. One such exception, with the east dip the steeper, occurs in the Schoharie beds on the east side of route 32 at the four corners a mile and a half northwest of Saugerties.

This over-pushing may amount to an actual overturning of the strata, as in the West ridge of the Fuyk and in much of the Normanskill, which, having been through two periods of mountain-folding and being mostly unresistant ("incompetent") shales, has been sharply (isoclinally) plicated back and forth upon itself (figure 63) with some of its folds even laid upon their backs, and nearly all of them greatly pinched. But plication occurs also in the Catskill shaly limestone (figure 69) which has been through but one mountain-making.

One of the prettiest little folds in the country is that produced in the Rondout waterlimes at the entrance to Austin's glen (figure 13) by the gliding over it of heavier beds of the Manlius—a complete S with the middle limb (or reverse curve) rotated beyond 180 degrees. In miniature we have similar crumpling in clays where they have slumped.

2 Faults. In beds so greatly compressed as ours it would be surprising if they did not fracture and slip. Such displacements are called faults and in our region they are invariably thrust-faults, in which relief was obtained by telescoping. An overturned anticline easily slides on over its neighbor syncline (figures 26, 69), or it may rupture at the crest and shove before folding has gone far. A syncline in heavy beds when pinched too far may have its core wedged upward at both sides (figure 65). Steeply upturned strata may be simply torn across and one block pushed farther west than the other, resulting now in slight offset of the whole ridge such as occurs in the limestones north of the Ulster town line. Normally our thrusts are overthrusts, the upper block (slice) being driven westward. But occasionally there are underthrusts, in which the lower block moved west. Thrusts have also developed in slid clays.

On the fault planes, the grinding of the surfaces upon each other produced slickensides (figure 19), which sometimes follow bedding

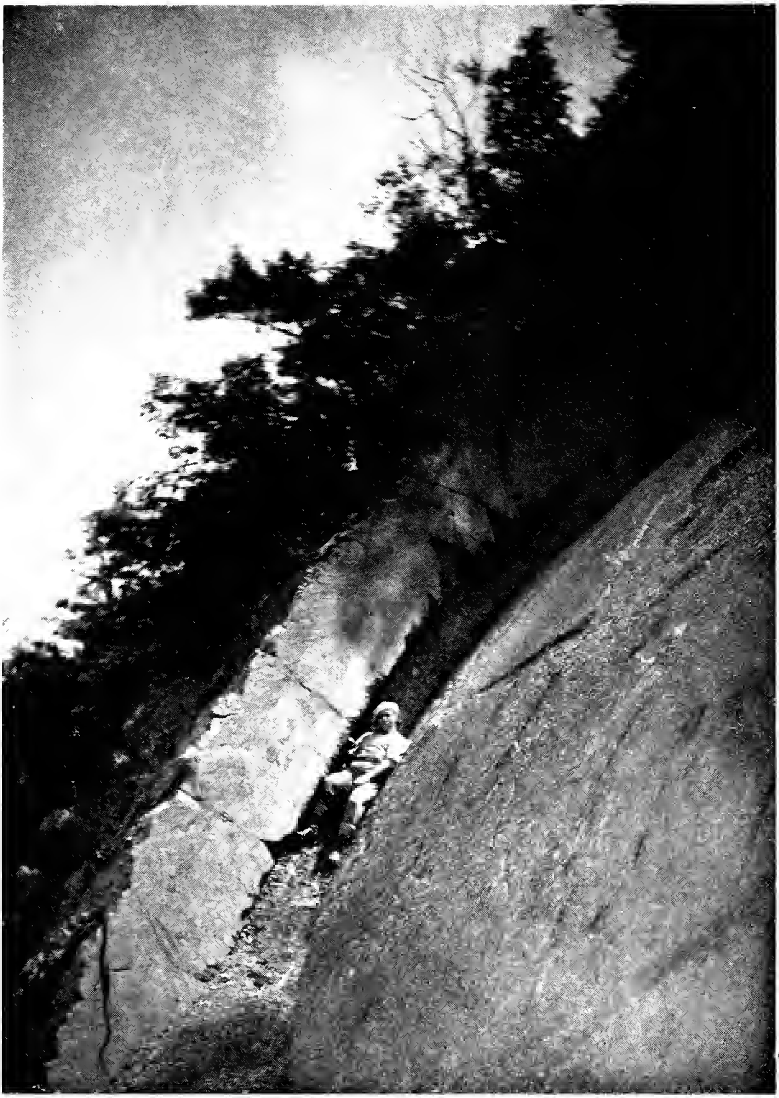


Figure 61 Part of a graceful anticlinal arch in Normanskill sandstones and shale on the Cats kill (old railway grade) at south portal of Austin's glen, Jefferson Heights. Looking north-northeast. Columbia University photo: about 1917, courtesy of H. L. Alling.

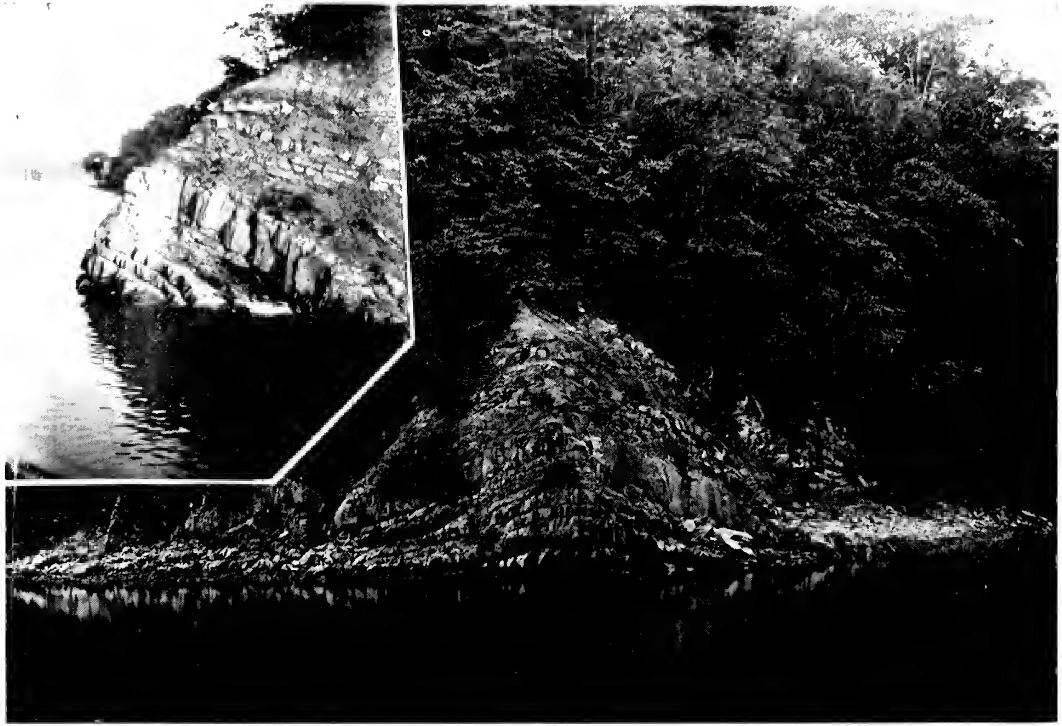


Figure 62 False anticlinal effect in Normanskill beds at the Hoponose on the Cats kill, in south part of Catskill village. Looking nearly south. Columbia University photo: about 1917, courtesy of H. L. Alling. Inset, looking east-southeast, shows the real dip, which was away from the camera. Photo: about 1920, Charlotte Pettengill.

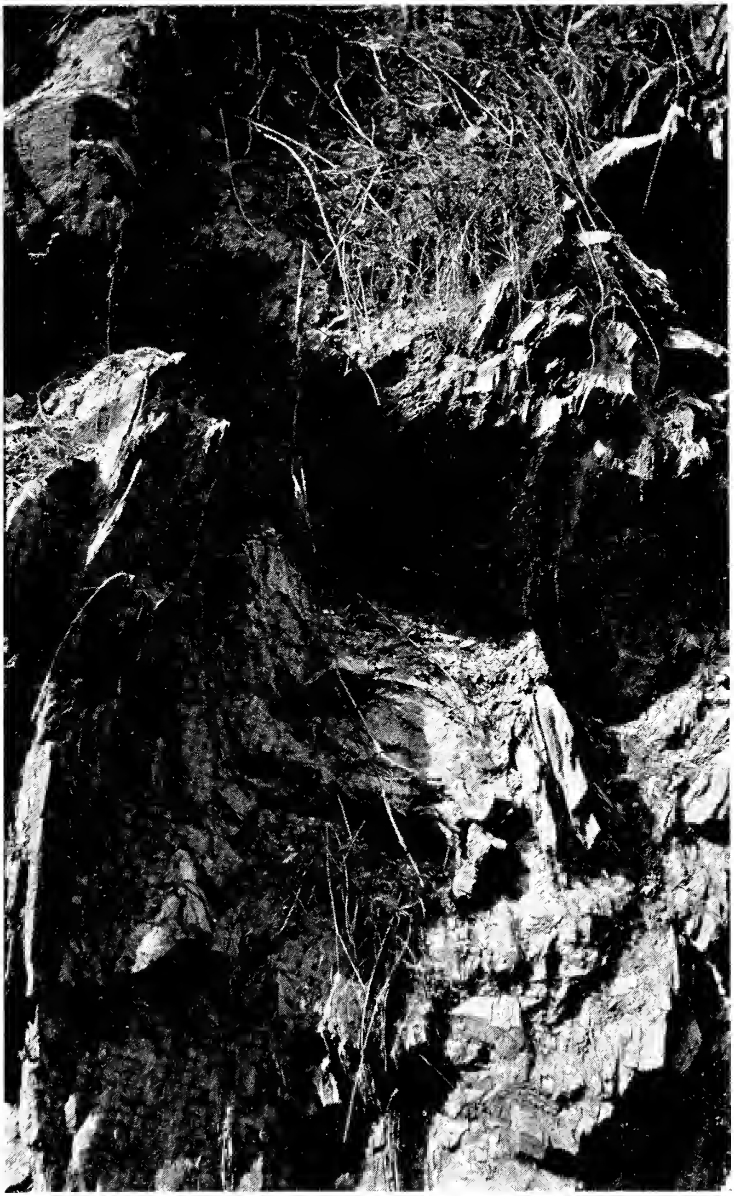


Figure 63 Isoclinally compressed synclines of Normanskill shale in old Catskill Mountain Railway cut (now filled up) between Main street and River street at the "Point," Catskill village. Part of a succession of such tight folds. Looking south-southwest. Photo: April 1915, G. H. C.

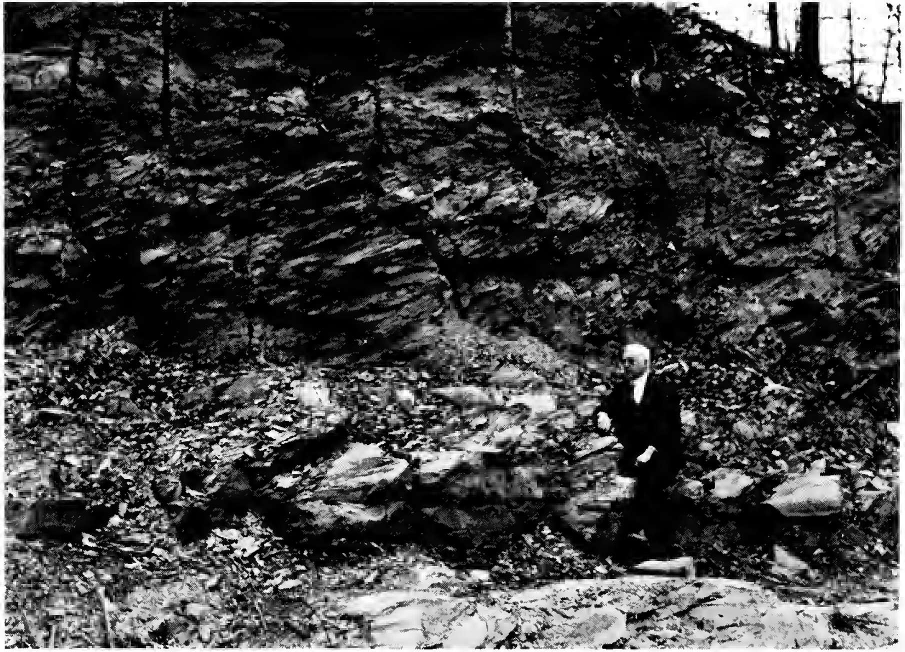


Figure 64 Diagonal cleavage of horizontal beds of Schoharie shaly limestone on Cauterskill-Leeds road about one mile north of Cauterskill. North end of a syncline, showing push (with overturn farther east) toward west. Chadwick sits on harder limy beds less affected. Looking southwest. Photo: April 1938, W. J. Schoonmaker.

planes. Adjacent edges were often curled under (dragged) as they slid (figures 26, 67), and at the same time, or independently, so strained as to become strongly cleaved with the cleavage angle pushed over in the direction of thrust (figures 64, 34, 41) whether in fault or fold. Cleavage in the homogeneous Esopus shale is, however, more inclined to be vertical to the bedding (figures 32, 33) and reminiscent of that in the unconsolidated deposits known as loess.

Fault planes may contain up to several inches of ground-up rock that yields quickly to the weather and is known as gouge, as well as indragged fragments oriented with the fault plane. Or some feet of beds may be rolled up and crumpled between the moving surfaces, as well shown in the far wall of the south quarry at the North American plant (figure 68 and compare figure 66). The larger masses thus dragged in are known as horses and may consist of rock different from that which incloses them, thus show on the map, as the bit of Fuyk sandstone two rods long by one rod wide beside the woodroad through the pines three-eighths mile south-southwest of the Red Schoolhouse and directly back up over the brow from the "big spring" (page 12) on route 9-W; or the eerie and much larger knoll of misplaced Becraft and New Scotland beds on the west fork of the woodroads along the Kalk berg, at summit of the Esopus vale seven-eighths mile southwest by south from the junction of route 23-A with route 9-W, near Catskill.

In place of a simple slip, a mass or zone of broken rock may occur at the fault. Such a fault breccia is well displayed in Rondout limestone where route 9-W bends around it 300 feet south of the North American conveyor-underpass. In the multiple slicing of the Fuyk sandstone on the south end of the West Fuyk ridge, brecciation characterizes the third and fourth of the five slices and excellent specimens may be obtained.

Calcite veins are common in both fault planes (figure 69) and fault breccias, as well as in strain cracks. In fact, the presence of calcite veins in our rocks is a trustworthy index of faulting. The calcite often takes a mold of the slickensides, as on Quarry hill, and it was probably this that received the name "fibrous calcite." Nice specimens of the white cleavable calcite may be gathered near the upper end of the old Austin millroad, derived from joint cracks and especially from a thrust plane up in the cliff (Davis 1883, figure 3).

While thrust faults accompany folded rocks, quite a different type of faulting is usual in flat-lying strata, and having been the first kind studied is called "normal." In a normal fault the upper block moves down, relatively, instead of up. No true normal faults have come to notice in our folded rocks and but one in the monoclinal zone to west, namely at the south (left) end of the cliff shown in figure 42 where a slip of at most a few feet cuts off the coral bed in the water, as discovered by Doctor Cooper, and is traceable up to a notch in the hilltop as a down-dropped wedge or small "graben." A small normal fault in our mountains will be described with the keystone faults, of which the preceding may also be an instance.

ARRANGEMENT OF STRUCTURES

The rock folds of our region all lie east of the Bakoven valley and do not involve the thick Hamilton and Catskill Mountain beds. Those of the Ordovician strata, which went through a second compression after erosion had bevelled the tops of their earlier plications and which have since been much covered by Lake Albany clays and other Pleistocene deposits, on both sides of the Hudson, are today scarcely decipherable. It is in the thin formations of the narrow belt of the Kalk berg that one's wits may be employed, yet even where exposures are plentiful and the surface facts not obscured that which is found is often almost incredible, difficult to imagine in underground extension, impossible of satisfactory reconstruction as to the mode and processes of origin. The map itself, especially in the cement region, looks like a disordered nightmare and that is just what the region has proved to be to the cement companies, whose quarries have revealed to us marvellous complications (figure 69, for example).

A peculiarity of our folds, in which they seem to differ from the great mountain folds of Pennsylvania, is their discontinuity. Except the large syncline extending from Quarry hill to West Camp, which so conspicuously offsets the whole series eastward, few folds can be traced any distance before they rather abruptly die out and give place to new ones arising beside them. Odd zigzags and diagonal cross folds are thus repeatedly found to occur. This is specially characteristic of the Onondaga and Schoharie in the Saugerties district, where the edges of these formations regularly fray out northeastward every mile or two. The ends of folds where they terminate against the cross synclines frequently plunge underground with surprising speed; as the north end of the great arch of Alsen limestone at Klee's hill, southwest of Van Luven's lake, which terminates northward the anticline of the Great Vly, and the companion or overlapping arch of the Schoharie-Onondaga beds on the west of it. Similarly, route 23-A goes down a diagonal vale between overlapping ends of Schoharie anticlines, from the Old King's road to the Webber bridge over the Kaaters kill.

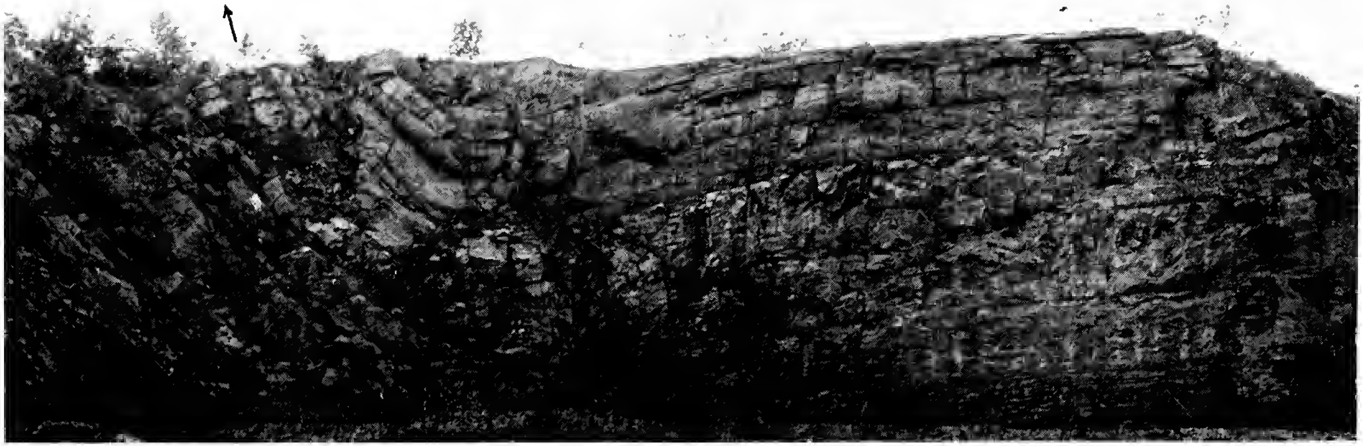


Figure 65 Wedge faulting in the south quarry at Alsen. A wedge of massive Becraft limestone is driven up to right (west), by the squeezing of the syncline, on the plane marked by the arrow, and a similar wedging is less clearly visible on the opposite limb. Note **overturn** of Alsen limestone at skyline on left of axis, as marked on figure 28, and cave opening in Becraft half way up on far right. Looking south. Photo: May 1938, W. Storrs Cole.

Figure 66 Detail showing "takeup" of the fault by contortion of the lower thin-bedded Becraft in bottom of the syncline; position in figure 65 identified by dark solution cavities at top of view. Mr Kilfoyle's hand marks the fault plane. Photo: April 1938, W. J. Schoonmaker.

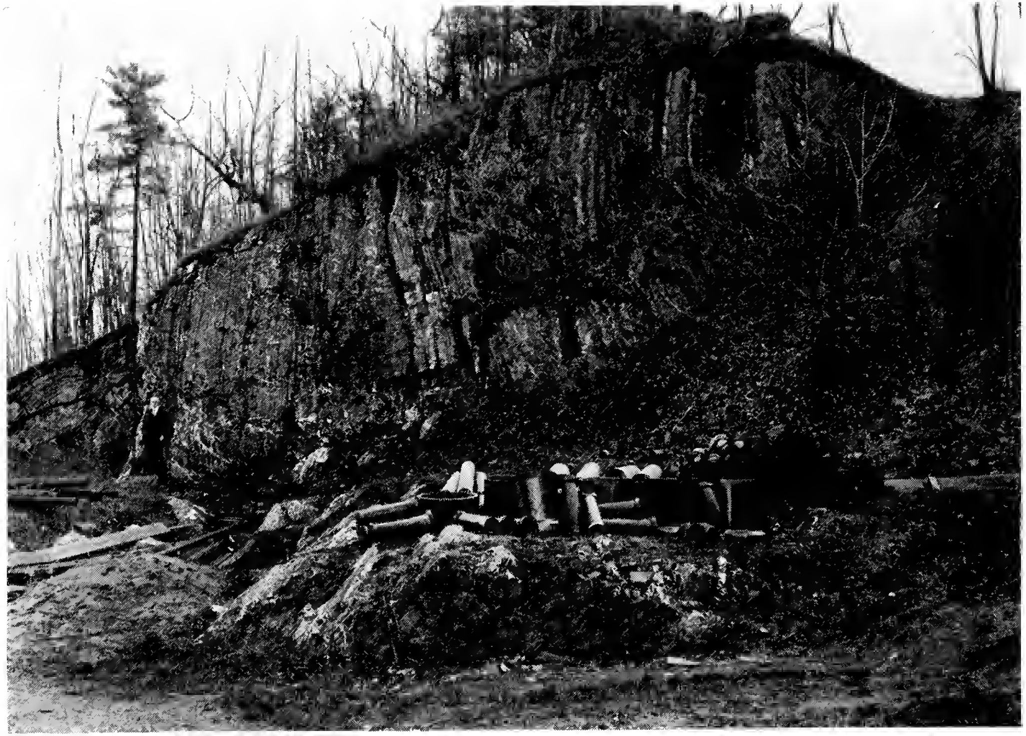


Figure 67 Underdrag on overthrust at Canoe Hill town stone-crusher quarry, just north of Saugerties. West limb of an anticline (note arch in Manlius on left) driven west (right) on a plane located almost at nearest floor of quarry, with marked "drag" overturn of (Kalkberg limestone) beds below the tiles. Coeymans (man standing against basal layer) about 21 feet thick. Kalkberg (et cetera) about 39 feet. Looking south. Photo: April 1938, W. J. Schoonmaker.

Figure 68 Operations (1938) in south quarry of the North American Portland Cement Corporation, west of DeWitt's point, five miles below Catskill, on route 9-W. Transportation is by dump-cars and steam locomotives to crusher plant. Quarry being cleared for blasting of far (south) face. An unsymmetrical syncline of Becraft, Alsen and Glenerie beds, very sharply upturned and squeezed thin on east limb, as seen at extreme left, near which the Alsen makes about lower third of height of the wall, and the Glenerie cherts the upper two-thirds, with separation at a line of dark shale. Line between Alsen (darker) and massive Becraft (lighter) well seen in middle of view (below the drilling rig), to right of which this Becraft is duplicated by a wedge-fault zone (of much crumpled layers) rising and narrowing diagonally up to right. West wall is rejected lower less pure and thinner layers of Becraft, with strong east dip. Looking about south. Photo: November 1938, by courtesy of their general

Figure 69 The noted overthrust in the north wall of the north Alsen quarry of present Lehigh company's cement plant at Alsen, N. Y. Observe fault plane rising to west and bent upwards where a wedge of Alsen limestone is driven under it; above, the vertical to overturned beds in the upper slice, consisting of Becraft limestone at left (no Alsen there) and the somewhat plicated Catskill shaly limestone at middle and right; beneath the fault, the undisturbed Becraft limestone (light colored) at bottom, overlaid by successive wedges of Alsen limestone, becoming drag-cleaved in the upper part, whose exact limits (fault planes) are not easy to trace, even in the field. Looking about north-northeast. Photo by Robert W. Jones.

The general westward overturn of the axes of the folds, which carries the beds always deeper westward in each such undulation until those at the Hudson go far beneath sea level under the Catskills, and the simpler cases of faulting have already been described. Some special cases are soon to be taken up. It is well first to note how frequently we have to deal with eastward as well as westward thrusts. Not all of these are to be classed as underthrusts. In the folding of a syncline, the layers naturally tend to glide upon each other upwards on both sides of the axis, eastward (figure 19) as well as westward. The heavy Mount Marion sandstones have thus overridden eastward the Bakoven black shales at Houck's "coal mine" (page 103).

The same relief may be accomplished instead by faults rising diagonally (figure 65) up both limbs and lifting a wedge-shaped mass within the core of the fold. The snap on the east limb is then as much of an overthrust as that on the west limb. Such snapping or wedge-telescoping eastward (as in lower part of figure 19) accounts for much of the repetition of the Manlius and its inclosing beds along the east front of the Kalk berg from West Camp northward through the cement region to the Red Schoolhouse. It accounts also for the long parallel strips of Becraft, Alsen and Glenerie on the opposite side of this syncline through a part of the same stretch. It explains many other "strike faults" and many little diagonal cross slips on upturned beds, as in the Schoharie east of Asbury.

Deceptive resemblance to young normal faults may result from fresh cliffing of the overriding mass along major joints, as frequently in the Becraft strips on the far side of the West Camp syncline, but the truly overthrust relations are revealed in the quarries and by the behavior when followed on the surface "trace." It is unfortunate that the already crowded formational lines upon the map have made it inexpedient, where not actually impossible, to draw fault lines as such on it. Therefore the presence of the faults is revealed only where they offset the formations and is concealed at intermediate points.

SPECIAL CASES

Some of the features that do nevertheless show on the map deserve particular description. These fall into several classes, but it is noteworthy that all of them appear quite uninfluenced by the jointing now present in their rocks and seem to prove that jointing is a later and probably more superficial (shallow-seated) process than folding and thrust faulting.

1 Pivotal faults. All our fault lines tend to die away and disappear unexpectedly. This is most noticeable on the map, and most easily

explained, in the case of fault blocks anchored at one end, from which they have pivoted westward, rotating upon the under block. Such faults are illustrated at the Indian Caves locality a mile and a half southwest of the bridge at Saugerties and again in the same Schoharie beds at Mower's crossroad nearly three miles north, in both cases the north end being swung, as it is also in the east or upper block on the hill south of Schoentag's in the New Scotland and lower formations and in the special case of the Canoe hill, Saugerties, to be described in another connection. Doubtless if we had the whole story, now lost by erosion, we would find the strata returning eventually to another pivot. Such pivoting of the other end indeed occurs farther north, in the rotated blocks on the hill above Cementon which puzzled the operators. A case in which the upper block appears mysteriously to have been rotated east instead of west is that of Mr Fera's hill a half mile east of Katsbaan church. The pivoting at the Fuyk (figure 15) is plainly part of a ruptured anticline.

2 Derelict hilltops. We may coin this expression for the disconnected block on the Kalk berg two and two-thirds miles southwest of the bridge at Catskill, and for others like it which have trespassed far across other structures. The noted overthrust hilltop (figure 69) above the Alsen railway station has been taken for such a mass, but it is actually pivoted to the south end of the south quarry as the map shows, being similar to the hill summit north of the bucket line at Cementon but oppositely oriented. In both cases the strata are vertical; in both there are jammed against the east face masses of the lower limestones in inexplicable fashion.

3 Multiple slices. The imbricated arrangement of the successive pivoted blocks above Cementon is easier to recognize on the map than is the vertical imbrication of four successive sheets of Manlius in the hill south of the Red Schoolhouse and above the "big spring" on route 9-W. Visual separation of these may be made by following the discontinuous bands of the underlying Fuyk sandstone or of the overlying Coeymans-Kalkberg limestones that are drawn in between them, often giving place one to the other abruptly along the strike. Though the upper slice is interrupted at the crossroad, it resumes beyond, and the disconnected or derelict hilltop already mentioned seems to be but another (fifth) slice, as will come out in the section on nested folds. Multiple slices, five in number, occur also in the West ridge of the Fuyk, where figure 15 represents the topmost or fifth slice. Incipient imbrication of four slices is found on the south side of Austin's glen (see figure 26 for one of the faults).

4 "Downward" overthrusts. Discovery at Canoe hill, Saugerties,

of a thrust fault (Chadwick 1910) in which the upper block appears to be slid downhill was the first intimation that our "miniature" overthrust planes are undulated (folded) as are the great ones in the southern Appalachians. The course of the field mapping found this to be by no means an unique example. The Canoe Hill fault may be looked upon as essentially pivotal, though possibly a little broken on the pivot and also complicated by a sharply pinched anticline on the east that brings up the Glasco limestone. It is so easily visited, with a village street continuing through the hill on its trace, that it is worth brief redescription.

On the south or overthrust block the Glasco limestone makes a sharp rib just behind the modern house on the corporation line. West on this line all the succeeding limestones up to the Glenerie at west base of the hill are found in regular order and highly upturned (figure 67). Northward are quarries, a larger one in the Coeymans-Kalkberg (figure 67) formerly worked for the town stone-crusher, and smaller diggings in the Catskill shaly and the Becraft, near where all of these terminate against the road. Just east across the road from the crusher quarry, in the yard behind the house at the intersection of the sanitarium spur-road, are ledges of the Becraft limestone, soon backed on west by the Glenerie at the roadside but best displayed beyond, opposite the next houses and past the tip of the south block, where it makes bare surfaces running steeply far up the west slope of the north half of the hill, while Becraft still shows in the houseyards far below it.

On the west side of the road at the first telephone pole up from the crusher quarry may be seen the slickensided, calcite-filled fault plane itself or a split of it, sloping down west between Kalkberg limestone above (Coeymans at left) and about three feet of what looks like Glenerie limestone below, with a rotted zone under the fault. There is marked drag on the bottom of the upper block, shown on a larger scale in the quarry (figure 67), in which the fault plane still drops rapidly west beneath the quarry floor. A calcite-cemented fault breccia of the Manlius makes a ledge south of the quarry entrance.

The important thing in this description includes the strong westward "hade" of the fault plane where seen and the still steeper attitude that it must take to north to let the Becraft down below the big bare surfaces of the Glenerie. The difference between such a fault and a normal fault is that the latter continues down into the earth whereas the thrust plane curves back up again. It is now possible at many points in our area to see thrust planes folded into anticlines and synclines, as will come out in the next section. The possibility of this being a "snap" in which movement was up east instead of down west is opposed by the thickness and number of formations involved and negatived by the relations farther north. A similar pivotal fault, with similar westward tilt of the fault plane, occurs in the north half of Canoe hill, wholly unconnected with this one, and is definitely not a "snap."

5 Nested folds. Four examples have been found, in the Kalk Berg range of the Catskill quadrangle, of a structure in which the strata are repeated upward within the same anticline. The impression given in every instance is that of flat overlapping fault slices having been subsequently arched, simultaneously, into an anticline. As there has been no north-south telescoping in our region, no other mode of origin suggests itself. All of them are fully open to observation. (See figure 70.)

a The simplest one is on the high hill east of the Cats kill (right hand of figure 1) at the point in Austin's glen where that stream crosses the Manlius and Rondout formations. The beds are upturned steeply, at right angles to the creek where it leaves them (just above which it has been approximately on their strike; see figures 23, 25), and they rise up the east bank at a high angle of west dip, then arch over prettily in an outlook cliff.

Along the creek and the old railway grade that follows it all seems to be regular in the section of the Manlius, Coeymans, Kalkberg and Catskill shaly limestones. But on the hill crest (the anticlinal axis) the case is different. Starting from the outlook cliff of Manlius at the south end, which is plunging noticeably northward, one comes in six rods north to a ledge of Coeymans topped by three to four feet of cherty Kalkberg showing a strong cleavage dragged over to west. The next exposure above this, seven rods farther north, is Manlius again, the Stromatopora bed, capped by Coeymans making a good ledge at three or four rods beyond. Finally, in another five rods, comes a high ledge of the full thickness of Kalkberg limestone, whose top is the level crestline of the hill.

As these ledges roll down the west side to their steep west dip into the creek, a fine vertical cliff of the Catskill shaly comes up on the flank, reaching the level of the broad hilltop within 200 feet north. Down this slope, also, the upper Manlius cliff bevels out, from base upward, against the Kalkberg below the fault plane, letting the upper Kalkberg sheet down upon that. But on the east slope, where the anticline is followed by a quick upturn on a subordinate syncline, it is the lower Kalkberg and Coeymans that can not be traced far north before the two Manlius sheets seem to close in and cut them off, though the exposures here are not so good. This is exactly the relations that would obtain if a low-angle thrust had cut up across horizontal strata and then all had been folded into anticline and syncline. The mechanics of telescoping the beds in this fashion, on a recurving plane, after they were folded are unbelievable. That it is not a "snap" is proved by the direction of drag-cleavage on the lower sheet of Kalkberg.

At creek level, this fault plane is probably concealed up in the weak shaly limestone, in which there are several little ruptures visible to right of figure 23, and may re-emerge beyond in one of the three or four thrusts of the Becraft already mentioned, on far side of that syncline. Moreover, it likely is the same as the plane found across the eroded anticline to east in the "Glen Cliff" Manlius ledge on which are the three cottages (page 145), responsible for the sharp prong in the Manlius outcrop at its north end, and therefore that of the Austin millroad (Davis 1883, figure 3). That would take it over three synclines and two anticlines. Whether it is the one that offsets the Schoharie beds still farther west, near north edge of the quadrangle, remains to be learned.

b A second instance is on the Kalk Berg ridge overlooking the Pine View filling station on route 9-W about two and a half miles south of Catskill. Access is good by two old woodroads that sidle southwest up the ridge, from respectively 400 feet north and 100 feet south of the station.

Up the north road, vertical Fuyk and Manlius are crossed in small exposures and flat-lying Manlius (a different slice) found in the hairpin loop at the top resting on folded Coeymans and Kalkberg that strike north under it but break off south in a good cliff looking down upon the other woodroad. This cliff rises thence west, arches over the hill and down on the far side, in the edge of the evergreens, picturesquely. In it was observed a favosite coral almost two feet in diameter. But this arch plunges slowly north into a hollow in which runs a connecting woodroad, and a second similar arch of Kalkberg limestone (underlaid partway by Manlius and Coeymans) wraps over it, also plunging north and going under the Catskill shaly where the north woodroad winds around on the line of contact between these. The intervening wedge of Manlius comes up from the flat exposure on the east brow and cuts out down the dip as did the one in Austin's glen, while the Coeymans continues on around with the Kalkberg of the upper sheet far south on the west of the north-south connecting road.

Eventually, at south, this fault plane connects with one of the higher ones in the multiple slices south of the Red Schoolhouse. Northward, the strata of the upper slice soon turn up on edge, the lower Kalkberg and Coeymans being immediately lost and the two sheets of Manlius merging finally somewhere under the talus. The conditions thus parallel closely those at Austin's glen and a similar fishhook of Manlius appears on the map in both places.

c A third example, but much more complex and requiring wider exploration to encompass, lies not far southwest of the preceding, easily reached by the south path from the filling station. It includes the derelict hilltop already discussed, as its uppermost slice. There are here four anticlinal sheets of Becraft nested one above another, with intervening beds of Catskill shaly and Alsen.

The exposure of the lowest Becraft sheet is small, the mere eye of a fenster (page 185), but easily found in the open ground just east (four rods) of the Streeke sink—point of disappearance of all the drainage from the surrounding wilderness as well as that from Van Luven's lake. Here is a west-leaning anticline of the limestone, but the actual exposure is only a hundred feet long and three or four yards wide, merely the vertical west limb and the arching crest. The east slope, of gentle dip, is grassed over, though other deep but dry sinkholes down to east a few rods betray the presence of the limestone still beneath them. On south, the Alsen overlaps short of the powerline tower (No. 418), and may sheet over all the back slope.

Following the powerline north, one finds a second fine ledge of Becraft arching over this Alsen, though bevelled out on west, and running far southeast behind the sinkholes mentioned. It bears Alsen again, the full thickness, on its back, then the Glenerie cherts northward from the next tower (No. 419) well into the woods, nicely arched and declining northwards. Diagonally across these comes the Catskill shaly of the next slice, followed regularly up the slope in the woods by the third Becraft sheet wrapping over it and curving down likewise to the deep Esopus vale on west, into which all the beds have dived. Once more the Alsen succeeds, in good ledges, and has a long and broad north-plunging crest against the fourth and highest crest of the Becraft, equally anticlinal with all that precedes it and making the high summit north of the evergreen woods.

We must leave others to struggle with the problems of magnitude and of the eventual takeup of such extensive movements. The present visible width of the Becraft-Alsen slices, flattened out, inclusive of their known synclinal extension eastward in the two upper slices, is not less than 400 feet for the top slice, 900 for the next and 500 for

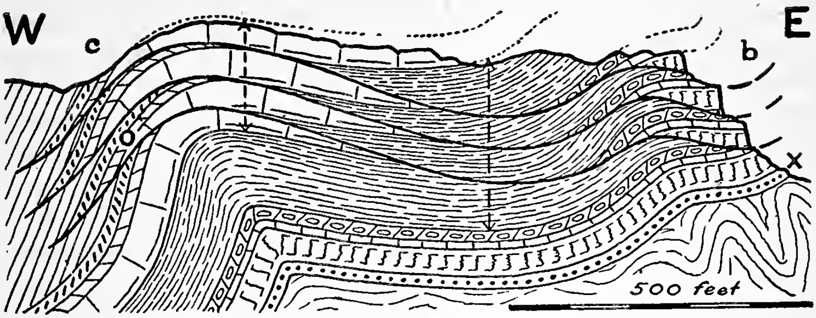


Figure 70 Schematic diagram of "con-plicate" fault-slices (nested folds), as in Kalk Berg range near "b" and "c" of the text, which are one structure. No vertical exaggeration except that folds plunge away from the eye. Water entering at O somehow emerges at X without apparent limestone connection. Note overthickening of beds as marked by arrow-tipped lines.

the third one down, which, considering the bottom slice as stationary, means at least 1800 feet of telescoping of the Becraft-Alsen. If the beds were practically horizontal when the thrusting occurred, these thrust planes should have run westward up into parts of the Esopus (and greatly overthickened it) that are now turned down under the Schoharie just to the west—merely across the Streeke lakebed, as the map shows. But if so, then this upturned overthickened Esopus must subsequently have been largely overridden by the whole mass of limestones driven over it from the east, for the present belt of Esopus outcrop is here now decidedly narrow.

The point to be emphasized again is that of the two thrust planes that can be followed (the lowest one being lost to view underground from the fenster), both recurve synclinally on the east, and strongly broadly so, along with the inclosing strata. That they could have developed at all with the beds folded or even slightly deformed from straightness is unthinkable. Each of the upper slices has Manlius finally on its eastern edge and the lower of these two is identical with the higher sheet in the locality to northeast previously described, thus extending the middle fault-plane over a second anticline and syncline. Directly west of all this disturbance (and more faulting yet on south), runs the remarkable straight (only slightly arcuate) syncline of the Schoharie, to which the perfectly straight powerline is tangent at both horns.

d Somewhat different, simpler but a bit harder to see in the field, is the anticline over anticline in the Onondaga, Schoharie and Esopus beds northeast of the Green schoolhouse on the Old King's road. Access is best by an old wagontrail just south of a new house three-eighths mile north of the school, where the highway bends away from the hillslope and out upon the clayplain. Not far up the slope is found Onondaga limestone with calcite veins (always indicative of faulting). The limestone makes a good arch, southeast up over the hill, in the woods, while on north its outcrop is an increasing ledge. Straight east one climbs up on west-dipping Schoharie to a ridge that breaks down to east, across an anticlinal axis of Esopus, beyond which the Esopus forms a syncline holding another strip of the Schoharie. All is regular, to the eye, in this cross section, except for a sinkhole in the Esopus at foot of the first drop. Neither the Esopus nor the Glenerie below it makes sinkholes.

But just south across the fence, in the woods, is the arch of Onondaga limestone that has been mentioned and that is now seen to pass north directly under this Esopus arch with its sink. The anomaly of a sink in the Esopus is explained.

The Onondaga dips east underneath the Schoharie syncline of the upper slice (with a cave that receives the waters of a small brook), and these relations continue onward to south for a third of a mile until all goes under the meadows. Within a quarter mile in the opposite direction (north), the Schoharie ridge of the west strip is found to offset abruptly, its wide outcrop of moderate dip superposed upon a narrow belt of vertical Schoharie beds that run on north out from under it, and south from here back to the start the Onondaga limestones are found to be diagonally overridden and cut out by the upper slice Schoharie until only a small thickness remains where first seen.

Though there is not so close correspondence of the axes in these superimposed anticlines as in the cases previously given, yet the amount of movement that would be required here to slide one large anticline over upon another, along a curved plane, involves greater mechanical difficulties than to slide the beds first, a much less distance, and do most of the folding of them afterwards.

6 The incompetent Esopus. Attention should be directed to the variety of formations in contact with the Esopus shale along its eastern boundary, in the north half of the quadrangle. These range from the expected Glenerie down to the Catskill shaly limestone, the different beds coming and going at the contact with surprising facility. The explanation is, of course, that the Esopus shale was sufficiently yielding as to serve for the buffer zone or "takeup" rock of the overthrusts of more rigid and more brittle beds beneath it.

There is a continuous overthrust upon it for nearly its entire front of three miles in the Quarry hill-West Camp syncline, and again from the Great Vly south for nearly two and a half miles to near Katsbaan Church, with lesser strips both north and south of that one. Why the same thing is unknown in the south half of the quadrangle is not clear, except that the point of cessation coincides both with the bend in the Kalk berg and Hooge berg at Katsbaan discussed on page 12 and with the north termination of the highly fossiliferous upper Glenerie limestone.

There is one clear case of thrust from the west upon the Esopus, that ot the Onondaga upon it something over a half mile north from Van Luven's lake, nearly meeting a thrust of limestones from the east.

THE BELT OF FOLDING

The folds and faults of our Silurian and Devonian rocks have been mentioned as peculiar to the thin formations of the Kalk berg. As we step west of the Hooge berg we leave behind us practically all traces of disturbance. Our mountain rocks lie almost as flat and placid as when they were born. Northward the zone of folding runs but a short way into Albany county; southward it stops short almost at Kingston and gives place to the great Appalachian swells of the Shawangunks.

The older idea that our "little mountains" are the tail end of the Pennsylvania mountain folds, greatly diminished in size, seems no longer tenable. There are similarities of structure, to be sure; our Kalk berg imitates in miniature many of the most characteristic elements of Appalachian structure. But there is no gradation. The tiny folds stop short and the big ones begin. An angle between the two complexes, near Rondout, serves further to differentiate them. The Pennsylvania folds mostly run out into southern New York and fade away in the far western outskirts of the Catskills. They do not join up with our little undulations.

Rather significant to us is the fact that the folds in the Helderberg scarp, as traced north from Catskill, end suddenly just where a major overthrust in the underlying Ordovician beds emerges from beneath the Manlius cliff. The general course of this thrust trace, projected southward, would pass about along the general line of the Esopus shale on our map. Significant also is the fact that the Becraft's Mountain outlier of these same limestones does not show the same intense plication except in its southeast rim (Grabau 1903) but does possess, according to Doctor Grabau, a system of normal (as well as of overthrust) faults not found on the west side of the Hudson.

The narrowness yet intensity of this folded belt, its localization east of the Catskills and still more its coincidence with the Ordovician thrust zone where that can be observed, namely at both ends, all strengthen the belief that these strata have been crumpled upward upon the toe of the underlying Ordovician overthrust fault slice in a recrudescence of its westward progress occasioned by the urge of the second mountain shove. It is wholly possible, as discussed beyond, that this second shove was independent in time as well as in localization from that of the Pennsylvania folding to which authors assigned it and which infringes upon it in the Rondout-Binnewater region.

KEYSTONE FAULTS

Recognition of the letting down of vertical wedges of rock (see page 17) in zones of close-spaced master joints, as a process still in progress, explains some physiographic features of our mountains, as already noted. In the fissured zone any blocks that happen to narrow downward will settle by gravitation whenever the zone is opened the least trifle, as by temperature changes or momentarily but repeatedly during the passage of earthquake waves, just as the latter drop the keystones in arches of buildings or bridges. The ensuing compression may wreck these blocks, as in the jaws of a stone-crusher. Deep fresh trenches in solid rock result. Displacement of the opposite jaws is not implied, seldom happens.

Paralleling the mountain valleys are some long straight slots in the anticlinal limestone ledges of the Kalk berg suggestive of keystone faulting. Mr Tipp's house road, on east of the old stage road (upper road) one and an eighth miles south of Schoentag's, runs in such a slot in Becraft limestone behind but not quite parallel with the faultline cliff of an overthrust. The association is accidental, though the two are combined northward behind Mr Brink's barn as a deep dry chasm.

A half mile west of Van Luven's lake the little used road on the west side of Klee's anticlinal hill follows up another such gash in the Becraft and Alsen, the line of which is prolonged southward, perhaps even to the entrance of the "back" Lehigh quarry. East of it 750 feet is a notch in the Becraft where the power line bends through it and then follows its extension south to the Lehigh power take-off. Another large slot in the same limestones 400 feet farther east splits the north end of the high hill three-fourths mile northwest of Alsen. All these parallel slots are out of natural relation to drainage but they do accord with the direction of glacial flow as well as that of master jointing. They deserve further study.

EROSIONAL STRUCTURES

Under this seemingly contradictory title will be discussed features that are sufficiently stratigraphic to have no place in the scheme of physiographic classification yet exist only by virtue of erosion, namely outliers, inliers, faultliers and fensters. These show upon the map as isolated patches of color.

Outliers are patches of rock sundered from the main mass by erosion and surrounded therefore by older rocks. Commonly they occupy the troughs of synclines. Inliers are unroofed exposures of older rocks looking up through a rim of later ones. Commonly they occupy the crests of anticlines. Faultliers are disconnected patches torn from the main mass by faulting, and may rest upon either older or younger rocks, or both. Fensters ("windows") are inliers of younger rocks looking up through a rim of older ones in a superior fault slice.

1 Outliers. The largest outlier of Silurian and Devonian rocks in the Catskill quadrangle is Becraft's mountain southeast of Hudson, with all formations of the Kalk Berg belt except the Rondout. It is described separately by Doctor Ruedemann, on whose side of the river it lies. On the west side, a smaller one is Eagle cliff (figure 16) in Austin's glen, carrying Rondout, Manlius, Coeymans and Kalkberg limestones wholly surrounded by the Ordovician (Normanskill). The Limekiln hill just west of Flatbush, near the south edge of the quadrangle, supports a Manlius outlier and that northwest of Schoentag's a Becraft outlier, north of which is a small but spectacular outlier of Kalkberg and Coeymans. A large outlier of Onondaga limestone lies in the meadows northeast of Katsbaan Church and the map shows three other good-sized and one tiny (doubtful) outlier of this rock farther north, three of which are in the diagonal syncline running west of north from Van Luven's lake. The most northerly one contains Palmer's (or Cauterskill) cave. Northeast of the last is an elongated outlier (the only one) of Schoharie limestone.

Another Becraft outlier lies high on the hill east of Austin's glen, with a tiny one north of it (at Dick Hartley's and onto Otto Margraf's land), extending a bit over the quadrangle edge, while a third one enters the map east of that and close to the east front of the Kalk berg. An artificial outlier of Becraft has been made by quarrying, west of Cementon, just south of the Alpha crusher. A typical outlier of Kalkberg and Coeymans, though riding on a Manlius fault block, caps the hill south of the Red Schoolhouse, above the "big spring" on route 9-W.

Thus of true natural outliers on west of the Hudson the Onondaga limestone has five, four of them large, the Becraft has only four, not so large, the Kalkberg and Coeymans three, the Manlius but two, one of which it shares with the Kalkberg-Coeymans and the Rondout (in Eagle cliff), and this is the only one of Rondout. The Schoharie also has just a single but large outlier, making a total of 15 for the Catskill quadrangle, including Becraft's mountain. Not a single outlier or even sundered fault mass is known for the Esopus, the Marcellus, the Mount Marion, the Ashokan and the Kiskatom beds in our area. Nor are there outliers of Catskill shaly limestone.

On the other hand, the mountain peaks of the Kaaterskill quadrangle carry large and striking outliers of all the succeeding formations (Kaaterskill, Onteora, Stony Clove and Katsberg), as the map shows so well that they do not require enumeration (see figures 52, 54, 55).

The list of outliers on the Catskill quadrangle may be incomplete. It is not at all certain that the patch of Onondaga limestone north of Lost brook, halfway between Saugerties and the peak of Mt Marion, may not be isolated, as shown in the alternative mapping, instead of connected beneath the clays. Three small synclines on the east ridge of the Kalk berg above route 9-W though mixed up with faulting seem to have been natural outliers of Alsen and Glenerie beds. The simplest and largest of these is the middle one, at Van Luven's lake, which has been jammed over upon the Esopus and thus lost its western edge in the fault. Under the big overthrust hill (figure 69) at Alsen runs a long narrow syncline of these same beds, north to the south quarry (figure 68) of the North American company. A shorter strip looks out at both ends from under the derelict hill north of the Streeke, northeast of the Red Schoolhouse. There is also a linear synclinal strip of Glenerie chert midway of the ridge, a third of a mile back from Alsen, but in slight contact (faulted) with an unrelated Glenerie strip on the northeast end.

2 Inliers. Being generally more infrequent than outliers, inliers attract more attention. On the Catskill quadrangle they almost outnumber the outliers, without including artificial ones.

Largest of these and of unusual beauty both on the map and in its ruggedly cavernous Becraft limestone surfaces, is Mr Mower's hill, the Sup berg, a mile and a half north-northwest of Saugerties. This is an inlier of Alsen and Becraft. A third of a mile west of it, on Mower's crossroad, the Esopus is unroofed east of route 32 between two ridges of Schoharie tailing south from the hill on north, but is not exposed through the glacial till. Another inlier of

Alsen and Becraft lies five-eighths of a mile west by north from Van Luven's lake, north of Percy Holmes's house, and is partly rimmed around by sinkholes, two of which swallow brooks just west of Mr Klee's entrance.

In the Streeke fenster, the Becraft makes a tiny eye through the Alsen (see page 176). A similar inlier of Becraft pinched up through the Alsen on the hill south of Schoentag's has its south end overridden by New Scotland beds; but pushed right against it is a companion pinch of Kalkberg up through the Catskill shaly. An eighth of a mile northwest of these is the Manlius inlier cut through by route 9-W and a brook, in the core of a slightly ruptured anticline. There is another up-pinched rib of Kalkberg limestone 500 feet northeast of the natural dam (figure 78) in Austin's glen. Nearly half a mile southwest of this natural dam, along the old railway grade, the Schoharie pokes up under the arch of Onondaga limestone and probably extends south beneath the clays across the Cauterskill-Leeds road.

The pinched rib of Rondout limestone at the north line of Saugerties has been mentioned (pages 46, 53, 173), and it is to be noted that all such buckles, including all those above listed, are associated with overthrusts, perhaps as part of the takeup. A similar though somewhat mashed pinch of the Catskill shaly that seems to have been naturally exposed but has been more largely developed by quarrying lies between the old and the middle Alsen quarries, cut through by their railway.

Most interesting of all, because unique, is the inlier of Normanskill in Silurian beds three-eighths of a mile due north of Schoentag's. Glacial drift and grassland cover all but a doubtful square foot of exposure, but the disposition of the surrounding Rondout waterlimes is such as to leave no other possibility than a fair-sized inlier of the Ordovician. This is on the north end of the same ruptured anticline as the Manlius exposure of route 9-W, but the slight faulting is in no wise responsible for the inlier in either case.

A glacial moraine at Mr Dederick's, one-half mile north of Katsbaan Church, prevents certainty as to whether the Schoharie here closes over and makes another large inlier of Esopus north nearly to Asbury. A mile north of Asbury the broad expanse of Onondaga limestone over a double anticline shows no interruption with the exception of a small strip in plowed field and north into woods where the basal Onondaga stratum is in such relation and so glacially disrupted into boulders as to imply a small inlier of Schoharie, without known exposure.

Although rock is concealed, the visible depth of the clay-filled valley at Lost brook, a mile and a half southwest of Saugerties, is such as to make inevitable a trenching to the Esopus down through the Schoharie arch. Southwest of this, on the west side of the Old King's road at the crossroad to the base of the Mt Marion, is an "island" of Onondaga limestone, rising as a perfect elongate dome through the Lake Albany clay, that might be termed an inlier in the Pleistocene.

Quarrying in the cement region has several times gone through the Becraft and made inliers of Catskill shaly. A large one of these shows on the map, south of the county line, in the back Alpha quarry west of Cementon. The still larger one at Alsen may have been originally natural and is listed above. There is a small one mapped at the entrance to the northwest North American quarry south of Van Luven's lake and another too small to map upfaulted in their south quarry on its west side.

3 Faultliers. Generally sufficiently evident upon the map, the faultliers of the Kalk berg in the north half of our area are too numerous to specify. Many of them have been discussed in the section on faults. Most conspicuous, and economically most consequential, are the long strips of Becraft in the cement region. While in some respects the faulting here has hindered operations, particularly by interpolating the flinty and worse than useless Glenerie, on the other hand it has kept near the surface and presented for removal a much larger amount of high-grade limerock than would otherwise have offered.

To what extent such masses, disconnected on the surface, have underground continuity can in most cases be known only by exploration with the drill. As yet, the quarries have not demonstrated such continuity save for the slight "snaps" (figures 65, 66, 68). But in some cases drilling seems to have done so.

The large patch of Onondaga limestone on the latitude of the Pine Grove school, listed as an outlier, should perhaps be called a faultlier, for the Schoharie is thrust upon its east margin. To the imbricated structure of the Kalk Berg front is due many fault-isolated strips of Manlius, of Rondout (Fuyk), and of Coeymans-Kalkberg beds margining route 9-W, some of them partly concealed and inferred. The most interesting relations are at the conveyor-underpass of the North American plant: the lower slice begins with Fuyk sandstones down by the West Shore tracks and ends with the Coeymans making a fine cliff just east of the highway summit; the upper slice begins with (reworked?) grits exposed slightly in the west road gutter just north of the underpass and concealed under its concrete, followed upwards by Fuyk etc. This is the only case known to me of possible Normanskill infaulted with the limestones (and sandstones) of the Silurian, but is too crowded to map.

In the south half, except the two marginal cases described on the hill south of Schoentag's, there are but two faultliers. One is a tiny patch of Coeymans southwest of the larger Coeymans-Kalkberg outlier a half-mile north of Schoentag's; the other a long strip of Manlius-Coeymans-Kalkberg in the north half of Canoe hill, Saugerties, above crags of New Scotland west of the rifle range.

4 Fensters. A fenster is a window in an overthrust slice, revealing what is beneath. The cement quarries have made three of these, each time exposing Glenerie chert beneath overthrust limestones, but two of these have subsequently been breached through the rims on the west, namely in the middle and west (or tunnel) quarries at Alsen, making T's of them on the map. In the original or northernmost quarry of the Catskill Cement Works (now Alpha) at Cementon the mass of Glenerie chert encountered in the quarry floor was finally uncovered southward, with its slickensided hummocky surface rising fast, over a space of five by ten rods before the quarry was abandoned, with the rim unbroken.

Not so easily distinguished on the map is our one natural fenster, east of the Streeke Lake depression contour (see page 176), accessible by a farm road west from the top of the road hill above the Red Schoolhouse. The bottom sheet of Becraft and Alsen is here completely rimmed around by the second slice of these same rocks, but, as the Becraft fails to carry across the west rim for about 400 feet, Alsen there is in contact with Alsen and the colors merge on the map. Nevertheless, this is a true fenster, a thousand feet long and over two hundred feet wide, ending southward in a cattail swamp.

5 Fault floors and fault swamps. Tramping the rugged and generally rocky ridges of the Kalk berg, one frequently comes out on broad featureless and exposureless surfaces, from a few rods up to a half acre, often cleared or natural meadow or shallow cattail swamp. Almost invariably such a surface proves to be the glacially stripped floor of an overthrust, and often it is most annoying to the mapper of the rocks. For it is wholly noncommittal—the hardest, or the weakest, rock may be under it. Here one man's guess is as good as another's; the map can express only the weight of probability. Just why they should be so lacking in exposures is a problem for some one to solve.

FEATURES DUE TO GLACIATION

Without attempting to cover all the glacial geology of our region, some outstanding examples of the effects of glaciation may now be mentioned as essential elements in our physiography, and also to emphasize the very minor role played by the glaciers in the making of our geography.

GLACIAL EROSION

The largest effect of the ice sheet upon our area was doubtless that of erosion and removal of material—chiefly the soils and rocks deeply rotted through long preglacial time. After viewing the depth of such rotted material in our nonglaciated Southern States, one reasonably accepts a hundred feet as by no means an impossible maximum depth for such ice erosion, with a likely average of from 25 to 30 feet. Such an estimate is supported by the amount of glacial drift heaped into the moraines farther south or left nearer home.

The great blocks, often of several tons weight, of our local limestones that occur as far south as Long Island show that the ice also tore loose such jointed rock-masses of undecayed material, mostly from projecting ridges or cliffs, and carried them away. This would have tended to reduce the ruggedness of the surface. In some cases there seems to have been also a tendency for the ice to scoop softer rocks out of hollows. Normal surface erosion ought to have left many isolated remnants of Bakoven shale in the Onondaga synclines, of Esopus shale in the Glenerie synclines, of Catskill shaly limestone in the Kalkberg limestone synclines, as well as hilltop cappings elsewhere. Not a single such outlier of these formations is known today in our area.

Instead, there are often undrained or clay-refilled hollows where these rocks should be and may formerly have existed, such as Van Luven's lake, the marshes on the West Camp syncline (which, being narrow, are not shown on the topographic map), clay-filled synclines along the Old King's road near Saugerties and Asbury.

It seems inevitable, furthermore, that the ice deepened and straightened the Bakoven valley in the soft black shale (figure 40), increasing the rectilinearity and the steepness of the Hooge Berg front (figures 2, 3, 73). For not only does this "strike" valley run in the same general direction as that in which the ice flowed, but the glacial gravels along its course are well filled with pebbles of the black shale itself—pebbles necessarily derived from perfectly fresh rock (to stand the wear) and only subsequently rotted (see page 191).

That being true of the Hooge berg (figure 3), we are led to inquire to what extent the renowned "Wall of Manitou" or mural front of the Catskills (figure 5) is the product of glacial erosion. Here again we have a weak-rock belt at the foot, namely thick masses of red shale with interlarded heavy flagstone ledges split lengthwise by great master-joints parallel both with the (present) mountain front and with the direction of ice movement. There is, moreover, a curiously fresh and abnormally regular appearance to these parallel steplike ledges with such immaturity of the drainage upon them in a segment of a circle swinging from the base of Overlook mountain to that of North mountain for two miles east of West Saugerties and of Palenville (out as far as Saxton and Lawrenceville on the Catskill quadrangle) as reasonably to suggest a preglacial conformation of the mountain front actually so rounded out eastward to the extent of two miles.

Even the inadequate contouring of the 35-year-old Kaaterskill sheet shows the contrast in topography and drainage between the piedmont segment thus delimited and the continuation of the same strata (with equally high dips of three to four degrees) around southwest past Woodstock and, for the little section within the map limits, in the opposite direction around northwest of "Sleepy Hollow" (Rip Van Winkle clove). In addition, along the entire linear front of the mountains, which is visibly straighter than the map depicts it, all the mountain spurs are sharply truncated, as they are not in the recurved sections to north and south.

If this suggestion in the topography is trustworthy, then we can postulate that the ice, in its several occupations of the Hudson valley, being crowded by this huge protruding front of the Catskills, took advantage of the weakness of the flagstones in their powerful parallel jointing and their interlarded soft shales to whittle back the obstruction and eventually plane away the mountain front to its present position, for a maximum distance of two miles.

There are two peaks that in the configuration of their summits show the effects of this process. One is Overlook, which is only a half-peak for erosion on the east has eaten back to its crest. The other is Pine Orchard mountain, namely the little eastern peak of South mountain directly south of the Mountain House, which has been more than half cut away, as is seen when it is viewed from the North Mountain paths.

Ordinary atmospheric erosion seems inadequate to account for the straightness and abrupt declivity of this long mural front. Doctor Clarke's interpretation of it (1915*b*, p. 156-57, 160-61) as due to "rifting" by solution of underlying limestones loses weight when it is seen that the limestone outcrops are over five miles away to the east (on another quadrangle), and that the intervening country is not rifted. Hence we are left with the Hudson Valley icelobe as the likely agent, great as is the volume of rock (over a cubic mile) that seems to have been removed. But it is reasonable to ascribe most of this work to the earliest (Jerseyan) ice invasion rather than to the latest (Wisconsin).

Another striking piece of ice erosion is found in the cross-notches of the mountain ranges, a fact first pointed out to me by Professor Albert C. Hawkins, formerly of Rutgers College, as he observed it from Skytop tower on the distant Shawangunk mountains. Each such valley has been widened to a U shape (figure 71) by the ice pressing through in its southward movement. Normally all these valleys would have been V-shaped in cross-profile, as are the Kaaterskill (figure 7) and Plattekill cloves which lay transverse to ice flow.

The sawtooth profile of many peaks (figures 4, 5), all the teeth pointing southward as viewed from the east, has also found explanation in the unequal effects of ice erosion upon the "struck" and the lee sides of hills that the ice overrode, grinding down the former slope to a less angle but steepening the other by plucking away whole masses of rock. The dip of the mountain strata is insufficient to account for these sawteeth, though it does bring certain specially hard and thick beds to the summits of all the peaks that show this form, and in many cases the form is just as plainly seen from the north, pointing east, as for example in High peak and Roundtop (figure 52) south of Haines Falls. Nevertheless, the ice unquestionably did the final shaping.

GLACIAL AND GLACIOFLUVIAL DEPOSITS

The ice-eroded material came to rest in various forms. During ice movement, but probably after the ice had grown thin, drumlins (whaleback hills of glacial till) were formed underneath it by a process of upsqueezing and upbuilding (plastering on), the mass kept smoothly rounded by flow of the ice over it. These drumlin hills, conspicuous north of our map from Greenville into the Helderbergs, are uncommon on our area but the summit of Bethel ridge is a fine large drumlin, beginning 500 feet south of the schoolhouse and extending for half a mile south. It overtops anything within two miles of it.

There are also drumlin-shaped hills for a few miles east from the Hudson river in the townships of Germantown, Clermont and Red

Figure 71 U-shaped (glaciated) notch through the central range of the Catskills—Mink Hollow, near Elka Park, as seen from western part of Tannersville. Plateau mountain on right, Sugarloaf on left (see figure 54). Note rimming ledges of Stony Clove sandstones. Gap was originated by stream erosion along a keystone fault, then was widened by the ice. Looking south by west. Photo: April 1938, W. J. Schoonmaker.

Hook, some of which may be true drumlins while others are doubtless shale hills given a similar form by ice erosion—in short, they are rocdrumlins. The distinction between the two kinds (of opposite origin, the one built up, the other ground down) can be made on the ground by the nature of the component material: bouldery till in the drumlin, rotting shale in the rocdrumlin. Many true drumlins have rock cores or noses.

Beneath the ice also were formed eskers, namely gravel ridges, usually winding, that were the beds of subglacial streams flowing in ice tunnels under the glacier. Since they usually follow the bottoms of the valleys that run in the direction of ice flow, as ours do, a large esker should be expected down the middle of the Hudson valley, perhaps in the river channel itself. If such is there it has not been detected. In the Bakoven valley, however, there is an interesting esker awaiting further exploration.

This, which we may call the Quatawichnaach esker, is twinned—a double ridge of gravel rising higher than the clay-plain in the stretch west and northwest of the Green Schoolhouse, as the contours plainly show. They show also the deep gulch that has been cut across the west half of this esker by a tiny brook. The spot is easily reached and worth visiting. From the Old King's road may be seen a gravel pit that has been worked in the fragment north of the gulch.

Though carved up by the Kaaters kill, the same esker, or rather its gravels beneath the clay, can be seen again just south of the road bend beyond Quatawichnaach, where a fresh pit reveals much Bakoven black shale in pebbles. Actually the gravels continue north in the ridge to the bridge and resume across the creek under the clay knoll just where the farmhouse road turns in northwest. On the north end of this clay knoll this esker has been reuncovered by erosion of the clay and makes a nice little ridge again with a gravel pit on east side that likewise has numerous Bakoven shale pebbles. North across the creek, opposite to a house, is a further piece of it. Shale gravels (Chadwick 1910*a*, p. 28) that may belong to the same esker are dug two and one-half miles farther north, on the road that goes up under the east face of Vedder's hill, but the intermediate tracing has not been attempted. Here is a pretty little job of mapping left for someone to do.

A long way south in the same Bakoven valley is another (or is it the same?) good esker, though involved with the cuesta-ridge of the hard basal beds of the Mount Marion formation. On first one and then the other of these runs the road northwest from Mt Marion hamlet to Veteran. The esker section, characteristically serpentine in its course, is all within the first mile from the highway intersection. No eskers have yet been found on the Kaaterskill quadrangle.

The termination of the rivers running out from or off from the ice into standing waters (such as glacial lakes) is usually indicated by gravel deposits of other shapes. When these are more or less rounded knolls, singly or in groups, they are known as kames. A pretty little kame, shaped like an inverted bowl, lies on the west of route 385 just south of the first public road branching west (Harvey Brown's) north of the Rip Van Winkle Bridge intersection, namely at the "148" corners. A remarkable kame a hundred feet high is prominent on the map, a mile east-northeast of Blue Store. A very typical large kame at the north entrance to the Stony clove is supplying abundant gravel for the town roads of Hunter (compare Rich 1935, figures 19-20, p. 142-43). Beyond the notch are other kames, near Edgewood, (Rich 1935, p. 81-82).

More frequently the glacial stream gravels were spread out in plains, broad or narrow, not uncommonly today making a terrace with the drop-off on the side toward the vanished ice. "Pitted" gravel plains with undrained hollows (kettle-holes, not to be confused with potholes; see page 221) are surely glacial, with buried blocks of stagnant ice left to melt out afterwards. Largest of these plains on our maps is the one extending from Twin lakes past Manorton and Livingston to Bell pond (Woodworth 1905, p. 121-22, 256, plates 7, 28 No. 11), as discussed by Mr Cook in his chapter (Part I, pages 202 to 209). No such pitted plain, (except a very small one with a single kettle noted by Mr Cook at mouth of Stony brook), has been found on the west side of the river in our area. Doctor Rich (1935, p. 41, 84, 85, 97) has mapped kame terraces (without kettles) northeast of Kaaterskill junction and northwest of Lake Hill, and a prettier one on the north side of the Little Beaver kill one mile west of Yankeetown, besides others, all on the Kaaterskill quadrangle.

In the kettle-holes of the pitted plains lie numerous lakes, of which Bell pond is the largest lake on the Catskill sheet, rivalled in our area only by Cooper's lake (natural limits) on the Kaaterskill sheet. The Twin lakes and Warackamac, also the Spring lakes, besides many smaller unnamed ponds in the same gravel plain, are kettle lakes.

Most of our lakes, indeed, are a result of glaciation, since all lakes are temporary features of the landscape. Like Van Luven's lake (page 186), North and South lakes ("Kaaterskill lakes" of Rich 1935, p. 21-22) at the Mountain House appear to be in glacially excavated rock-basins, but they have been enlarged artificially by damming, and Echo lake north of Overlook mountain may be likewise a rock-basin lake; yet both it and North lake are suggestive of cirque-lakes, and both Echo and South lakes are mapped by Rich (1935, p. 85) with thick drift moraine blocking the outlets, which opens a little problem for field study. Cooper's lake is distinctly a morainal lake (Rich 1935, p. 84), held up naturally by a morainal dam on the east (but lately greatly enlarged artificially). So is the lower lake on the Colgate estate above East Jewett, the blockading dam here being mapped by Rich as a drumlin, whereas their upper lake was purely artificial. The little pond at Mead's is likewise morainal, and so perhaps is that on Church's hill, besides surely the tiny one back of West Camp cemetery. Such of the remaining lakes or ponds shown on our maps as are not man-made are mentioned beyond under other origins.

Our region has been said to be lacking in good glacial moraines, at least in the Hudson valley, but this is only partially true. There are certain moraines of very interesting character even in the valley. In the mountains are conspicuous loops (now breached by streams) across the valleys and, except in the main Schoharie Kill valley, the curvature of these loops shows that they were built at the tips of ice tongues spilling westward from the Hudson Valley ice lobe. The Schoharie Kill loops, nearly to the divide at its head, are all convex southward.

Specifically, there is the morainal ridge rising to over 2100 feet elevation northeast of Kaaterskill Junction (partly a kame) and holding behind it a brook that runs towards Tannersville. Northwest of this, lower and later, is the moraine at 2000 feet damming the "Shanty Hollow" basin of Mossy brook on the one side of the valley, coming down as a long snout from the East Jewett range on the other side of the valley (between Hunter village and Hunter notch), and finally crossing the valley bottom just northwest of Kaaterskill Junction. To ascribe parts of this moraine to local glaciers as Rich's map does seems unnecessary and his argument (1935, p. 97) unconvincing.

Farther southeast and older are the loops at Elka Park, particularly the big one (partly kame) that turns Roaring brook so far eastward to meet the Schoharie kill. There is another good one a mile south of this, with half-mile segments of its arc on each side of the valley. Within less than a mile east of that one, however, is a similar moraine but of opposite curvature, made from the Hudson Valley side; up its south segment runs the trail to Indian Head and to Overlook mountain.

The loops at Tannersville and east of that village also round westward and were built from the east, as shown on Rich's map for the large group around Haines Falls. So does that at Colgate's lake, besides others farther west on the East kill. But the Beach's Corners moraine and seemingly one at East Jewett church were formed from the west by a tongue of the Schoharie lobe.

The moraines partly encircling Cooper's lake and forming its dam on the east are convex westward and northward, therefore terminated ice tongues coming from the east, the Hudson valley, one by way of Woodstock and Baehrsville, the other down the Saw kill from Echo Lake pass. At an earlier, higher stage, when these tongues coalesced, was built the big morainal plug west of Willow that forces the Beaver kill south into the rock wall of its valley (route 212).

For a fuller account of the glacial deposits and glacial features of the entire Catskill Mountain region, including the Kaaterskill quadrangle, the reader is referred to Doctor Rich's bulletin, number 299 (1935), above mentioned, except that so many unproved local glaciers are not being generally accepted.

In the Hudson valley the moraines are smaller but often much less eroded and prettier for study. A particularly interesting series of them lies west and southwest of Bethel schoolhouse, towards Kiskatom. Here as the thinning ice began to split around Bethel Ridge drumlin it made a succession (down the slopes) of long low ridges or morainal welts, declining slightly south on both slopes, east and west. With stronger ice flow on the east, at first, the moraines from that side are bent westward around the south end of the drumlin as the contours show (a few of these ridges are, however, of rock), to coalesce with those from the west. All the ridges continue southwest, the lower ones on the west side of the brook making concentric loop after loop, a third of a mile north of Kiskatom, then returning northward against the rock ridge on the west side of the brook. Thus the moraines are nested one into another northward. The later ones, south of the Lawrenceville road, are especially well shaped and of coarse flagstone debris between the road on east and the brook, making an interesting series to examine; but the loops at the south are the most unusual portion of this extensive display. The making of such moraines requires ice whose forward motion has not ceased.

Another series of morainal ridges, visible even in the contouring, sweeps around the southeast end of Cairo Roundtop, northwest of Lawrenceville, and is crossed at its tips by the road running up the east side of Kiskatom Creek valley. Parts of this series can be picked up again on the south side, near the schoolhouse. Again there is a series lapping off the south end of Timmerman's hill, a striking boulder-moraine of Rondout limestone blocks tails south from the

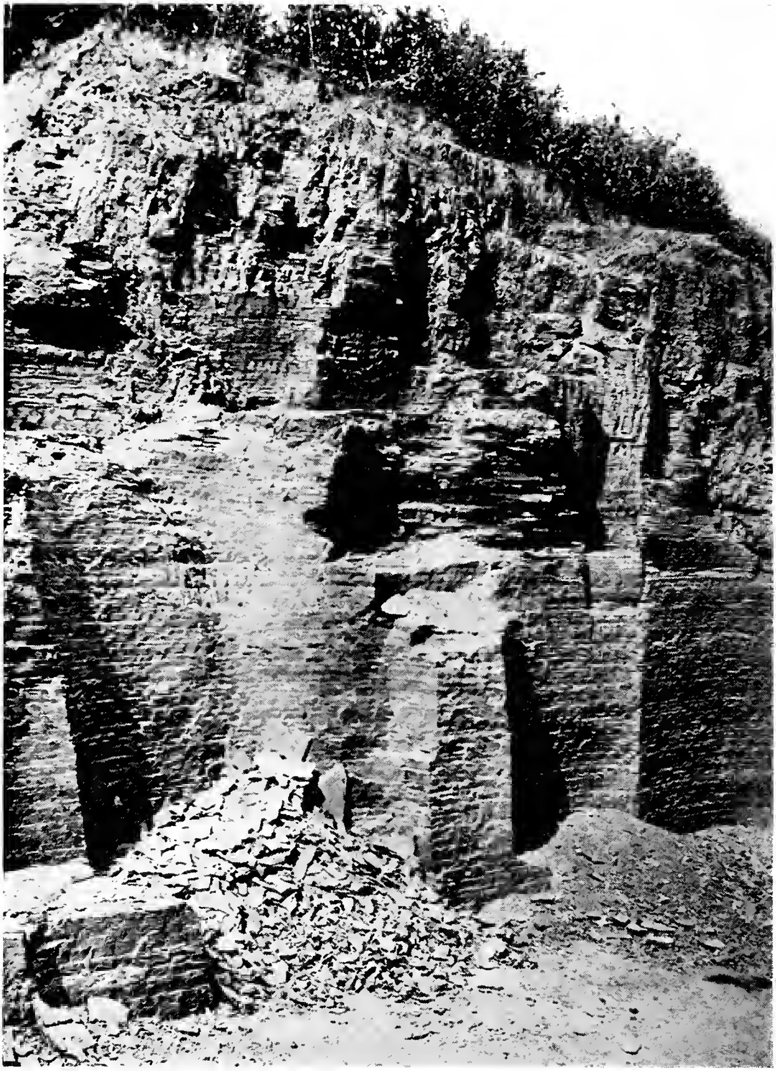


Figure 72 Varved Albany clays in north end of Washburn's upper brick-yard pit (now high school site), West Catskill, a part of the Cats Kill delta in Lake Albany. Face artificially excavated. Top brecciated by slip and creep. Looking northwesterly. Photo: About 1930, R. W. Jones.

Flatbush hill and a pretty moraine crosses the Bakoven valley at the north edge of the Catskill quadrangle in sight of Leeds, looping from the Hooge berg at Vedder's hill eastward across the Cauterskill-Leeds road to the Kalk berg and carrying the Vedder road on its back.

There are, besides, many lesser examples, too numerous to list, on the west side of the river; as near to it in one case as that which turns east from Rushmore's hill across route 9-W and the railway, half a mile south from our north line, and continues southwest of the Corlaer's kill to the hilltops southwest of Hamburg. The presence of such a moraine means that there could not have been any large body of stagnant ice on the west side of the Hudson. The evidence for smaller stagnant masses is given beyond.

On the east of the Hudson the situation is unquestionably different. Instead of moraines are pitted gravel-plains and other evidences of torpid ice melting away *in situ*. What looks from Catskill like a large "lateral" moraine extending high along the east bank of the river from Mt Merino south past Greendale station and cut through at the east end of the Rip Van Winkle bridge is, according to Mr Cook, a succession of drumlins *en echelon;* and, if ever a moraine, has been overridden and drumlinized, therefore is older than the final melting stage of the ice.

While the glacier itself built moraines and drumlins out of its own unsorted grist, its escaping meltwaters made the eskers, kames and pitted gravel-plains of sorted, water-rounded materials. These consist, however, only of the coarser stuffs—gravel and some sand. The finer material, namely silt and clay (rock flour) drifted farther afield, mostly into large bodies of standing water the major and final one of which we call "Lake Albany," (Woodworth 1905, p. 175). Here the pulverized stuff settled slowly, far out from its icy source, and made the beautifully layered or "varved" clays (Woodworth 1905, p. 180-81; Antevs 1922, p. 46, 67, 83; see figure 72) that have been the foundation of our brick and tile industries. On top of these, as the water was shallowed by them and by land uplift, silts were spread and often finally coarser sands and gravels. Large sources of at least this final capping were the creeks coming off from the newly reuncovered lands, particularly the Esopus, the Jansen kill and the Cats kill.

The Lake Albany delta of the Roeliff Jansen kill is the broad plain at Linlithgo and southward past Burden, with a marginal elevation now of about 150 feet. It must be remembered that all deltas have a sloping surface, often far out under water, and continued landward (Chadwick 1910*a*, p. 28) as a slowly rising floodplain (grade-plain). Thus the Mississippi delta reaches out beneath the Gulf of Mexico well beyond navigable depths before it drops steeply off, while its true head is at the mouth of the Ohio, 630 feet above sea level. So our Lake Albany deltas rise headward, and for the additional reason that the Lake Albany level was presumably already slowly lowering as the land rose (see page 212) and as the delta was being extended outward. The true head of the Jansen Kill delta may therefore be placed as far upstream as the former grade-plain reaches, at least to Blue Store, probably to Clermont.

Similarly the Esopus delta, underlying both Saugerties and Glasco and now bisected by its parent creek, has a front margin at about 140 feet altitude above tide but rises through the Lost brook and Glenerie passes to levels over 170 feet elevation in the Bakoven valley behind the Kalk berg. (Sands and fine gravels cap the debouchure of this delta, south of the Oak Ledges, Saugerties, where its altitude is nearly 150 feet.) Its contributory, the Sauger's kill from the north, grades its clay meadows up to the same elevation where they merge with those of equal height in the Bakoven valley at Percy Holmes's place west of Van Luven's lake, and also southward through the archipelago of ridges until they similarly merge at Churchlands northwest of Saugerties. Blockade of the Great Vly (Vlaie) by this Sauger's Kill grade-plain entrapped the swampy lake that occupies the Vly.

In short, no separate origin can be argued for the seemingly higher clay plains in the Bakoven valley. While deposition may have begun there earlier, as it was first to be relieved of ice, such deposition ended contemporaneously with that of the lower portions of these plains nearer the Hudson. All are ascribable to one receiving body of open water, Lake Albany. The higher alcove deltas of earlier date will be mentioned beyond.

Largest of all these Lake Albany deltas in our area is that of the Cats kill (Chadwick 1910*a*, p. 28) reaching in its prime from the mouth of Austin's glen (actually from above this glen, off our map) south to the Great Imboght. Its surpassing size is due not so much to superior volume of the combined Cats kill and Kaaters kill, for this does not match that of the Esopus, but to augmentation of the Cats kill at that time by large glacial rivers coming around the Helderbergs from the Mohawk valley and perhaps from the Adirondacks. The channels of these rivers, and their high-level gravel deltas into the Cats Kill valley, are on the Coxsackie quadrangle next north.

Marginal elevation of the Cats Kill delta, now divided by the creek that made it into two large remnants—one in Jefferson Heights, the other in West Catskill—is barely over 80 feet at the Imboght,

Figure 73 Eroded remnants ("bake ovens") of Lake Albany clays on both sides of the Bakoven (bok-o-fen) valley four miles west of Catskill, on the Rip Van Winkle trail. Compare figure 74. Distant houses are on the clay, which crosses the valley at a higher level in far right. Hooge Berg range on left (see figure 3). Modern floodplain of the Kaaters kill in right foreground. Looking north. Photo: April 1938, W. J. Schoonmaker.

Figure 74 The original Bak-oven (Dutch, "bake oven"), in center of view, at the ancient stone house of the Abeel family (scene of Brandt's raid), about a half mile south of figure 73. Valley underlain by soft black shale. Looking north, from rear of the house. Photo: August 1938, G. Arthur Cooper.

but the delta rises to over 180 feef at the Austin stone house, a decline of one hundred feet southward in four and a half miles. This is not a continuous grade, however, but about forty feet of it is accomplished in one jump, from the north remnant at 160 feet to the south one at 120 feet, though with a tiny portion of the 120 foot level remaining on the north side, near the route junctions, as proof of the drop.

In short, we have here two deltas at different levels, in the lowering waters. The north remnant, in Jefferson Heights, is the earlier and higher delta, built chiefly eastward (across the Hans Vosen Kill valley) with lobate front forcing that brook over into the rock wall. This plain is topped by fairly coarse sands (note the cemeteries) even to its south margin, and these coarsen to gravel at its head (Austin's); but thick varved clays underlie all its mass and cause landslides on west and south sides facing the Cats kill (figure 60). Contemporary with it was a filling of the Bakoven valley directly west, that rises also to over 180 feet (figure 73) where it connected through the old railway pass to Austin's glen at the north edge of the map.

On completion of this Jefferson Heights delta, which had crowded also the Kaaters kill against the rocks because the latter was dropping its own burden up near Asbury and therefore flowing clear (from a lakelet in the Bakoven valley) the Cats kill happened to have swung to this south or Kaaters kill side of the delta as the lowering of the Lake Albany waters caught and held it there to intrench, and to begin building the lower, larger West Catskill delta from the West Shore station south to the Imboght. (See figure 72.)

Just what part stagnant ice (Woodworth 1905, p. 81 figure 4; 84-85, Cook 1924) may have played in this rather sudden shift of level is not yet evident. In this alcove of the preglacial Vosen Kill valley, then reaching south to the Imboght, there was ample catchment for dead ice; but the higher north sector of the delta does not itself show any sign of the presence of stagnant ice. It was finished in open waters on an ice-free foundation. That ice may have lingered under West Catskill, however, and for a time obstructed delta-building is a possibility, though unproved. This plain also has its sand-capping, so was completed by the creek, and its well smoothed top shows no sign of settling over buried ice. But, on the other hand, along its east margin from Green (Van Orden's) Point north to the Kykuit rock knob the presence of much stagnant ice is demanded to account for the long hollow that makes a nearly linear edge to the main mass of the delta and separates from it a huge sand ridge (moulding sand)

and unburied rock ridges on the east, towards the river. There are not the cut banks to this hollow that it should have if a part of the Hudson river once ran through it, yet it is refilled and its original bottom must go below the river level of today.

The anchored ice block thus postulated must have reached also south into Duck cove. It, and the natural termination of the delta at this point, explain the presence of the Great Imboght, including the cove. Moreover, although the apparent absence of an esker argues for persistence of ice flow in the main channel (inner gorge, Woodworth 1905, p. 71) of the Hudson until the ice there became fairly submerged under Lake Albany, yet that ice too must have stagnated at the end. None of the raised deltas protrude at all into this fairway of the Hudson, or show evidence of having cut-banks towards it as if they had once so invaded.

This is true not only for the Cats kill, Jansen kill and Esopus, but also for the delta plain (140 feet) of Stony creek at Madalin and eastward that fails to fill North bay but grades up to over 200 feet elevation at Elmendorf school, and of the Saw Kill delta (140 feet) at Annandale that fails to fill South bay. It is equally true at Albany and southward of the great delta of the Iromohawk, north of our area.

Certainly these facts spell ice blocks in the inner gorge of the Hudson, submerged under Lake Albany. But that lake had open waters and wave work. There is reason to think that it beat against and bared the limestone and Normanskill cliffs around Cementon, Alsen and northward where its waters were least obstructed by shoals. Professor Fairchild (1919, p. 35-36) reports definite beaches of Lake Albany on the north slope of a glacial hill southwest of Becraft's mountain, near Mt Pleasant church (formerly Greendale), and especially a large gravel bar on route 9 at the "245" corners south of the city of Hudson. But a water level at (present) 240 feet altitude is all that is required by these beaches, not the 275 feet that Fairchild (on old data) here assigned to Lake Albany. A detailed examination of the abandoned shore line may reveal many significant features hitherto neglected.

GLACIAL VESTIGIA

Glaciated surfaces, always interesting, are common in both of our quadrangles but generally better preserved in the valley. On an unusually good large glaciated surface of Kiskatom sandstone at Bogardus's corners north of School No. 7, Kiskatom, there are, in addition to the usual striae, several finely preserved series of chatter-

Figure 75 Glaciated surface of Kaaterskill sandstone at former Otis Summit, north of the Catskill (Andron's) Mountain House. This ledge is at junction of service roads (formerly Little Delaware turnpike and Mountain House stage-road) of North Lake Recreation Park at rim of Hudson valley a few rods east of the parking area. Surfaces in general strongly striated westward (toward us) by last ice movement, from direction to which the pencil points. In protected (lee) foreground, strong remnants of earliest striation at right angles to the latest. Right of center a few traces of striation in intermediate 45° direction. Looking southeast toward Hudson valley. Photo: April 1938, W. J. Schoonmaker.

marks—crescentic flaws three or four inches across nested closely one within another and due to the chattering movement of boulders as the ice dragged them slowly over the rock. The ends of the crescents always point in the direction of ice movement, here west of south. Half a mile south-southwest, on route 23-A at a filling station, is another good glaciated surface partly blasted away for the road.

Glacial striae on the mountain front (Wall of Manitou) run horizontally along the face of the ledges. On the north end of Quarry hill, Catskill, a Normanskill sandstone exposure up south of the elbow in the Kaaters kill has striae that run straight and steeply up the hill in a direction still parallel with those of the mountain front. The same direction holds all over the mountain divides and peaks, showing how little topography affected the rigidity of onward flow when the ice was thickest. But when mountains or hills reemerged as islands in the waning ice, then the glacial flow had to divide around them. Still later, when only tongues remained in the mountain valleys, these even turned back toward the north. Thus on the north rim of the Kaaterskill clove, especially along a now abandoned carriage road (shown on the map) southeast of the burned Hotel Kaaterskill, they run northwesterly, indicating movement into the Tannersville valley from the Hudson Valley ice lobe, as Rich's map shows.

A most interesting case in point exists on the plateau rim east of North lake at the service road intersection a few rods north from the former Otis Summit station (see Ramsay 1859, p. 334-38). Here three directions of striae are superposed (figure 75). The oldest set, preserved only in favorable hollows on the west lee, trends south-southwest parallel with the mountain front and the Hudson valley. This set was made at ice-maximum. A few deeply cut but rather poorly preserved lines run west-southwest, made when the thinning ice was split around Pine Orchard (South) mountain. The latest and most perfect set comes up over the mountain front (as on Rich's map) and heads north of west, straight for the lake, marking the flow of the small ice tongue that gouged out the lake basins and reached on west towards Tannersville. This set was also well seen at North Lake park in the "sidewalk" leading from the bathhouses east up to the "stadium."

Glacial erratics (transported boulders) are widespread in distribution on both quadrangles. The ice brought us samples of all the rocks that outcrop to the north, even the little bostonyte dikes of Lake Champlain. Enduring Potsdam quartzite, various Adirondack granites, syenites, anorthosite and gabbro, with also granite-gneisses and other northern crystallines, are mingled with rocks of nearer source, from Saratoga, Mohawk valley and Helderbergs, but also chlorite-quartz vein masses from the Green mountains of Vermont.

The most conspicuous of our glacial boulders are, however, all near at home to their parent ledges. A famous one is of cross-bedded flaggy sandstone and overhangs the puddingstone ledge on South mountain. The Twin rocks on the Old King's road one-eighth of a mile south of route 23-A were Onondaga limestone, resting on Schoharie grit; road building has destroyed one of these. Onondaga limestone has made a disproportionate share of the more noticeable erratics in our area and is distributed east over the outcrops of the other limestones and even to the shore of the Hudson.

But note that not all boulders are glacial ones. The mountain slopes in particular are strewn with talus masses, downfall from the cliffs, of which the Devil's Tombstone is one (of Stony Clove sandstone) placed in its present position and attitude by man. A similar mass in its natural location and similarly on edge is alongside route 23 at the west end of East Windham hamlet (Durham quadrangle). Limestone boulders tumbled down from the Kalk berg catch the traveler's eye north of Alsen on route 9-W.

INDIRECT EFFECTS OF GLACIATION

Glacial obstruction and diversion of drainage was naturally highly effective in a region of such varied relief, particularly in the north-draining Schoharie Kill valley and along the plateau front. The cutting of channels now mostly deserted and the building of gravel deltas now hung high record the story. In the Hudson valley, gravel deltas above Lake Albany level are associated either with present streams or with the temporary glacial ones. Because the melting of the ice plus any forward urge within it tended to keep its surface convex, the easiest escape for the meltwaters was along its margin. Here too the surface drainage meeting the ice would often find outlet. Always, of course, some waters of both kinds made their way into the esker-tunnels under the ice.

In the mountains, however, while the Hudson Valley ice lobe remained strong and spilled into the mountains it forced all waters into lakes held in the Schoharie Kill valley by ice dams to the north and compelled them to escape westward through the central range by whatever lowest pass then was unblocked, into the ice-free valleys of the Esopus or the Delaware. Whether any such waters went early through the more eastern and higher gaps (Pekoy notch at 2850, Mink hollow at 2600 feet) we do not yet know; in any case such

Figure 76 Glacial stream outlet, the Stony clove through the main range of the Catskills (figure 54), four miles south by east from Hunter (route 214). View north-northeast with Hunter mountain (see figure 55) at left, Plateau at right. The lake, converted from a swamp-col by an insignificant earth-dam, is a remnant of the stream channel across the notch which has been blocked by talus and landslides in the background (see figure 53). Photo: November 1936, E. J. Stein.

Figure 77 Bed of glacial Lake Kiskatom, now the Kiskatom flats, looking west of north from Rip Van Winkle trail toward Cairo Roundtop (note faint west dip of Kiskatom red-beds in this outlier of the Catskills and see figure 6) about seven miles by road west from Catskill. Several concentric meander loops of the Kaaters kill (present course just behind camera) indicated by darker streaks, especially the latest and deepest ox-bow channel against the far margin of woods and past big tree on right. Photo: April 1938, W. J. Schoonmaker.

flow must have been transient. The first important westward outlet was the Stony clove (figure 76), with present divide (on landslide and talus stuff) at 2050 feet. But the channel bottom here is just about 2000 feet, as is witnessed by its unrefilled portion occupied by the little artificial lake formerly a swamp-col (figure 53).

The earliest flow through the Stony clove was at a higher level, between the ice and the south wall of the notch. Standing on top of the large kame at the north portal (page 192) and looking across the clove one sees this early channel hung up on the mountainside, on top of a moraine, and baring a cliff. Here the imprisoned water ate its way through along the melting ice edge. Eventually, when the clove became clear of ice it took all the drainage, including melt-waters, from as far east as Haines Falls, southeast as far as Platte Clove, and north beyond Hunter, a volume that must have made a respectable river, with power to deepen its channel rapidly. Moreover, this flow and the enlarging glacial lake (Lake Hunter) that it drained lasted until the next lower pass was opened, namely Westkill deep notch 11 miles west at 1920 feet, present elevation.

It will be understood that the cutting of Stony clove was not wholly the work of this river. Like its parallel companions on the east already mentioned, this notch was initiated by antagonistic brooks eating headward from its opposite ends along the weakened zone of a keystone fault (page 180). But on each of the several ice advances and departures in this region there must have been drainage through it, each time cutting it some deeper, with each time a tendency for it to refill afterwards by infall of rock from the side precipices, as today. It is not logical to ascribe much deepening of a V-shaped valley to ice work; it was done by water.

With no land streams of importance entering Lake Hunter and with the glacial streams entering it far below its water surface, there was little opportunity for the building of deltas into it, but the search for small ones is worth undertaking. Some will be found.

The next lower water body, Lake Westkill, lay only a hundred feet lower and therefore also lacked large deltas. Some puzzling things on the road from Hunter to Beach's corners lie near enough to the unrefilled channel elevation (below 1900 feet) to deserve more study, and the delta contoured at 1870 feet between the two brooks out of Hunter notch, mapped by Rich, may belong to this lake if the contours are too low. But especially we have the gravelly deltas of Mossy brook on the Hunter Mountain trail at the proper altitude up to 1900 feet, besides some levels that look suspicious in and around Tannersville.

After Westkill came a long-lived lake with outlet through the Grand gorge, 22 miles west-northwest, at about 1560 feet—a fine abandoned river channel threaded by railway and route 30, well worth visiting. Into this lake ran the combined waters of both branches of the Schoharie kill at Hunter village, building the terraces seen on route 23-A just west of that village, as the outlet channel was being cut down.

Rich (1935, p. 100, 85, 81-82) reports glacial lakes (higher than the Grand Gorge lake) in the East Kill valley, a lake delta in the Little Beaver Kill valley and water levels in the west portion of Stony clove.

When the ice deserted the mountain-plateau and began to occupy only the Hudson valley, strong flow of waters must have swept along its western margin, against the mountain front (Fairchild 1919, p. 35). As yet we know very little about this on the higher slopes except the great swampy terrace on which a trail runs high on the east face of South mountain, with some other water-swept terraces at intervals all along the Wall of Manitou.

Lower channels are more conspicuous, out across the piedmont, wherever not subsequently buried by the alluvial fans of the mountain streams (see page 18). The long southward flow of the Platte kill tributaries from Palenville, of Black brook and Stony brook farther north, is indicative of the controlling effect of these temporary channels upon modern drainage. Where Stony brook crosses route 23-A its course to south, rimmed by a kame-moraine on the east, shows a nice channel-form.

On the whole, however, the ice edge, sloping south, was veering off diagonally across these ledges, rounding around to its tip in midvalley. Hence the opening of diagonal passageways by the escaping waters, such as that of the Platte kill at Fish Creek, of the (eastern) Beaver kill above Unionville and especially of the Kaaters kill from Kiskatom flats to Asbury, which is a distinctly postglacial gorge above and below High Falls (figures 43, 44). With the occupation of the High Falls channel by the Kaaters kill is connected the episode of glacial Lake Durham (on the Coxsackie and Durham quadrangles) discharging behind Cairo Roundtop through the Kiskatom creek into glacial Lake Kiskatom (figure 77), where now are the Kiskatom flats, (Chadwick 1910*a*, p. 27). Temporary earlier employment by the Kaaters kill of another such diagonal escape through the Hooge berg is indicated east and southeast of Saxton via the Mine Kill pass, with a little plunge-basin pond under the 300-foot contour on the far lip, followed perhaps by brief flow through the capacious channel of Rocky brook.

Fairchild (1919, p. 35 and plate 13) has called attention to the ice-margin rivers along the east front of the Hooge berg. One such channel (Chadwick 1910*a, p. 27*) is easily seen from the road under the east face of Vedder's hill at Shetland farm, between a rock terrace and the hillside and containing a pond. Part of the process of individualizing the hard-beds terrace under the Hooge berg has been done by such confined waters, especially in the east base of Mounts Airy and Marion, but these channels are subject to obscuration by alluvial fans of hillside brooks, as has happened a mile northeast of High Falls on the road to Quatawichnaach. Nearer High Falls on the same road is the remarkable channel pictured by Fairchild (1919, plate 13), a unique by-pass that isolates a mass of the Mount Marion formation in a manner difficult of explanation. This broad, deep and typical abandoned channel of a glacial river, worth seeing, had southward flow, but the present tiny brook in it has been reversed to northward outlet either because that had the advantage of steeper drop and softer materials or because of temporary northward tilt during uplift (see pages 214, 218).

Not many of these temporary rivers on the piedmont and Hooge berg could build deltas, though they left some scattering gravel deposits such as the one dug for road metal on the improved road two and one-half miles due south of Palenville. But when the larger streams got down to impounded or open waters they made characteristic deltas (Fairchild 1919, p. 35). In our area all these are on the Catskill quadrangle, beginning with the delta of the glacial Kiskatom creek into Lake Kiskatom at Lawrenceville (since converted by the creek into an alluvial fan) blockading the Vly (swamp) on north. Then comes the 230-foot delta of the Kaaters kill southeast of High Falls, which is strictly confined to the alcove, then the 220-foot one of the Beaver kill at Veteran, which is equally so restricted, and the 210-foot one of the Platte kill west of Mt Marion hamlet, which also is held west of the hard-beds cuesta and shows the print of dead ice on its south margin. (These elevations are for delta margins and are lower than Fairchild's figures for delta heads. Fairchild reports also a 220-foot delta at Ruby, on Kaaterskill sheet.)

Thus, except at Lawrenceville, each of these was ice-confined on its east side. Yet each in turn, from south to north, marks the locus of final escape of all the waters (both land and ice-margin drainage), debouching between the rock wall and the ice lobe into an angle of the northwardly expanding level of Lake Albany. Each, then, is a dependable index of the initial height to which the Lake Albany waters rose at that spot. For, if they were built in tiny local impondments higher than Lake Albany, where are the outlet channels leading on down from these and where are the final deltas required by such a postulate? The ice front declined too fast, veered too much away from the hills, corroded too readily, to have maintained such lakelets in these alcoves while the deltas were built. Beaches (page 202) confirm these heights.

That there then comes a drop of two contours from these deltas to the unconfined deposits in each case is attributable to three factors: subsequent compaction of the (later) water-logged deposits in the deeper and open Bakoven valley, natural lowering of the water level when deprived of the gravitational attraction of the ice, elastic rebound of the land when relieved of its ice burden (preceding isostatic readjustment); therefore it can not be used as an argument against their construction in a true lake. Gravel deltas do not compact noticeably when the receiving water body is drawn down, but the clays, which underlie all the deposits in the deeper basins, do so compact to a marked degree, proportional to their primal thickness, for they weigh two and a half times as much out of water as under it. To all our clay deposits we must add something of height in order to visualize their appearance and their influence on subsequent events when the waters began to lower and to expose them to the air.

The effect of the ice on land altitude should not pass unmentioned. Depression of our northern lands, with reelevation since ice-melting, is proved beyond dispute by the "raised beaches" along the open seacoast, reaching as high as 290 feet above present sea level on Mt Desert island, Maine,—wave-washed clean (nonglacial) gravels spread out in characteristic level-topped series, with salt-water mussels and clams of living species in the under-clays. In northern New York and Vermont abundant marine shells, barnacles, even a whale skeleton have been found up to still higher altitudes, the beaches going up to 523 feet above sea. These are postglacial features resting upon the glacial stuffs.

It is pretty generally conceded that the depression of the land during glaciation was due directly to the weight of the ice, a mile or more thick over Catskill and Saugerties since it overtopped Slide mountain, 4204 feet, (Chadwick 1928, since confirmed as late Wisconsin by Leverett and Antevs). Inevitably, therefore, our region was tilted down to the north, in comparison with today, and had this attitude when the ice was deserting it. Thus Lake Albany shore lines, still more those of the mountain glacial lakes, will now be found tilted southward. For the Lake Albany initial heights we have a southward slope of (roughly) 40 feet in 18 miles, from Sandy plain

(Coxsackie quadrangle; see Chadwick 1910*a*, p. 28) to the Platte Kill delta at Mt Marion, or about two and one-fourth feet per mile.

But while the land has risen, the sea has also risen by return of water from the melting of the great ice-caps; consequently our Hudson is a drowned river, an estuary with tidal fluctuations of three or four feet.

Land uplift has trenched the streams down into their own deposits, here and there in new courses upon rock where they have cut post-glacial gorges. The Jansen kill flows far below its Lake Albany plains, the Esopus halves its delta and affords two fine waterpowers, one at Glenerie, the other at Saugerties; below High Falls, the Kaaters kill meanders (figures 73, 74) in the clays of the Bakoven valley for six miles until it breaks through the Kalk berg. The Cats kill has divided its own delta, as already noticed (page 198). In this process, which was necessarily as slow as land uplift, slower whenever the stream encountered a rock barrier, it left some interesting mementos. Between West Bridge street (routes 23-A, 385) and Broome street in West Catskill is an old stream meander (Chadwick 1910*a*, p. 28), 25 feet below the original surface of the delta plain, with a beautiful smooth curve (poorly contoured on the map) that formerly carried around in a complete semicircle where now route 9-W has destroyed it by grading, and even as far as Division street. A rock nose on the east end held this meander "frozen" there until its upper loop closed in and cut it off. Since then, as the creek channel deepened, small brooks have gnawed headwaters into both horns of the oxbow, even begun gullying between and accentuating the concurving lines of flow in the bed of the ancient channel, behind the "diner."

Another abandoned meander of the Kaaters kill at the same altitude lies south of the Cauterskill natural dam and bridge, in the mouth of the Fuyk valley, as is shown by the contours, but can not be seen well from the highway. The accordance in height of these two oxbows, with the presence between of cut-terraces at about the same elevation north and northwest of the West Shore station and across the creek on "Jefferson hill," suggests that they belong to one episode of prolonged stillstand possibly connected with the encountering of the rock barrier at the Hopenose (or Hoponose) through which the Cats kill now emerges to the Hudson, (figure 62).

The beautiful meander sweeps of the Esopus at Saugerties are down too near present (artificial) level to be easily discriminated for dating except a small remnant northeast of Oak Ledges and close to Main street, which is contoured above 80 feet elevation. This creek met with no obstruction at Saugerties until it reached its sill on the Normanskill grits at the 9-W bridge, at not much over 50 feet present altitude (the millpond is 47 feet). But farther up, the abandoned meanders of the Esopus and the Platte kill between Glenerie falls and the Old King's road have determined the sinuous course of that road south from Mt Marion church (where the clay is possibly cored and upheld by esker) and are in contrast to the present straightness of these streams, especially the Esopus, though not much above present water.

The effect of land tilt on stream courses is also to be considered, along with that of morainal blockade, preglacial channels, available passes and another factor of a speculative nature that we may discuss under the title "wave of uplift" though some prefer to think of it as the pursuing "peripheral bulge."

If the land rose like the tilting of a rigid plane, the effect of such tilting should have been to discourage northward-flowing streams, encourage south-flowing ones, produce southward reversals rather than northward ones. Why then our north-flowing Jansen kill, Esopus and Kaaters kill? Some other factor must have controlled in the case of these and numerous similar streams throughout the Hudson valley.

Most of these north courses are in the clayplains, namely under Lake Albany level, increasing the difficulty of the problem. On plains originally horizontal, when uptilted from the north, water should have run southward and so continued to run. This assumes that the clayplains were completed up to water level everywhere. In the slow settling out of the suspended glacial rock-flour to make these clays, they took at first the surface configuration of the floor on which they rest, and only gradually lost that figure as their thickness increased faster in the deeper spots. It was only on building up to lake level, or to "wave base" in it, that they developed a nearly horizontal top, doubtless shoaling northwards toward the ice, their source, and thus further favoring southward drainage on uplift.

But there are two other things entering in to modify this, besides the failure of the clay deposits ever to attain full height over much of their extent. One of these modifying elements is the contributions made by land streams, which continued after the ice itself had ceased to play an important role locally. For example, the clayplain in the Bakoven valley which, where the Kaaters kill leaves it, is under 160 feet elevation, is encroached upon thence northward by a diverticulum of the Cats Kill delta rising to nearly 200 feet altitude (figure 73) at the north edge of the map, as does the main delta mass over east at Austin's. Evidently this is not a plain built behind beaver dams but is the natural slope of a delta surface. The Lake Albany plain of the Jansen kill declines northward, as already noted (page 198), and in its final shaping is plainly the work of the creek, assisted possibly by beavers in its upstream part but dependent fundamentally on discharge into deep open waters for its base-level. Stony creek, the Sauger's kill and the (eastern) Saw kill likewise topped off and graded their plains, as did the Esopus its big delta at Saugerties. The only clays to which no land-stream contributions seem to have been superadded are in such intermediate spots as Alsen and Cementon, where they could later have had no influence on the courses of major creeks. That even in such places the clays rise to elevations of 80 to 100 feet (in the Fuyk, figure 17, to over 140 feet) shows that the land-streams did not have a major share in producing the clay portions of the Lake Albany deposits elsewhere but chiefly built coarser stuffs upon them to top them off. Nevertheless it was just this final topping that shaped the direction of subsequent stream flow over them.

The second modifying factor is compaction (page 212). Compaction being greatest where depth of clay-fill was greatest, would lower the surface most over buried valleys, thus tend to draw the streams back into them. Many times, however, it failed to do so because its effects were too tardy. The Esopus got started around the north edge of its delta at Oak Ledges before the uplift had raised the delta enough to have much compaction follow. When this compaction came, all it could do was to initiate a small gully turning surface drainage from the delta back into the Esopus above the Ledges and a companion gully leading east to the Hudson. The Cats kill was already so strongly sunk into its present course, which has let it down on one rock barrier after another, that only the small Mineral Spring brook and Burget's creek (plus companion gullies on north) could take advantage of the settling by compaction in the preglacial extensions of the Hans Vosen Kill and Corlaer's Kill valleys. The Cats kill was not even able to evade the rock rib of the Hopenose at its mouth, where little DuBois's creek (Uylen Spiegel kill) goes around it unobstructed on the south.

Nevertheless, compaction helped to hold the Beaver kill (figure 2) to its course in the Bakoven valley, whereas it might just as easily otherwise have wandered off east through the archipelago of ridges, as Lost brook has. In fact, rigid plane uplift should have compelled the Beaver kill to do this and to take the Kaaters kill with it. Yet in the face of land-tilting the Beaver-Kaaters Kill drainage found its way northward for 10 miles to the exceptionally favorable low passage through the Kalk berg, then moraine-filled. Then why not also the

Esopus, which has chosen the much higher gap at Glenerie falls, but whose northward flow in this Bakoven valley is mostly off our map, on the Rosendale quadrangle? Will compaction explain all this?

A longitudinal profile of the clayplain in this Bakoven valley for the length of the Catskill quadrangle shows that even today after tilting it declines slowly northward (not southward) from 180 feet elevation where the Old King's road crosses it at Mt Marion to about 150 elevation where the Kaaters kill leaves it, just short of the obstructing Cats Kill delta above mentioned. The evidence as to the buried rock valley does not suggest greater width (presumptive greater depth) at the north than at the south end of this stretch. The narrowest point between the rock walls is nearer the lower end, namely just north of the county line, below the mill and bridge north of Asbury, where there is, moreover, a further constriction by esker gravels on east and delta gravels on west. Yet the Kaaters kill turns abruptly north through this narrows instead of continuing south in the broader unobstructed part where the Beaver kill now meanders lazily. Incidentally, there is no mark anywhere that the Kaaters kill ever had and abandoned such an escape across the clays and out to east in that southward direction, nor at the other favorable spot at Percy Holmes's two and one-half miles north of Asbury to the Sauger's kill.

Evidently we must seek something other than compaction to explain this steady and unexpected northward grading of the clayplain from Mt Marion to west of Cauterskill. Indeed, because of stream trenching down its middle, the plain gradient could be plotted only on the marginal remnants, where compaction was least effective. This gradient leads up suggestively to the Esopus and Platte kill as the source of the detritus that veneered and gave northward slope to this plain. That raises two difficulties. First is the apparent failure of the Kaaters kill to keep its own constructional work up to match that of these streams. Second is the question why the Esopus or the Platte kill if once established on a surface that even now declines northward should have deserted so favorable a location (improved by compaction as that went on) and, neglecting the more capacious pass where Lost brook escapes, have turned east over the hard and high barrier of Glenerie falls.

The answer to the first may be that the Kaaters kill was leaving its burden farther up, to fill the bed of Lake Kiskatom (figure 77), and had only the short stretch of the High Falls channel (then shallow) to clean out (figure 44). Still we have no proof that Lake Kiskatom had not already been fully upgraded as the receptacle of glacial rivers from around both sides of Cairo Roundtop. Such an answer is therefore only a surmise.

The second difficulty might be answered by invoking either stream capture or original alternative discharge such as the Cats kill had at the north end of our map; but with this difference, that while the Cats kill distinctly favored its present eastward course and built its larger delta mass there as compared with the short stretch in the Bakoven valley, the delta of the Esopus at Saugerties, its present course, is not large as compared to the long filling in the Bakoven valley that would thus be attributed to it. To make that the work of the Platte kill alone (with later capture of the Platte kill by the Esopus) might be attractive when one notes that northward drainage at Mt Marion starts on the plain right in line with the debouchure of the Platte kill from the Hooge berg, were it not that a rock rib 20 feet higher lies athwart this proposed connection. There seems to be no evidence left of any flow of the Platte kill northeastward around this rock barrier, nor indeed that either it or the Esopus crossed the inconspicuous divide at the route intersection in Mt Marion hamlet. So again we have only a surmise.

Recalling that initial Lake Albany deposits gave us (page 212) a measure of two and one-fourth feet per mile for the southward tilting since they were formed, equivalent to about 30 feet in the 13 miles that we are considering, and that the clayplain now slopes 30 feet in the opposite direction, we seem to see the sum of these or 60 feet as the initial north slope of this stretch of plain in Lake Albany times, or four and one-half feet per mile. The present north slope of the Jansen Kill high-level or Lake Albany plain is 70 feet in six miles, more than 11 feet per mile without adding for tilt. The comparatively low gradient of the Bakoven plain and the comparative absence of coarser alluvium upon it suggest that it was made under rather than out of water and allow us more readily to fall back upon the Esopus as its parent.

Nevertheless it would be easier to understand this history of northward flow in terms of a reversed or northward tilting of the land at a crucial time in its emergence. The streams of our area are not exceptional in this anomaly. From Halfway creek at the north end of the broad Hudson valley to the Rondout creek and Wall kill at its south, this so-termed pine-tree drainage prevails. It was the case also with the postglacial discharge of the Iromohawk river, running far north to Gansevoort (Chadwick 1928*a*, p. 910, figure 5). Does the "wave of uplift" give the solution?

Under this hypothesis of the wave of uplift (Fairchild 1919, p. 16-

17, 21, 28, 29; anticipated by Woodworth 1905, p. 224-26, 229-34; Upham 1892, p. 335), the land rose not as a rigid plane but in a wave-like progression from south to north as the ice front melted back and its load was removed. Thus Saugerties would be gaining something of its present altitude while Catskill lay still submerged. This would mean a temporary increase in northward gradients, sufficient perhaps to enable the streams to attain and later to maintain their anomalous northing. Meantime, during this period of northward flow, they might upgrade the clayplain in the Bakoven valley to such a gradient as would exceed the amount of subsequent reversal of tilt when the wave passed on north.

The hypothesis of the pursuing peripheral bulge involves even more movement. Starting with the evidence (mathematical and physiographic) that a bulge of the earth's crust surrounded the areas depressed by the weight of continental ice sheets (compare Cook 1924, p. 160), and that this bulge must form while the sheets were smaller and be driven ahead of them in increasing bulk as the ice augmented, a reverse process is postulated during ice-waning, the bulge contracting in size and radius with the contracting ice area but naturally lagging at some distance from the ice front. Either view will explain Lake Albany, not as a single continuous water body from Staatsburg to Fort Edward, (Woodworth 1905, p. 175, 177, 241-42, pl. 27), but as one that continuously migrated northward between the ice and the "wave" or the "bulge" and thus never lost its individuality nor its right to a single name.

The bulge hypothesis implies an overtilting southward as the bulge is passing and a distinct fall-back or northward retilting after it has passed. The implications and criteria of such a movement in our Hudson valley have never been faced nor the field evidence for or against it worked out. Whether the northward gradient of the Bakoven plain may best be explained by such a reversal remains an open problem for someone to solve. Northward drainage today in the channel northeast of High Falls (page 211) may have originated while the wave or bulge was passing. One might look upon the swamps of the Great Vly and north of Kiskatom flats as due to such retilting were it not possible to explain each of them as unfilled alcoves blockaded by the alluviation of the Sauger's kill and Kiskatom creek respectively. But the remarkable northward decline (noted by Woodworth 1905, p. 122 and plate 7) of the Livingston pitted plain from 280 feet at Twin lakes to 250 feet at Bell pond, 30 feet in eight miles, can hardly be ascribed, in this ice-margin deposit, to either wave of uplift or peripheral bulge.

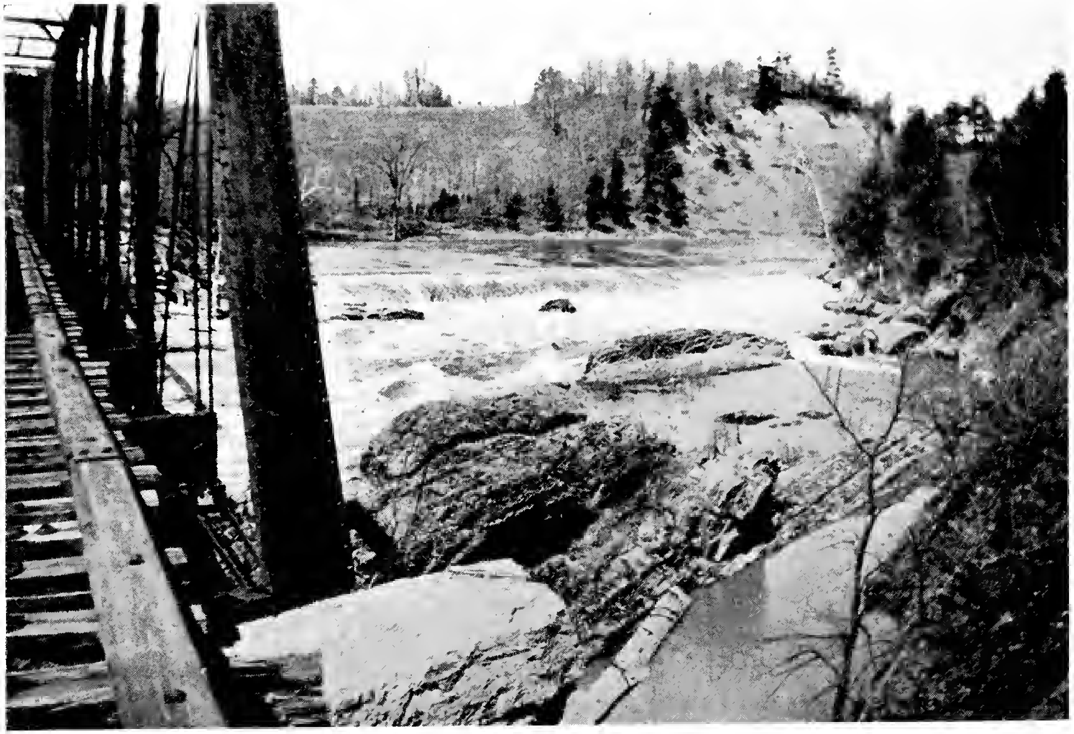


Figure 78. Postglacial gorge of the Cats kill showing structural control, at upper end of Austin's glen (above "Third Bridge" of former Catskill Mountain railway) not far below Leeds. (North edge of Catskill quadrangle passes through the far cliff of Esopus shale.) Stream on strike of Glenerie vale to the natural dam of Glenerie-Alsen-Becraft beds and again on strike of Catskill shaly beds (foreground) below the fall. Looking north-northwest. Photo: April 1923, Clayton H. Brown.

Our preglacial Cats kill may have received the upper Kaaters kill on the Coxsackie quadrangle by way of Kiskatom flats, and may itself have turned south down the Bakoven valley to cross the Kalk berg where the Kaaters kill now crosses. Only small moraines now block these routes, forcing the Cats kill to fall into the tortuous post-glacial gorge of Austin's glen (figure 78) and the Kaaters kill to drop over High falls (figure 43). The Esopus may have crossed the Kalk berg at the Indian caves, with a long tributary from Asbury in the Bakoven valley. But these are open problems.

The interesting subject of glacial potholes has been passed over. Formed by cataracts in ice crevasses, such potholes may occur in spots where no land drainage could have made them, such as the one described by Osborn (1900) in the shales of Church's hill, opposite Catskill, first reported by Hubbard (1889).

GEOLOGICAL HISTORY

THE LOST INTERVAL

Depositing of the early Paleozoic beds, Cambrian and Ordovician, was brought to a close by a spasm of mountain-making—the "Taconic orogeny" or "Green Mountain revolution" of writers. Beginning as far back as Lorraine time, the premonitory restlessness of this great upheaval had become evident in more rapid rising of the old mountains on the east in New England that were supplying the sediments to the sea waters lying over New York. Already perhaps, certainly by Queenston time, eastern New York had been raised out of water and was being re-eroded by the rivers crossing it from New England westward. The final cataclysm was doubtless well under way during Queenston deposition (Richmondian).

Folding of the Cambrian and Ordovician strata, thousands of feet thick, was progressing on the New England border. The intensity of the compressive force, on these comparatively weak and yielding beds, eventually ruptured them across into slice after slice, driven over (telescoped) one upon another, thus thrusting the folded rocks from the edge of New England into our region. One need go no farther afield than the Helderberg scarp near New Salem on the north, or to Eddyville southward, below Kingston, in the opposite direction, to see comparatively undisturbed and later Ordovician beds that were resident in our area before these older folded ones were jammed over upon them. In fact, it is likely that the western edge of the overthrust sheet is buried but a very short distance behind the concealing cover of the Kalk Berg escarpment and that wells drilled west of this line will encounter the Snake Hill beds immediately beneath the Rondout strata.

But this means a prodigious amount of erosion of the overthrust Ordovician deposits, their vertical thickness so much increased by the folding and telescoping, in order to get down to the earlier portion (Normanskill) that had become exposed before the Silurian sea returned. We have, thus, a story of great mountain-making (folding and thrusting) closing the Ordovician and of prolonged erosion during the early and middle Silurian of the mountains thus formed until they were reduced to a nearly featureless surface by the opening of Rondout time.[1] The record of this is the great hiatus (figures 58, 13) between early Ordovician and late Silurian strata that lie in unconformable erosional contact throughout our area. See pages 141 to 150 for the field facts.

Absence of a soil band at the contact, with marine Silurian shells lying directly in the fresh clean-swept little hollows on the top of the bevelled Normanskill, shows that the final leveling of the old land was done by the waves of the returning sea, itself. Detrital material from the Normanskill graywacke grits was reworked by the waves and came to rest in some places as a basal bed of the Rondout (see pages 146-47). Over a considerable stretch, a sandbar was built, inclosing lagoons of quieter water where only the finest waterlime muds were laid down, devoid of the open-sea shells, corals and bryozoans of the limestones outside the bar.

Supplementary Note

[1] There is ample evidence that the Ordovician rocks were intricately folded and upedged before erosion took place. There is also convincing evidence that the surface they presented to the reception of the Silurian deposits was a very smooth one. No hills in this surface are known. The overlap of the Rondout upon it is broad and gentle, differing only 40 feet in maximum and minimum thicknesses of those beds across the quadrangle. The under surface of the Rondout at any given exposure is not known to exhibit undulations or variations of more than two inches at most.

Such a smooth surface cut across plicated strata of hardnesses varying from weak shale to resistant grit beds may be looked upon as the product either of prolonged atmospheric erosion—a peneplain—or of wave-planation. A noticeable feature of the sandstone beds of the Normanskill just under the (present or past) contact with the Rondout is a limonitic staining similar in color to that of the overlying buff waterlimes of the Rondout, so that one may be mistaken at first glance for the other. This is not a usual weathering color of the Normanskill beds elsewhere; indeed, a few feet away from the contact that may be dun-colored as usual. Whether such discoloration should be looked upon as derived from the waterlime and thus essentially modern or as of pre-Silurian age and the source of the ferrous stain in the Rondout may be debatable. The former seems a more likely explanation, in which case we are left without any indications of weathering at the contact. Moreover, such perfect peneplanation is difficult to conceive.

This compels us to face the evidence for wave-planation by the advancing Silurian sea. The products of such planation should be in part gravels and sands. Of such gravels there are none, nor have I learned of any pebbles of Normanskill imbedded in the base of the Rondout. If there are any, to be wave-made they should have the "peppermint-drop" rounded-flat form characteristic of beach shingle. Basal sands, such as the Binnewater sandstone that comes into the section farther south, are restricted here to a limited belt, outside of which the soft buff waterlime or even a purer limestone reposes directly on the Ordovician. Where the basal bed is a sand, it usually differs from the quartzitic sand of the sandbar above it in being a reworked Normanskill arkose, to which lime (organic) particles have been added, and does not suggest heavy or considerable wave-work. Neither does the structure of the Fuyk sandstone, which, with a width of over half a mile, is only 20 feet high and has a smooth and parallel stratification (compare figure 15) not at all cross-bedded. The basal bed behind this bar, around Catskill, has of course no bearing on the problem; it is a lime mud half filled with quartz grains that appear to have been blown into it from the Fuyk bar by the wind. But into the waterlime above it no sand was blown from either sea or land.

The source of even the sand that we have may not have been wave erosion, for rivers from the land could carry and contribute it ready for the waves to spread out. Unless pebbles are found, which rivers would not have transported across the subdued surface, we are left, therefore, equally without evidence of wave-planing. That the Normanskill beds were then as hard as today is implied in the great compression they had undergone, at such depths underground that they barely escaped the metamorphism that befell the Ordovician and Cambrian rocks not far east of the Hudson. It is proved directly by the rounded aspect of the harder layers where they project on the ancient surface, looking "sandpapered" as they doubtless were by the waves before burial.

Certainly these waves could not have battered very high irregularities of the surface without entombing some of the debris of them. Thus it seems that wave work merely gave the final touch to a process of leveling already far advanced over this region, and this after a long period of stillstand, a time during which no detrital deposits of any magnitude were forming to the west but only the very fine lagoonal or calcareous muds of the Vernon, Syracuse, Camillus and Bertie deposits (and their equivalents, Bloomsburg, Wills Creek and Bossardville beds at the south) closing with the pure Cobleskill limestone. It is only the earlier beds, the Medina, eastern Clinton and Shawangunk, that mark the initial vigorous erosion of the newly uplifted Ordovician Taconic mountains. The higher Silurian strata show clearer and clearer seas of the old-age stage in the erosion cycle on the bordering lands.

According to published accounts, the Rondout sea failed to reach Becraft's mountain, the top surface of the Ordovician is more uneven, in shales (Schuchert and Longwell 1932, figure 5 and page 318), and the Manlius is conglomeratic where it fits into the hollows. This looks like more hasty submergence in the Manlius sea, when that arrived.

TIME OF OPEN SEAS

When thus reestablished over the region the sea remained for a long time, with only few and minor interruptions. These came (see pages 150 to 154) at the close of the Cayugan, the close of the Helderbergian, possibly within the Oriskanian, and at the close of the Ulsterian. Before taking these up more fully it is well to emphasize that orderly deposition of conformable strata was not seriously interfered with by them and that on the whole the region remained one chiefly of limestone-making in clear waters of the inland sea until the great "Catskill delta" of the later Paleozoic began to encroach upon it.

There were times, to be sure, of inroad of terrigenous material from the eastern mountains, making the limestones impure with shale, as during New Scotland time, or even temporarily overwhelming lime-secreting life with inorganic silts, as during the Esopus. Here is record of geographic and climatic changes on the neighboring lands to east and south, or in the sea floor itself, producing those differences that mark off each formation from its predecessor, often sharply. Rivers and rainfall shifted, seas shoaled or deepened, new congeries of sea life found the habitat to their liking—and a new formation began to be deposited. To rehearse all these little variations seriatim would be wearisome. They are implicit in the descriptions of the formations themselves (pages 44 to 99) and to those descriptions the reader may turn.

Of the interruptions mentioned, that at the close of the Helderbergian is the most striking. Although the contact of the Glenerie on the Alsen or the Port Ewen is a smooth one at any given exposure throughout our area, yet there is often, perhaps always, a zone of phosphatic nodules in the contact seam, usually with a dark blue-gray ("black") shale resting upon it that is suggestive of a soil band. Farther west in New York the equivalent Oriskany sandstone rests upon lower and lower beds, and by filling cracks and caverns in these gives proof that its ocean returned upon a long-weathered land-surface. We can not yet safely assert that the Helderbergian strata here in the east shared even briefly in this exposure to the air before Oriskany time. The time break is here much shorter than there. Nevertheless, there is missing already at Glasco over a hundred feet of Port Ewen beds that at Kingston, only six miles south, intervene between the Alsen and the Glenerie. Either these layers failed to be deposited hereabouts, or they have been subsequently eroded away. The presence of the phosphatic nodules and the concentration of worn fossils at the contact argue for re-erosion and hint at uplift out of the sea as the reason for it. But wave ablation may have sufficed.

Less conspicuous, but more surely subaërial, is the erosion of the top of the Manlius preceding Coeymans time. Here we have a bonded contact between rather like rocks, both of them clean limestones though differing in coarseness of grain. At almost every exposure a careful examination shows a foot or two of disturbed and rounded-edged slabs of the Manlius interfiltrated with the Coeymans lime-sand and fossil fragments. Once, in the Helder berg, Mr Hartnagel and I found a quartz pebble as large as one's thumbnail, in this contact zone. These conditions bespeak exposure to weathering, followed by wave work on a sea platform during resubmergence. All of upper and middle Manlius is missing. This break too, however, was brief.

The failure of the highly fossiliferous upper Glenerie beds to reach north of Malden seems to let the Esopus down upon the cherty or "bony" beds of the lower Glenerie, suggesting a break within the Oriskanian, though this may be illusory and due to change of facies northward. The last marked break came at the close of the Onondaga limestone deposition, allowing the top surface of that limestone to become corroded (pitted by solution) and some of its fossils to accumulate loose in these pits, with brownish material looking phosphatic, before the black Bakoven muds came to rest upon this surface. This again looks like, though it may not be, an effect of exposure to the atmosphere.

But with this Bakoven shale, limestone-making here ceased, and there began the upbuilding of the great "Catskill delta."

THE GREAT DEVONIAN DELTA

From the close of Onondaga time, with its widespread making of purest limestone (coral reefs), onward, an entirely new episode began in our sedimentary history. Instead of the thin limestones of the open seas, heavy masses of land-wash came piling in upon us from newly rising mountain lands at east and south of our region. That such and not Canada is the source-direction for the sediments of the later Paleozoic rocks in New York and Pennsylvania, stretching even far into Ohio, is shown by the manner in which they thicken and coarsen to the southeast, transforming also in that direction into land-made red-beds with forest trees.

These sediments are distinctly unlike any that came before them, in our area. From the equally thick delta sediments of the Ordovician which they most resemble they differ in ways immediately evident to the accustomed eye. What these differences mean as to the conditions of origin is at present largely a closed book. The precise study of sedimentary rocks, particularly with the petrographic microscope, is very young, its devotees few. We know that "sandstones" and "shales" are as diverse among themselves as some of them are from limestones. And there, for now, the story rests.

The zoning of these delta sediments into five different facies, each in turn farther away from the mountain sources, has been described on page 140. After the regular fashion, black shale (Bakoven) of the most seaward ("Genesee" or in this case "Marcellus") facies zone was the first to reach us, constituting essentially the "bottomset" beds of the approaching delta. Then followed barren sandstone (really siltite) of the next zone landward ("Portage" facies), and the delta proper was upon us. The fossiliferous sands and shales of the shallower warmer waters ("Chemung" facies), coming next above as the sea shoaled, comprise locally the Mount Marion formation, closing with the "storm-rollers" that may mark the surf-line on the emerging delta surface.

This emergence unquestionably came about chiefly from the upbuilding of the sediments themselves, as today the Mississippi is ever raising its flood plain and pushing its mouth farther into the Gulf. Yet we face a puzzling fact, not merely in the immediate region but as far as these delta sediments extend—to central Ohio and to northern Alabama. In any given formation, the kind of sediment, the kinds of fossils, and therefore the approximate depth of water, remain the same through perhaps hundreds of feet of strata, as in the 600 feet of our middle and upper Mount Marion. Either subsidence of the ocean floor or steady rising of the sea level, equal to the thickness of these beds, must have obtained during their depositing. The delicate timing of the one to the other is partially explained by the power of the waves to take and redistribute into appropriate depths of water (facies zones) the materials supplied to them by the rivers.

Nevertheless, the arriving land-wash came in such quantity as eventually to force the shore line westward beyond Kiskatom (and then beyond Palenville), so that beds of the fourth (the "Catskill") facies commenced to be laid down, upon land, upon perhaps such a land as the western Colorado has built in the vicinity of the Salton sea and the Imperial valley of southern California, but less confined. This change, so conspicuous to the eye as reds suddenly appear among the rocks and so striking paleontologically as marine fossils give place to land-plants, river-clams and river-fishes, is thus seen to be, after all, not nearly so significant genetically as that at the base of the Bakoven shale. Here are the same sands and the same muds from the same hills and on their way to the same sea, but how different they look before the waves and the life of that sea have had their way with them!

What happened in the closing stage of the Kiskatom red-beds, resulting in the deposition of the three Kaaterskill sandstones upon such irregular surfaces of their interbedded shales (figure 49), is not clear except that the strandline had shifted farther afield, the delta surface built higher above sea level, become more subject to alternate scour and fill as the river channels swung this way and that across it. A slight westward tilting and re-erosion (or at least nondeposition on the steepened gradient of the surface) is suggested as occurring at the close of the Kaaterskill (close of Middle Devonian; see page 136). The Genesee (Sherburne) beds seem to wedge out towards us. The next conspicuous deposit in our area is the great pudding-stone conglomerate (figure 51).

Pebbles in this conglomerate (especially at the Boulder) are largest at the base, some as large as one's head, at times almost devoid of binding matrix between them, and not always as perfectly rounded as might be expected of far-transported cobbles if carried solely by rivers. No one has yet searched them diligently for the marks characteristic of glacial cobbles, the faceted and striated surfaces, but it will not be surprising if such are found. For the conglomerate is so widespread, of such varied materials, so lacking in bedding-planes, so far removed from any possible source in the old New England Alps, that one turns naturally to the thought of glacial kame-gravels, of an ice sheet moving down over the plain from those eastern mountains in early Upper Devonian time. This puddingstone has nothing to do with the sea; could rivers have brought such coarse stuff so far? Red-beds and glaciation go together elsewhere in the Paleozoic.

All through the overlying stuffs small pebbles are scattered, mostly of pure quartz, as sometimes also locally in the beds below. There is an interesting interlude, that of the Stony Clove flagstones, in which the red color temporarily ceased altogether (largely because no true shale was deposited), and above that level the reds are increasingly scarcer while the sands grow coarser, more pebbly and whiter. These are the deposits of the last (or "Pocono") facies zone, best seen in our area in the summit of Hunter mountain but far better developed in the later Katsberg strata of the Witten berg near Slide mountain (Phoenicia quadrangle). These may be looked upon as the "topset" beds of the delta and it is perhaps unlikely that any considerable thickness of other beds was ever laid down upon them, wherever they occur in this facies.

The delta grew on far westward, and through a much longer span of time than is represented by it in our region; but very little if any sediment came to rest on its surface hereabouts during the later Senecan, the Chautauquan and the Bradfordian epochs that ensued. Erosion may even have begun, in a small way, before the great uplift came.

TIME OF THE SECOND FOLDING

It has been quite generally assumed that the second folding of our strata, which plicated the Silurian and Devonian beds of our Kalk berg (up to the Bakoven shale) and gave dip tilt to all the rest of them, took place at the same time as that of the Pennsylvania folds, namely the Appalachian "revolution" or orogeny at the close of the Paleozoic. A dissenting voice is that of Doctor Clarke (1915*b*, p. 156-57), who puts the folding before the commencement of the red rocks, if we read him aright. Because of the tilting of the lower part of these reds (Kiskatom beds) along with the underlying rocks of the Hooge berg, Clarke's intent may be understood as applying to the beds from the Twilight Park puddingstone up and in this sense has much to commend it. It accords then with the state-wide break between the Middle and Upper Devonian formations. But there is a larger break at the close of the Devonian, which is the time of climax of the Acadian orogeny to which these earlier movements led up.

Dating of our folding as post-Paleozoic, Appalachian, brings up two snags: one, that the direction of our folds does not agree with that of the Appalachian folds as they come northeast through the Shawangunk mountains to the vicinity of Kingston; the other, that they fail to agree with those also in size. They are miniature crumplings, confined to a narrow belt of less than two miles maximum width on the west of the Hudson, failing west beyond the Bakoven valley and equally failing east over most of Becraft's mountain but with another and narrower such belt on its southeast rim. Two narrow belts, with undisturbed strata between, do not resemble the folds of Pennsylvania. The association of our folds with those has been on geographic contiguity rather than structural connection and because no folding between the Taconic and the Appalachian had been noticed elsewhere in New York.

But in Nova Scotia and New England, between these two times, another great mountain-folding, with metamorphism and igneous outbreaks, fully the equal of either of them was going on during the Devonian and culminating at its close, the Acadian "revolution" or orogeny. Twice already its earlier convulsions had been felt in our area: first at the close of the Helderbergian time of limestone making and initiating the terrigenous deposits of Oriskany-Esopus time; second at the cessation of all limestone making after the Onondaga and the beginning of the huge deltaic deposits of the Hooge berg, Kats berg (Catskills) and westward just described above. The mass of this Devonian delta is enormous, signifying a new very great and continuously progressing uplift of the feeding grounds in New England. The slow folding of our Kalk Berg belt, so slow that the brittle Manlius limestones are sometimes doubled back on a radius of two or three inches without fracture, may have been under way throughout the delta time from the Onondaga onward, as overthrusting before the heaviest load of the delta beds was put upon it, later bending under this load so as to give us our undulated thrust planes and our nested folds.

The diagonal cross-folding in the south half of our quadrangle, already adverted to (page 164), might be taken as indication of two successive movements in slightly different directions. Even if so, neither one of them would be Appalachian in direction or character. The diagonal lines of the south half are the trend lines of the north half and also of the mountain front and of the major jointing. So it is rather the general trend, in the south half, than the folding that is askew, corresponding there rather to the strike of the Ordovician ridges whereas the folds throughout the Kalk berg are disposed acutely across these.

There comes to our aid the hypothesis put forth on page 180 that our miniature folds in such narrow belts are merely crumplings upon the toe of the rejuvenated Normanskill overthrusts. This would imply that the fault-trace bent at Katsbaan as does the Kalk berg. A shove that was at right angles to its north half would then be oblique to the more southerly portion and should produce just such diagonal crumplings as there found.

Whatever the age of the limestone folding, there is one major element in our structures that belongs to the Appalachian movement and that is the northerly dip on the southeast side of the Catskill Mountain plateau and the gently broadly synclinal structure of the whole mountain mass of which that dip is a part. Our Catskills lie at the northeast tip of this great geosyncline, the synclinal axis passing northeast through its three highest peaks: Slide, 4204; Hunter, 4025; Black Dome, 4005 feet, on respectively the western, central and eastern border ranges.

The net result of all these movements, with at least two periods of folding, was to make the complicated structures we see today, but not immediately to expose them to view. That came later. The notable thing is that in the upheavals attendant upon these two or three mountain-makings no portion of our Paleozoic rocks wholly escaped. The Ordovician strata experienced two compressions, the Silurian and Devonian beds suffered but one, though it was quite enough to render this the most intricate area, geologically, in New York State.

The folds of our region are therefore of two kinds. In the Normanskill beds, twice compressed with an erosion interval in which their first anticlines were decapitated and weakened, the naturally incompetent strata have been mashed into a systemless confusion of "isoclines," folds with the two limbs brought into apparent parallelism of dip (figure 63), as may be seen best in the fresh cut at the west end of the Rip Van Winkle bridge. Only occasionally have beds in this group been stout enough to take on regularity of folding such as at the entrance to Austin's glen (figure 61) on the Cats kill and at Saugerties on the Esopus. The folds of the Silurian and Devonian beds, on the contrary, are of the "competent" type, in which the cores of the folds have not been squeezed out.

The absence of normal faults in an area so close to the major faults of that type in the Mohawk valley is noteworthy. Conditions that one would think favorable to normal faulting are found in the strongly developed master joints of the flagstone belt and throughout the flat-lying strata of the red-beds; moreover it is a common experience in other regions that compression, folding and thrusting are succeeded by normal faulting. In this respect our region is exceptional, for that closing chapter in the structural readjustments seems to have been omitted. The small normal faults described (Grabau 1903) in Becraft's mountain appear to have been contemporaneous with the shakeup during its ride on the back of the Ordovician overthrust.

THE LONG HISTORY OF EROSION

The erosion that has removed a mile and a half of rocks from over Saugerties, Catskill and Hudson must have had its inception at the moment of any upbuckling of these strata. That such erosion was already under way when the later Devonian beds with their quartz-pebble conglomerates were forming in western New York seems reasonable, helps to explain these deposits far from the mountain sources in New England. The earliest rivers still flowed west.

The major erosional features of the region concern larger areas than that of our maps. The great contrast between the Hudson valley on the one hand and the Catskill mountains on the other (figures 4-6) is a part of the physiography of all eastern North America, for the one is a segment of the great Appalachian valley with its included folded mountain ridges and the other is but the extreme northeast corner of the Allegheny (Cumberland) plateau. The beds of that plateau once extended continuously over the valley, as will be seen when one views their present cut edges in the mountain front (figures 4, 5, 50). But rivers running west could not do this carving of the Hudson valley.

There are many proofs that the courses of our rivers were not originally or formerly as they are now and many theoretic reasons why they could not have been so. In what directions they successively ran and just how they got into their present channels are the subjects of most engaging and divergent views by those who have essayed the solution; (see the titles in the bibliography for Davis, Fairchild, Guyot, Heilprin, Johnson, Mackin, Rich, Ruedemann, and Tarr). Some of these writers believe that our entire region went once more under water, in Cretaceous time, after its surface had been considerably lowered and flattened by erosion, and was covered over by an extension of the Atlantic coastal plain deposits all trace of which has since vanished except the new courses impressed upon the rivers crossing it, such as the Delaware and the Hudson.

For our area we can neglect all that lies outside and consider only how the Hudson drainage took the place of westward drainage. In whatever manner the Hudson first crept into our quadrangle from the south, whether by the Mamakating (or Wawarsing) valley from Port Jervis or across the Highlands as today, it found here a belt of rocks much weakened by uplift and folding. With its shorter run to the sea, it was able to capture one after another of the headwater rivers flowing across this belt and far westward, thus extending its own valley ever northward. Later, as it sank to the weak Ordovician shales, it made its bed permanently in these, annexed their extension around south of the Adirondacks in the same manner by means of its tributary Mohawk and from the last sent the Schoharie south up into the Catskill plateau to complete its conquest of the area. Now, in the Kaaterskill and Plattekill cloves it is even robbing its own tributary. (See figures 7, 10, 50.)

Systematic stream piracy, as Doctor Ruedemann has said (1932, page 348), thus holds sufficient explanation for the drainage features that concern us locally. But the long process of erosion has other phases. The removal of all this thickness of rock was not accomplished in one continuous episode. It proceeded by stages and pauses, with intervening renewal of uplift. Such stages betray themselves in peneplains, namely in base-levelings of the region whose traces still remain after it was again raised and dissected anew. Our higher peneplains are present in the mountains; a lower and later one, better preserved, is seen in the horizontal skyline of the Kalk Berg and Hooge Berg ridges of upturned rocks (figures 4, 5, 6) as so well viewed from the Catskill Village reservoir near routes 23 and 385, or from Quarry hill. The whole floor of the Hudson valley once stretched unbrokenly across where now these hilltops mark the line. After its further uplift above sea level, the streams etched out the weaker rocks, rain and weather carved the ridges but left long stretches untouched to tell the story. In this interim many changes due to piracy must have occurred, their record now largely obscured by glaciation.

From this more easily observed sample of a peneplain we may go north to East Windham (Durham quadrangle) and look out upon the even skyline of the Helderberg plateau on the north, an older peneplain now raised to a much higher elevation, around 2000 feet, which continues on the north of the Catskills clear around into and across western New York and far southward behind the Allegheny mountains, the Cumberland plateau. Above this peneplain when it was formed, (probably then down near sea level), rose both the higher Catskills and the higher Adirondacks, as spared remnants ("monadnocks") of an older higher land surface. From it, broadly open valleys (figure 10) reached far up into these mountains, (as those of the Saw kill and Little Beaver kill do from the lower peneplain), are represented still unchanged in the upper sections of both forks of the Schoharie kill on the Kaaterskill quadrangle but are now somewhat deepened again from Tannersville to Hunter and below. The road from Hunter to Windham (route 296) rises over a remnant of the old valley floor on its way to Beach's Corners, and the East Kill valley above East Jewett post office is a part of one. The course of the Schoharie must have been determined before this peneplain was finished, as there are no other such broad outlets.

On this broad peneplain, beyond the Catskills of that time, ran also the early Hudson and the Mohawk, both of them probably much farther away than they are today. Starting with their courses on the weakest rock-belts then exposed for them, certainly the Mohawk and probably the Hudson have migrated down the dip (compare figure 44), towards the Catskills, by sticking to these weak rocks as they slope into the great geosyncline. This explains how the Hudson circumvented the resistant flagstones and conglomerates of the Catskill Devonian delta. It did so by "sapping and mining" from the eastern borderland.

Stepping once more backwards, we have the long sloping lines of the mountain summits (figure 54) both northwest and southeast from the ridge line of the three highest peaks (page 39), as pointed out by Guyot (1880), which may be the lingering record of a peneplain either subsequently bent or originally sloping both ways from a drainage divide. What seems like a considerable remnant of it is the long level crestline of Plateau mountain, which, as viewed from Tannersville, is nearly two miles of straight skyline. If these mountain summits are really on a peneplain, it is the oldest one of which we have existing vestiges.

Including it, three successive uplifts (see Chadwick 1935*f*, figure on page 2056) have left distinct record in our area, three stages of land lowering by erosion since our structural features were completed, the first stage of a wholly unknown amount, the next two of nearly two thousand feet each, with no knowing how many partial ones between, whose marks have been destroyed by those coming after. The last uplift is also of unknown amount, another two thousand feet if the submerged cañyon of the Hudson out in the ocean beyond Sandy hook was river cut. Locally, the Hudson had time to excavate its "inner gorge" (page 202) to a depth a hundred feet below present sea level before glaciation stopped it, and its tributary streams to do a large part of the etching out of their courses that we now see. Undoubtedly the land stood high.

What part that extra height had in bringing the glaciers down upon us, and how often they came and melted away, we do not surely know. Their work, already described, was a very minor episode in the long history of erosion.

ADDENDA (1942)

Wartime conditions and delays arising in the four years since this report was submitted have compelled drastic reduction in the illustrations. This task, with other editing, has been generously and judiciously accomplished by Dr Winifred Goldring, to whom for such and other assistance I am deeply indebted.

Meanwhile more than 200 geologists have attended a Catskill meeting of the New York State Geological Association (April 1940), in the circulars for which meeting a new term, "Saugerties shaly limestone." was proposed for what we have been calling "Schoharie" in this area. This name will now yield to that of "Leeds facies" applied (Goldring and Flower, 1942, p. 673, 681) in a paper that throws a flood of light on our "grit" beds.

Several papers published in the interim and now inserted in the bibliography have matter of importance. Mencher (1939, p. 1786) offers "Catskill alluvial plain" for "Catskill delta" of writers. He anticipates in print some ideas of the present pages in a refined study of the nature of our continental sediments, concluding (pages 1779-88) that they were derived from rapid erosion of freshly rising Acadian mountains not far to the east, in New England. Krynine's general studies (1940, 1941) are confirmatory of this. A paper by Anderson (1941) bears indirectly upon it.

Cooper (1941) has reached correlations close to those herein stated as to the Hamilton members on our quadrangles (see figure 57). As further explicated in letters to Doctor Goldring, his correlations seem to be about as follows:

Local names	*Feet*	*Berne quadrangle*		*Reference section*
		Moscow		Moscow Ludlowville Skaneateles
Kiskatom	2600	Kiskatom		
*				
"Ashokan"	300	? Panther Mtn.	Marcellus	Cardiff
Mount Marion	800	Otsego	Marcellus	Chittenango and lower beds
Bakoven	200			
Total	3900			

* Probable place of the type Ashokan.

Moore (1941) has selected our new exegesis of the "Catskill delta" to illustrate his review of the progress of stratigraphic interpretation in the past half-century; but his chart fails to incorporate newer correlations and measurements then available. Some recent papers, not here indexed, have stressed an asserted paleontological affinity of the Tully limestone to the Upper Devonian; in the face of the stratigraphic evidence (see figure 56) and the general "Hamilton" aspect of the faunal list, this testimony seems unconvincing.

The new correlation chart of the Silurian (Swartz 1942) recognizes the fluctuating value of the terms Rondout and Manlius; but it has no column for eastern New York. Verifying our prediction, the discovery by Howell (1942) of both Normanskill and Snake Hill fossils in the Kingston region shows that the overthrust plane between these formations re-emerges southward near that city, thus follows the belt of our "little mountain" folding (Davis 1882). In another paper, Howell (1942) adds to our list of Esopus fossils. Kay (1940) has restudied the Taconian orogeny closing our Ordovician, while Parker (1942) blinking Mencher's evidence of Acadian movements assigns all our joints in Silurian and Devonian rocks to the Appalachian mountain-folding.

Cressey (1941) classifies anew our physiographic divisions, putting the Schooley peneplane on the mountain tops, whereas Cole (1941) says it is at the next lower level (2000 feet), identifying its age as Jurassic.

Rich (1941) has a last say on the inevitable stagnation and burial of glacial ice behind any higher threshold of rock or moraine, a view that accords with ours as to the inner gorge of the Hudson.

Paleontologic papers are those by Bassler (1939), Arnold (1939) and Cloud (1942).

BIBLIOGRAPHY

Adams, Charles C.
1929 The importance of preserving wilderness conditions. N. Y. State Mus. Bul., 279:37-46

***Alling, H. L.**
1922 Petrographic studies of some New York sediments. Geol. Soc. Amer. Bul., 33:107
1928 The geology and origin of the Silurian salt of New York State. N. Y. State Mus. Bul. 275. 139p.

American Geographical Society
1907 The map of the Catskills. Amer. Geog. Soc. Bul., 139:200-1 and map

***Anderson, G. E.**
1941 Origin of line of color change in red bed deposition. Geol. Soc. Amer. Bul., 52:211-18

* Papers quoted in text but not bearing directly on the region are preceded by an asterisk.

*Arnold, Chester A.
1939 Fossil plants from the Devonian. Univ. Mich. Mus. Pal. Contrib., 5:271-314
Ashburner, C. A.
1888 Petroleum and natural gas in New York. Amer. Inst. Min. Eng. Trans., 16:906-59
Ashley, G. H.
1935 Studies in Appalachian mountain sculpture. Geol. Soc. Amer. Bul., 46:1395-1436, 2057
Bancroft, J. A.
1925 Restoration of the oldest known forest. Science, n.s., 61:507-8
Barker, J. F. & Baer, W. W.
1917 Ground limestone for use in New York State. N. Y. Agri. Exp. Sta. Bul., 430:21-32
Barrell, Joseph
1913- The upper Devonian delta of the Appalachian geosyncline. Amer.
1914 Jour. Sci., (4) 36:429-72; 37:87-109, 225-53
1916 Dominantly fluviatile origin under seasonal rainfall of the old red sandstone. Geol. Soc. Amer. Bul., 27:39-40, 345-86
1916*a* Influence of Silurian-Devonian climates on the rise of air-breathing vertebrates. Geol. Soc. Amer. Bul., 27:40-41, 387-436
1917 Rhythms and the measurements of geologic time. Geol. Soc. Amer. Bul., 28:745-904
1925 Marine and terrestrial conglomerates. Geol. Soc. Amer. Bul., 36:279-341
Barton, D. W.
1822 On the geology of the Catskills. Amer. Jour. Sci., 4:249-51
Bassler, R. S.
1915 Bibliographic index of American Ordovician and Silurian fossils. U. S. Nat. Mus. Bul. 92. 2 v. 1521p.
1939 The Hederelloidea, a suborder of Paleozoic cyclostomatous bryozoa. U. S. Nat. Mus. Proc., 87:25-91
——— & Kellett, B.
1934 Bibliographic index of Paleozoic ostracoda. Geol. Soc. Amer., Special Papers, No. 1. 500p.
Bather, F. A.
1895 Brachiocrinus and Herpetocrinus. Amer. Geol., 16:213-17
Beck, L. C.
1842 Mineralogy of New York (Nat. Hist., pt III). 534p. Albany
Beecher, C. E.
1890 On Leptaenisca, a new genus of brachiopod from the Lower Helderberg group. Amer. Jour. Sci., (3) 40:238-40
1891 Development of Bilobites. Amer. Jour. Sci., (3) 42:51-56
1892 Notice of a new lower Oriskany fauna in Columbia county, New York. Amer. Jour. Sci., (3) 44:410-14
Beers, J. B. & Co.
1884 History of Greene county, New York. (Geology, p.17-19). New York
Berkey, C. P.
1908 Quality of bluestone in the vicinity of the Ashokan dam. School of Mines Quart., 29:149-58
1911 Geology of the New York City aqueduct. N. Y. State Mus. Bul. 146. 283p.
[1912?] The Catskill water supply for New York City. 6p. (not numbered)
1933 New York City and vicinity. Internat. Geol. Congr. XVI, Guidebook 9. New York excursions. 1-3, 17-122. Gov't Ptg. Off.
Bigsby, J. J.
1858 On the Paleozoic basin of the State of New York. Geol. Soc. of London, Quart. Jour., 14:305-6, 335-452; 15:251-335
1868 Thesaurus siluricus; the flora and fauna of the Silurian period. 214p. London
1878 Thesaurus devonico-carboniferus. 447p. London

* Papers quoted in text but not bearing directly on the region are preceded by an asterisk.

Bowles, Oliver
1917 Sandstone quarrying in the United States. U. S. Bur. Mines Bul. 124. 143p.
Brace, Henry
1884 Old Catskill, in J. B. Beers 1884, q.v.:86-118
***Branson, E. B. & Tarr, W. A.**
1928 New types of columnar and buttress structures. Geol. Soc. Amer. Bul., 39:1149-56
Brigham, A. P.
1901 A text-book of geology. 477p. New York
1914 Early interpretations of the physiography of New York. Amer. Geog. Soc. Bul., 46:25-35
1916 The population of New York State. Geog. Review, 2:206-17
Bucher, W. H.
1920 The mechanical interpretation of joints. Jour. Geol., 28:707-30; 29:1-28
Callaway, Charles
1878 On the correlation of the Lower Helderberg group of New York. Geol. Mag., (2) 5:271-77
1878*a* [Geology of the excursion]. Albany Inst. Proc., 2:41-43
Chadwick, G. H.
1908 Revision of "the New York series." Science, n.s., 28:346-48
1910 Downward overthrust fault at Saugerties, New York. N. Y. State Mus. Bul., 140:157-60
1910*a* Glacial lakes of the Catskill valley. Science, n.s., 32:27-28
1912 Rocks of Greene county. Privately printed. 15p. Catskill. (Revised edition, mimeographed, 1921)
1913 Angular unconformity at Catskill. Geol. Soc. Amer. Bul., 24:676
1916 Rectilinear features in the Eastern Catskills. Geol. Soc. Amer. Bul., 27:107
1927 New points in New York stratigraphy. Geol. Soc. Amer. Bul., 38:160
1928 Glacial striae topping Catskill mountains, New York. Geol. Soc. Amer. Bul., 39:216
1931 The Catskill formation. Geol. Soc. Amer. Bul., 42:242-43
1932 Catskill, Chemung and Portage. Eastern States Oil & Gas Weekly, 1, no. 17:3, 4, 7 (September 2)
1933 Hamilton Catskill. Geol. Soc. Amer. Bul., 44:77-78
1933*a* Upper Devonian of the New York region. Geol. Soc. Amer. Bul., 44:177
1933*b* Hamilton red-beds in eastern New York. Science, n.s., 77:86-87
1933*c* Upper Devonian revision in New York and Pennsylvania. Pan-Amer. Geol., 60:91-107, 189-204, 275-86, 348-60 (and a correction sheet privately printed)
1933*d* Catskill as a geologic name. Amer. Jour. Sci., (5) 26:479-84
1935 Chemung is Portage. Geol. Soc. Amer. Bul., 46:343-54
1935*a* Faunal differentiation in the Upper Devonian. Geol. Soc. Amer. Bul., 46:305-42
1935*b* Map of New York Upper Devonian. Geol. Soc. Amer. Proc., 1934:70-71
1935*c* What is "Pocono"? Amer. Jour. Sci., (5) 29:133-43
1935*d* Chart showing formations and fish localities in the Upper Devonian, in A. S. Romer & B. H. Grove: Environment of the early vertebrates. Amer. Midland Nat., 16:822
1935*e* Summary of Upper Devonian stratigraphy (to accompany Romer & Grove). Amer. Midland Nat., 16:857-62
1935*f* Discussion of G. H. Ashley 1935: Studies in Appalachian mountain sculpture. Geol. Soc. Amer. Bul., 46:2055-57
1935*g* Discussion of G. B. Cressey 1935: Kaaterskill piracy. Geol. Soc. Amer. Proc., 1934:73
1936 History and value of the name "Catskill" in geology. N. Y. State Mus. Bul., 307. 116p.
1940 Columnar limestone produced by sun-cracking. Geol. Soc. Amer. Bul., 51:1923

* Papers quoted in text but not bearing directly on the region are preceded by an asterisk.

Chestnut, V. K.
1898 Thirty poisonous plants of the United States. U. S. Dep't Agric., Farmer's Bul. 86. 32p.
Clark, T. H.
1921 A review of the evidence for the Taconic revolution. Boston Soc. Nat. Hist. Proc., 36:135-63
Clark, W. B., et al
1913 Devonian [of Maryland]: Lower, Middle and Upper. Md. Geol. Surv., (3 v.). Lower, 156p.; Middle, 720p.; Upper, 156p. Baltimore
Clarke, J. M.
1889 The Hercynian question. . . . N. Y. State Geol. Rep't, 8:62-91
1891 The "Hercyn-Frage" and the Helderberg limestones in North America. Amer. Geol., 7:109-13
1899 Guide to excursions in the fossiliferous rocks of New York State. N. Y. State Mus. Handbook 15. 120p.
1900 The Oriskany fauna of Becraft mountain, Columbia county, New York. N. Y. State Mus. Mem. 3. 128p. 9 pl.
1901 Value of Amnigenia as an indicator of fresh-water deposits during the Devonic of New York. . . . N. Y. State Mus. Bul., 49:199-203
1902 Report of the state paleontologist, 1900, (issued separately 1901). N. Y. State Mus. Ann. Rep't, 54, v.1.:3-81
1902*a* The indigene and alien faunas of the New York Devonic. N. Y. State Mus. Bul., 52:664-72
1903 Mastodons of New York. N. Y. State Mus. Bul., 69:921-33
1903*a* Classification of the New York series of geologic formations. N. Y. State Mus. Handbook 19. 28p.
1905 Report of the state paleontologist, 1903. N. Y. State Mus. Bul. 80. 133p.
*1907 An interesting style of sand-filled vein. N. Y. State Mus. Bul., 107:293-94
1909 Early Devonic history of New York and eastern North America, part 2. N. Y. State Mus. Mem. 9, v. 2. 250p., 36 pl.
1912 Eighth report of the director of the science division. . . . N. Y. State Mus. Bul. 158. 50p.
1912*a* Early adaptation in the feeding habits of starfishes. Acad. Nat. Sci. Phila. Jour., (2) 15:113-18
1915 Conceptions regarding the American Devonic. N. Y. State Mus. Bul., 177:115-33
1915*a* The Oriskany-Pic d'Aurore episode of the Appalachian Devonic. N. Y. State Mus. Bul., 177:147-53
1915*b* The rifted-relict mountain, a type of "Old Red" orogeny. N. Y. State Mus. Bul., 177:155-61
1918 Strand and undertow markings of Upper Devonian time as indications of the prevailing climate. N. Y. State Mus. Bul., 196:199-238
1921 The oldest of the forests. Scientific Monthly, 12:83-91
———— **& Ruedemann, R.**
1903 Catalogue of type specimens of Paleozoic fossils in the New York State Museum. N. Y. State Mus. Bul. 65. 847p.
1912 The eurypterida of New York. N. Y. State Mus. Mem. 14. 439p., 88 pl.
———— **& Schuchert, Charles**
1899 The nomenclature of the New York series of geological formations. Science, n.s., 10:874-78
Cloud, Preston E., jr
1942 Terebratuloid brachiopoda of the Silurian and Devonian. Geol. Soc. Amer., Spec. Paper 38. 182p., 26 pls.
Cole, A. H.
1892 Paleaster eucharis Hall. Geol. Soc. Amer. Bul., 3:512-14
Cole, W. Storrs
1938 Erosion surfaces of western and central New York. Jour. Geol. 46:191-206
1941 Appalachian erosion surfaces. Jour. Geol., 49:129-48

* Papers quoted in text but not bearing directly on the region are preceded by an asterisk.

Coleman, A. P.
1926 Ice ages, recent and ancient. 296p. New York
Collison, R. C. & Barker, J. F.
1915 Limestones of New York, with reference to their agricultural use. N. Y. Agric. Exp. Sta., Tech. Bul. 47. 38p.
Cook, J. H.
1909 Some preglacial valleys in eastern New York and their relation to existing drainage. Science, n.s., 29:750
1922 Ablation of the eastern lobe of the Wisconsin ice sheet. Geol. Soc. Amer. Bul., 33:117-18
1924 The disappearance of the last glacial ice sheet from eastern New York. N. Y. State Mus. Bul., 251:158-76
1930 The glacial geology of the capital district. N. Y. State Mus. Bul., 285:181-99
1935 The glacial geology of the Berne quadrangle. N. Y. State Mus. Bul., 303:222-30
Cooper, G. A.
1933 Stratigraphic studies in eastern New York. Smithsonian Inst., exploration and field work in 1932, Pub. 3213:13-16
1933*a* Stratigraphy of the Hamilton group of eastern New York. Amer. Jour. Sci., (5) 26:537-51; 27:1-12 (1934)
1936 Facies relationships in the Hamilton group of New York. Internat. G. Congr. XVI, Rep't 2:1106
1941 Facies relations of the Middle Devonian along the Catskill front. Geol. Soc. Amer. Bul., 52:1893
———— **& Warthin, A. S., jr**
1942 New Devonian (Hamilton) correlations. Geol. Soc. Amer. Bul., 53:873-88
Cressey, G. B.
1935 Kaaterskill piracy. Geol. Soc. Amer. Proc., 1934:73
1941 Land-form regions of New York state. Geol. Soc. Amer. Bul., 52:1893-94
***Crosby, W. O. & I. B.**
1925 Keystone faults. Geol. Soc. Amer. Bul., 36:623-40
Daly, R. A.
1920 Oscillations of level in the belts peripheral to the Pleistocene ice caps. Geol. Soc. Amer. Bul., 31:303-18
Dana, J. D.
1880 Manual of geology, 3d ed. 911p. New York
1895 Manual of geology, 4th ed. 1087p. New York
Darton, N. H.
1893 The stratigraphic relations of the Oneonta and Chemung formations in eastern central New York. Amer. Jour. Sci., (3) 45:203-9
1894 Report on the relations of the Helderberg limestones and associated formations in eastern New York. N. Y. State Geol. Rep't, 13:199-228
1894*a* Preliminary report on the geology of Ulster county. N. Y. State Geol. Rep't, 13:289-372
1896 Examples of stream-robbing in the Catskill mountains. Geol. Soc. Amer. Bul., 7:505-7
Davis, W. M.
1882 The little mountains east of the Catskills. Appalachia, 3:20-33
1883 The folded Helderberg limestones east of the Catskills. Mus. Comp. Zool. Bul., 7:311-29
1883*a* Becraft's mountain. Amer. Jour. Sci., (3) 26:381-89
1883*b* The nonconformity at Rondout. Amer. Jour. Sci., (3) 26:389-95
1892 The Catskill delta in the postglacial Hudson estuary. Bost. Soc. Nat. Hist. Proc., 25:477-99
1922 Peneplains and the geographical cycle. Geol. Soc. Amer. Bul., 33:587-98
1930 Origin of limestone caverns. Geol. Soc. Amer. Bul., 41:475-628
***De Béthune, Pierre**
1935 Thrusting of unfolded rocks. Geol. Soc. Amer. Proc., 1934:325-26

* Papers quoted in text but not bearing directly on the region are preceded by an asterisk.

Dekay, J. E.
1823 Note on the organic remains termed Bilobites from the Catskill mountains. Lyc. Nat. Hist. N. Y. Ann., 1:45-49
1842 [List of fossil fishes; and fossil mammals]. Zoology of New York (Nat. Hist., pt. I), 1:75, 98-106, 108, 120; 4:385-87
Dewey, Chester
1824 On the geology and mineralogy of the western part of Massachusetts and a small part of the adjoining states. Amer. Jour. Sci., 8:1-60, 240-44
1837 Remarks on the rocks of New York. Amer. Jour. Sci., 33:121-23
Dickinson, H. T.
1903 Quarries of bluestone and other sandstones in the Upper Devonian of New York State. N. Y. State Mus. Bul. 61. 112p.
***Dorsey, G. E.**
1926 The origin of color of red beds. Jour. Geol., 34:131-43
Dwight, H. E.
1820 Account of the Kaatskill mountains. Amer. Jour. Sci., 2:11-29
Dwight, W. B.
1866 On a subsidence of land at Coxsackie, New York. Amer. Jour. Sci., (2) 41:12-15
Eastman, C. R.
1899 Fish fauna of the Catskill formation. N. Y. State Geol. Rep't, 17:323-27
1907 Devonic fishes of the New York formations. N. Y. State Mus. Mem. 10. 235p., 15 pl.
Eaton, Amos
1824 Ought American geologists to adopt the changes in the science proposed by Phillips and Conybeare? Amer. Jour. Sci., 8:261-63
1827 On the diluvial deposits in the state of New York and elsewhere. Amer. Jour. Sci., 12:17-20
1828 Geological nomenclature, classes of rocks, etc. Amer. Jour. Sci., 14:145-59, 359-68
1829 Geological prodromus. Amer. Jour. Sci., 17:63-69
1830 All primitive general strata, below granular quartz, are co-temporaneous and schistose. Amer. Jour. Sci., 17:334-35
1830*a* Travelling term of Rensselaer for 1830. Amer. Jour. Sci., 19:151-59.
1831 Four cardinal points in stratigraphical geology established by organic remains. Amer. Jour. Sci., 21:199-200
1839 Cherty lime rock, or corniferous lime rock, proposed as the line of reference. . . . Amer. Jour. Sci., 36:61-71
1840 References to North American localities. . . . Amer. Jour. Sci., 39:149-56
Eckel, E. C.
1913 Portland cement materials and industry in the United States. U. S. Geol. Surv. Bul. 522. 401p.
Eights, James
1835 A synopsis of the rocks of the state of New-York. Zodiac, 1:27-28
1836 Notes of a pedestrian. Zodiac, 1:111-16, 141-43, 146-47
***Elston, E. D.**
1917 Potholes, their variety, origin and significance. Sci. Monthly, 5:554-67; 6:37-53
Emmons, Ebenezer
1846 Agriculture of New York (Nat. Hist., pt V), v. 1. 371p. illus.
1854 American geology, . . . "Vol. 1." 194p. Albany
Fairchild, H. L.
1918 Glacial depression and postglacial uplift of northeastern America. Nat. Acad. Sci. Proc., 4:229-32
1918*a* Postglacial continental uplift. Science, n.s., 47:615-17
1919 Pleistocene marine submergence of the Hudson, Champlain and St Lawrence valleys. N. Y. State Mus. Bul. 209-10. 76 pl. illus.
1925 The Susquehanna river in New York and evolution of western New York drainage. N. Y. State Mus. Bul. 256. 99p. illus.
1929 New York drumlins. Rochester Acad. Sci. Proc., 7:1-37
1932 New York moraines. Geol. Soc. Amer. Bul., 43:627-62

* Papers quoted in text but not bearing directly on the region are preceded by an asterisk.

Fenneman, N. M.
1928 Physiographic divisions of the United States. Assoc. Amer. Geog Ann., 18:261-353
1930 Physical divisions of the United States [map]. U. S. Geol. Surv.
1938 Physiography of the eastern United States. 714p. New York.
Fenton, C. L. & M A.
1934 Scolithus as a fossil phoronid. Pan-Amer. Geol., 61:341-48
Fullerton, W. J. & Cox, A. W.
1931 Method and cost of quarrying, crushing, and grinding limestone at the Catskill plant of the North American Cement Corporation, Catskill, N. Y. U. S. Bur. Mines, Inform. Circ. 6522. 15p.
Gannett, S. S. & Baldwin, D. H.
1906 Spirit leveling in the state of New York for the years 1896 to 1905 inclusive. U. S. Geol. Surv. Bul. 281. 112p.
*Gardner, J. H.
1935 Origin and development of limestone caverns. Geol. Soc. Amer. Bul., 46:1255-74
Girty, G. H.
1897 A revision of the sponges and coelenterates of the Lower Helderberg group of New York. N. Y. State Geol. Rep't, 14:259-322
Goldring, Winifred
1921 Decreasing salinity of the Pleistocene Champlain sea going southward. . . , with a brief discussion of the Pleistocene fauna of the Hudson valley. Geol. Soc. Amer. Bul., 32:132-33
1921*a* The fossil trees of Schoharie county. N. Y. State Mus. Bul., 227:9-11
1922 Pleistocene fauna of the Hudson valley and its significance. N. Y. State Mus. Bul., 239:181-87
1923 The Devonian crinoids of the state of New York. N. Y. State Mus. Mem. 16. 670p., 60 pl.
1924 The Upper Devonian forest of seed ferns in eastern New York. N. Y. State Mus. Bul., 251:50-92
1925 The fossil forests of Gilboa, N. Y. N. Y. State Mus. Leaflet. 4p.
1927 The oldest known petrified forest. Sci. Monthly, 24:515-29
1931 Handbook of paleontology for beginners and amateurs, Part 2: The formations. N. Y. State Mus. Handbook 10. 488p., 62 fig.
1935 Geology of the Berne quadrangle. N. Y. State Mus. Bul. 303. 238p., 72 fig.
——— **& Flower, R. H.**
1942 Restudy of the Schoharie and Esopus formations in New York state. Amer. Jour. Sci., 240:673-94
Grabau, A. W.
1899 Moniloporidae, a new family of Paleozoic corals. Boston Soc. Nat. Hist. Proc., 28:409-24
1903 Stratigraphy of Becraft mountain, Columbia county, New York. N. Y. State Mus. Bul., 69:1030-79
1904 On the classification of sedimentary rocks. Amer. Geol., 33:228-47
1904*a* The geology of Becraft mountain, N. Y. N. Y. Acad. Sci. Ann., 15:176
1906 Guide to the geology and paleontology of the Schoharie valley in eastern New York. N. Y. State Mus. Bul. 92. 386p.
1908 A revised classification of the North American Siluric system. Science, n.s., 27:622-23
1909 Physical and faunal evolution of North America during Ordovicic, Siluric and early Devonic time. Jour. Geol., 17:209-52
1912 Stratigraphic and paleontologic features of ancient delta deposits. Science, n.s., 35:317
1913 Early paleozoic delta deposits of North America. Geol. Soc. Amer. Bul., 24:399-528
1915 North American continent in Upper Devonic time. Science, n.s., 41:509-10; Geol. Soc. Amer. Bul., 26:88-90
1921 A textbook of geology. Part 2, Historical geology. 976p. New York

* Papers quoted in text but not bearing directly on the region are preceded by an asterisk.

1924 Stratigraphy of China. Part 1, Paleozoic and older. Geol. Surv. China. 528p. Peking
1930 Problems in Chinese stratigraphy, part 3, Science Quart. Nat. Univ. Peking, 1 (no. 4) :303-40
1938 Classification of the Paleozoic systems in the light of the pulsation theory. Geol. Soc. Amer. Bul., 49 :1932-33

———— **& Shimer, H. W.**
1909 North American index fossils. v. 1, 853p., illus.; v. 2, 909p., illus. New York

Guyot, Arnold
1880 On the physical structure of the Catskill mountain region. Amer. Jour. Sci., (3) 19 :429-51

Hall, James
1859 Descriptions and figures of the organic remains of the Lower Helderberg group and the Oriskany sandstone. Natural History of New York: Paleontology 3. 532p. (pt. 1); 142 pl. (pt. 2)
1867 Descriptions and figures of the fossil brachiopoda of the Upper Helderberg, Hamilton, Portage and Chemung groups. Natural History of New York: Paleontology 4. 428p., 69 pl.
1874 Descriptions of bryozoa and corals of the Lower Helderberg group. N. Y. State Mus. Rep't, 26 :93-116
1876 Illustrations of Devonian fossils; corals of the Upper Helderberg and Hamilton groups. 38 pl. and expl. Albany
1879 Descriptions of the gastropoda, pteropoda and cephalopoda of the Upper Helderberg, Hamilton, Portage and Chemung groups. Natural History of New York: Paleontology 5. pt. 2, 492p., 120 pl.
1879*a* Corals and bryozoans of the Lower Helderberg group. N. Y. State Mus. Rep't, 32 :141-76
1883 Fossil corals and bryozoans of the Lower Helderberg group, and fossil bryozoans of the Upper Helderberg group [plates]. N. Y. State Geol. Rep't, 2 :17-[84]
1883*a* Bryozoans of the Upper Helderberg and Hamilton groups. Albany Inst. Trans., 10 :145-97
1884 Lamellibranchiata I. Monomyaria of the Upper Helderberg, Hamilton and Chemung groups. Natural History of New York: Paleontology 5. pt. 1. v. 1. 268p., 45 pl.
1885 Lamellibranchiata II. Dimyaria of the Upper Helderberg, Hamilton, Portage and Chemung groups. Natural History of New York: Paleontology 5. pt. 1. v. 2. 293p., 51 pl.
1887 Corals and bryozoa; descriptions and figures of species from the Lower Helderberg, Upper Helderberg and Hamilton groups, Natural History of New York: Paleontology 6. 298p., 67 pl.
1888 Descriptions and illustrations of pteropoda, cephalopoda and annelida; Natural History of New York: Paleontology 7 (supplement to v. 5 pt. 2). 42p., 18 pl.
1891 Continuation of descriptions of bryozoa, . . . N. Y. State Geol. Rep't, 10 :35-57

———— **& Clarke, J. M.**
1888 Descriptions of the trilobites and other crustacea of the Oriskany, Upper Helderberg, Hamilton, Portage, Chemung and Catskill groups. Natural History of New York: Paleontology 7. 236p., 46 pl.
1893 An introduction to the study of the genera of Paleozoic brachiopoda. Natural History of New York: Paleontology 8. pt. 1, 367p., 44 pl.; pt. 2, 394p., 64 pl.

Hartnagel, C. A.
1903 Preliminary observations on the Cobleskill ("coralline") limestone of New York. N. Y. State Mus. Bul., 69: 1109-75
1905 Notes on the Siluric or Ontaric section of eastern New York. N. Y. State Mus. Bul., 80 :342-58
1912 Classification of the geologic formations of the state of New York. N. Y. State Mus. Handbook 19. 2d. ed. 99p.

———— & Bishop, S. C.
1922 The mastodons, mammoths and other Pleistocene mammals of New York State. N. Y. State Mus. Bul. 241. 110p., 25 pl.

Heilprin, Angelo
1907 The Catskill mountains. Amer. Geog. Soc. Bul., 39:193-99

Henderson, Junius
1935 Fossil nonmarine mollusca of North America. Geol. Soc. Amer., Special Papers No. 3. 313p.

Hinde, G. J.
1887 On the genus Hindia and the name of its typical species. Ann. and Mag. Nat. Hist., (5) 19:67-79

Howell, B. F.
1942 New localities for fossils in the Devonian Esopus grit. N. Y. State Mus. Bul., 327:87-93 (*And associated papers.)

Hubbard, G. D. & Wilder, C. G.
1930 Validity of the indicators of ancient climates. Geol. Soc. Amer. Bul., 41:275-92

Hubbard, O. P.
1889 [Pothole near Catskill, N. Y.]. N. Y. Acad. Sci. Trans., 9:3

Hunt, T. S.
1864 On the geology of eastern New York. Amer. Jour. Sci., (2) 39:96-97

Ingram, H. B.
1894 The great bluestone industry. Pop. Sci. Monthly, 45:352-59

Jackson, D. D.
1904 The normal distribution of chlorine in the natural waters of the state of New York. (From) Add. Water Sup. Com. of City of N. Y. Rep't, 1903. 5p. and map

Jenkins, J. P.
1821 Notice of some facts at Hudson. Amer. Jour. Sci., 4:33-35

Johnson, D. W.
1916 Plains, planes and peneplanes. Geog. Review, 1:443-47
1917 Date of local glaciation in the White, Adirondack, and Catskill mountains. Geol. Soc. Amer. Bul., 28:543-53

Jones, R. W.
*1919 The geology of the Catskill Portland-cement region. Amer. Ceram. Soc. Jour., 2:870-82
1926 Limestone for Portland cement in Greene county, New York. Eng. & Min. Jour.-Press, 121:805-6

Julien, A. A.
1881 The excavation of the bed of the Kaaterskill, New York. N. Y. Acad. Sci. Trans., 1:24-31

Kay, G. Marshall
1940 Taconic disturbance and associated events. Geol. Soc. Amer. Bul., 51:1932

———— & Chadwick, G. H.
1933 The Catskill region. Internat. Geol. Congr. XVI, Guidebook 9A. 25p. Gov't Ptg. Off.

Kimball, J. P.
1890 Siderite basins of the Hudson River epoch. Amer. Jour. Sci., (3) 40:155-60

***Kindle, E. M.**
1914 Columnar structure in limestone. Can. Geol. Surv. Mus. Bul., 2:35-39
*1917 Recent and fossil ripple-mark. Can. Geol. Surv. Mus. Bul. 25. 56p.

Krynine, Paul D.
1940 Appalachian orogeny and sedimentation. Geol. Soc. Amer. Bul., 51:1999
1941 Differentiation of sediments during the life history of a landmass. Geol. Soc. Amer. Bul., 52:1915
1941*a* Paleogeographic and tectonic significance of graywackes. *Ibid.*:1916

Leverett, Frank
1930 [Glacial striae on Slide mountain] Nat. Res. Council Repr. & Circ. Ser., 92:88-89

* Papers quoted in text but not bearing directly on the region are preceded by an asterisk.

Lincklaen, Ledyard
1861 Guide to the geology of New York. N. Y. State Cab. Nat. Hist. Rep't, 14:17-84, 1-41 (plates)
Lobeck, A. K.
1921 A physiographic diagram of the United States. [map]. Chicago
1932 Atlas of American geology. 91 sheets (unbound), illus. Geog. Press, Columbia Univ., New York
Logan, W. E. & Hall, James
1869 Geological map of Canada . . . [and part of United States]. Canada Geol. Surv.
Longwell, C. R.
1933 Eastern New York and western New England. Internat. Geol. Congr. XVI, Guidebook 1. 118p. Gov't Ptg. Off.
Macfarlane, James
1879 An American geological railway guide, . . . 219p. New York.
Macfarlane, J. R.
1890 An American geological railway guide . . . 2d ed. 426p. New York.
McGee, W. J.
1894 Preliminary geologic map of New York [map]. N. Y. State Geol. Surv. (U.S.G.S.)
Mackin, J. H.
1933 The evolution of the Hudson-Delaware-Susquehanna drainage. Amer. Jour. Sci., (5) 26:319-31
1938 The origin of Appalachian drainage—a reply. Amer. Jour. Sci., (5) 36:27-53
Marshall, R. B.
1918 Results of spirit leveling in New York, 1906 to 1911, inclusive. U. S. Geol. Surv. Bul. 514. 139p.
1918*a* Spirit leveling in New York, 1896-1905 and 1912-1916. U. S. Geol. Surv. Bul. 671. 214p.
Mather, W. W.
1838 Report of the first geological district of the state of New York. N. Y. Geol. Surv. Ann. Rep't, 2:121-84
1840 Fourth annual report of the first geological district of the state of New York. N. Y. Geol. Surv. Ann. Rep't, 4:209-58
1841 Fifth annual report on the geological survey of the first geological district. . . . N. Y. Geol. Surv. Ann. Rep't, 5:63-112
1843 Geology of New York. Part 1, comprising the geology of the first geological district. (Nat. Hist., pt. IV) v. 1. 653p.
Mease, James
1807 A geological account of the United States . . . 496p. Phila.
Melish, John
1818 A geographical description of the United States. 134p. Phila.
Mencher, Ely
1939 Catskill facies of New York state. Geol. Soc. Amer. Bul., 50:1761-94
Merrill, F. J. H.
1898 A guide to the study of the geological collections of the New York State Museum. N. Y. State Mus. Bul. 19. 164p., 119pl., map
1902 Description of the state geologic map of 1901. N. Y. State Mus. Bul. 56. 42p.
Merwin, H. E.
1911 The topographic development of the Catskill mountains. Science, n.s., 33:550-51
1920 Some features of stream development and of glaciation in the Catskill mountains. Geol. Soc. Amer. Bul., 31:152
Meyerhoff, H. A. & Olmsted, E. W.
1936 The origins of Appalachian drainage. Amer. Jour. Sci., (5) 32:21-42
1938 Evolution of the northern Appalachian drainage divide. Geol. Soc. Amer. Bul., 49:1938
Miers, H. A.
1907 Obituary; Samuel Lewis Penfield. Miner. Mag., 14:264-68

Miller, A. K.
1936 Type invertebrate fossils of North America (Devonian); Ammonoidea. 50 cards, fig. Phila.
Miller, S. A.
1877 The American Paleozoic fossils . . . 253p. Cincinnati
1883 The American Paleozoic fossils, 2d ed. 334 p. Cincinnati
1889 North American geology and paleontology. 664p. Cincinnati
1892 First appendix to North American geology. p.665-718. Cincinnati
1897 Second appendix to North American geology. p.719-93. Cincinnati
Miller, W. J.
1914 The geological history of New York state. N. Y. State Mus. Bul. 168. 130p.
1924 The geological history of New York state. 2d. ed. N. Y. State Mus. Bul. 255. 148p., 52 pl.
Moore, Raymond C.
1941 Stratigraphy. *In* Geology 1888-1938. Geol. Soc. Amer. 50th Anniv. Vol.:177-220
Nason, F. L.
1894 Economic geology of Ulster county, New York. N. Y. State Geol. Rep't, 13:373-406
Newberry, J. S.
1889 The Paleozoic fishes of North America. U. S. Geol. Surv. Monog. 16. 340p.
Newland, D. H.
1916 Landslides in unconsolidated sediments, . . . N. Y. State Mus. Bul. 187:79-105
1921 The mineral resources of the State of New York. N. Y. State Mus. Bul. 223-24. 315p.
1933 The Paleozoic stratigraphy of New York. Internat. Geol. Congr. XVI, Guidebook 4. 136p. Gov't Ptg. Off.
New York Geological Survey
1842 Geological map of the State of New York
New York State Museum
1904 Economic geology of New York. N. Y. State Mus. Handbook 17. 40p.
Nickles, J. M. & Bassler, R. S.
1900 A synopsis of American fossil bryozoa. . . . U. S. Geol. Surv. Bul. 173. 663p.
Osborn, H. F.
1900 A glacial pothole in the Hudson River shales near Catskill, New York. Amer. Nat., 34:33-36
Parker, John M. III
1942 Regional systematic jointing in sedimentary rocks. Geol. Soc. Amer. Bul., 53:381-408
Parks, W. A.
1935 Systematic position of the stromatoporoidea. Jour. Pal., 9:18-29
1936 Devonian stromatoporoids of North America, part 1. Toronto Univ. Studies, Geol. ser. 39. 125p., 19 pl.
Peet, C. E.
1904 Glacial and postglacial history of the Hudson and Champlain valleys. Jour. Geol., 12:415-69, 617-60
Pepper, J. F.
1934 The Taconic and Appalachian orogenies in the Hudson river region. Science, n.s., 80:186
Pierce, James
1823 A memoir on the Catskill mountains. . . . Amer. Jour. Sci., 6:86-97
Prosser, C. S.
1891 The geological position of the Catskill group. Amer. Geol., 7:351-66
1899 Classification and distribution of the Hamilton and Chemung series of central and eastern New York, part 2. N. Y. State Geol. Rep't 17:65-315
1903 Notes on the geology of eastern New York. Amer. Geol., 32:381-84
1915 The middle and upper Devonian of the Romney, West Virginia, Region. Jour. Geol., 23:11-26

Rafter, G. W.
1905 Hydrology of the state of New York. N. Y. State Mus. Bul. 85. 902p.

Ramsay, A. C.
1859 On some of the glacial phenomena of Canada and the northeastern provinces of the United States . . . Geol. Soc. Lond. Quart. Jour., 15:200-15

Raymond, P. W.
1927 The significance of red color in sediments. Amer. Jour. Sci., (5) 13:234-51; 14:157-58

Raymond, R. W.
1876 The spathic iron ores of the Hudson river. Amer. Inst. Min. Eng. Trans., 4:339-43

Reid, H. F.
1922 Isostasy and earth movements. Geol. Soc. Amer. Bul., 33:317-26

Rich, J. L.
1906 Local glaciation in the Catskill mountains. Jour. Geol., 14:113-21
1911 Gravel as a resistant rock. Jour. Geol., 19:492-506
1915 Notes on the physiography and glacial geology of the northern Catskill mountains. Amer. Jour. Sci., (4) 39:137-66
1917 An instance of the changing value of geographical location. Jour. Geog., 15:185-89
1917*a* Local glaciation in the Catskill mountains. Geol. Soc. Amer. Bul., 28:133-34
1917*b* Cultural features and the physiographic cycle. Geog. Review, 4:297-308
1918 The glacial phenomena of the Catskill mountains. N. Y. State Mus. Bul., 196:32-39
1934 Mechanics of low-angle overthrust faulting . . . Amer. Assoc. Pet. Geol. Bul., 18:1584-96
1935 Glacial geology of the Catskills. N. Y. State Mus. Bul. 299. 180p.
1936 Questioning too many peneplains. Geol. Soc. Amer. Proc., 1935:98-99
1941 Buried stagnant ice as a normal product. Geol. Soc. Amer. Bul., 52:1929

Ries, Heinrich
1891 The quaternary deposits of the Hudson river valley between Croton and Albany. N. Y. State Geol. Rep't, 10:110-55
1891*a* The clays of the Hudson River valley. N. Y. Acad. Sci. Trans., 11:33-39
1897 Physical tests of the Devonian shales of New York . . . N. Y. State Geol. Rep't, 15:673-98
1899 Limestones of New York and their economic value. N. Y. State Geol. Rep't, 17:355-467
1901 Lime and cement industries of New York. N. Y. State Mus. Bul. 44. 332p., 101 pl.

***Rogers, H. D. & W. B.**
1843 On the physical structure of the Appalachian chain . . . Assoc. Amer. Geologists Rep't: 70-71, 474-531

***Roy, S. K.**
1929 Columnar structure in limestone. Science, n.s., 70:140-41

Ruedemann, Rudolf
1904 Graptolites of New York. Part 1, graptolites of the lower beds. N. Y. State Mus. Mem. 7. 350p., 17 pl.
1908 Graptolites of New York. Part 2, graptolites of the higher beds. N. Y. State Mus. Mem. 11. 584p., 31 pl.
1930 Geology of the capital district. N. Y. State Mus. Bul. 285. 218p., 40 fig., 39 pl.
1931 Age and origin of the siderite and limonite of the Burden iron mines. . . . N. Y. State Mus. Bul., 286:135-49
1932 Development of drainage of Catskills. Amer. Jour. Sci., (5) 23:337-49
1932*a* Guide to the fossil exhibits of the New York State Museum. N. Y. State Mus. Circ. 9. 53p.

* Papers quoted in text but not bearing directly on the region are preceded by an asterisk.

1934 Paleozoic plankton of North America. Geol. Soc. Amer. Mem. 2. 141p., 26 pl.
1935 Ecology of black mud shales of eastern New York. Jour. Pal., 9:79-91
——— & **Wilson, T. Y.**
1936 Eastern New York Ordovician cherts. Geol. Soc. Amer. Bul., 47:1535-86

Salisbury, R. D. & Atwood, W. W.
1908 The interpretation of topographic maps. U. S. Geol. Surv. Prof. Paper 60. 84p.

Sarle, C. J.
1906 Preliminary note on the nature of Taonurus. Rochester Acad. Sci. Proc., 4:211-14

Schuchert, Charles
1897 A synopsis of American fossil brachiopoda. U. S. Geol. Soc. Bul. 87. 464p.
1900 Lower Devonic aspect of the Lower Helderberg and Oriskany formations. Geol. Soc. Amer. Bul., 11:241-332
1903 On the Manlius formation of New York. Amer. Geol., 31:160-78
1910 Paleogeography of North America. Geol. Soc. Amer. Bul., 20:427-606
1925 Significance of Taconic orogeny. Geol. Soc. Amer. Bul., 36:343-50
1927 Winters in the Upper Devonian of New York and Acadia. Amer. Jour. Sci., (5) 13:123-31
1930 Orogenic times of the northern Appalachians. Geol. Soc. Amer. Bul., 41:701-24
——— & **Longwell, C. R.**
1932 Paleozoic deformations of the Hudson valley. . . . Amer. Jour. Sci., (5) 23:305-26

Shaler, N. S.
1879 On the existence of the Alleghany division of the Appalachian range within the Hudson valley. Amer. Nat., 11:627-28

Sherwood, Andrew
1878 Section of Devonian rocks made in the Catskill mountain at Palenville, Kauterskill creek, New York. Amer. Philos. Soc. Proc., 17:346-49

***Smith, Burnett**
1929 Influence of erosion intervals on the Manlius-Helderberg series of Onondaga county, New York. N. Y. State Mus. Bul., 281:25-36

Smock, J. C.
1885 Evidences of local glaciers in the Catskill mountain region. Amer. Ass'n Adv. Sci. Proc., 33:403-4

***Stansfield, John**
1918 Concentric ridges on naturally occurring silica. Roy. Soc. Can. Trans., (3) 11 IV:117-20

Stevens, N. E.
1912 Notes on the structure and glaciation of Overlook mountain. N. Y. Acad. Sci. Annals, 22:259-66

Swartz, C. K. & committee
1942 Correlation of the Silurian formations of North America. Geol. Soc. Amer. Bul., 53:533-38

Swartz, F. M.
1938 Ostracoda from the Lower Devonian of eastern New York and Pennsylvania. Geol. Soc. Amer. Bul., 49:1902-3

Talbot, Mignon
1905 Revision of the New York Helderbergian crinoids. Amer. Jour. Sci., (4) 20:17-34

Ulrich, E. O.
1911 Revision of the Paleozoic systems. Geol. Soc. Amer. Bul., 22:281-680. Index. *ibid*, 24:625-68
——— & **Bassler, R. S.**
1904 A revision of the Paleozoic bryozoa. Smith. Misc. Coll., 45 (1):256-94; 47(2):15-55
——— & **Ruedemann, R.**
1931 Are the graptolites bryozoans? Geol. Soc. Amer. Bul., 42:589-603

* Papers quoted in text but not bearing directly on the region are preceded by an asterisk.

——— & Schuchert, C.
1902 Paleozoic seas and barriers in eastern North America. N. Y. State Mus. Bul., 52:633-63
Upham, Warren
1889 Glaciation of mountains in New England and New York. Amer. Geol., 4:165-74, 205-16
1903 The glacial lakes Hudson-Champlain and St Lawrence. Amer. Geol., 32:223-30
1905 Glacial lakes and marine submergence in the Hudson-Champlain valley. Amer. Geol., 36:285-89
Van Ingen, G. & Clark, P. E.
1903 Disturbed fossiliferous rocks in the vicinity of Rondout, N. Y. N. Y. State Mus. Bul., 69:1176-1227
***Van Tuyl, F. M.**
1918 The origin of chert. Amer. Jour. Sci., (4)45:449-56
Vanuxem, Lardner
1842 Geology of New York. Part 3, Comprising the survey of the third geological district. (Nat. Hist., pt. 3) v. 1. 306p.
Ver Wiebe, W. A.
1932 Present distribution and thickness of Paleozoic systems. Geol. Soc. Amer. Bul., 43:495-540
Ward, L. F.
1889 The geographical distribution of fossil plants. U. S. Geol. Surv. Rep't, 8:663-960
***White, I. C.**
1882 The geology of Pike and Monroe counties. Pa. Geol. Surv., 2d, G6. 407p.
Whitlock, H. P.
1903 List of New York mineral localities. N. Y. State Mus. Bul. 70. 108p.
1910 Calcites of New York. N. Y. State Mus. Mem. 13. 190p.
***Willard, Bradford**
1935 Devonian ice in Pennsylvania. Jour. Geol., 43:214-19
Willis, Bailey
1893 The mechanics of Appalachian structure. U. S. Geol. Surv. Ann. Rep't, 13. pt. 2:211-81
1912 Index to the stratigraphy of North America. U. S. Geol. Surv. Prof. Paper 71. 894p.
Willis, Robin
1935 Development of thrust faults. Geol. Soc. Amer. Bul., 46:409-24
Wilmarth, M. G.
1938 Lexicon of geologic names of the United States. U. S. Geol. Surv. Bul. 896. 2396p. (2 vs.)
Woodworth, J. B.
1905 Ancient water levels of the Champlain and Hudson valleys. N. Y. State Mus. Bul. 84. 265p.
Wright, Benjamin
1821 Lime for water cement. Amer. Jour. Sci., 3:230-31
Zodac, Peter
1936 Phosphorescent selenite from Hudson, N. Y. Rocks & Minerals, 11:59

* Papers quoted in text but not bearing directly on the region are preceded by an asterisk.

EDITOR'S NOTE: Quoted material has been edited in conformity with editorial practices of the New York State Education Department.

FINAL ADDENDA

In the carefully thought-out correlation chart of the Devonian by Doctor Cooper (Dec., 1942; Geol. Soc. Amer. Bul., 53: facing page 1788), our "Erian" rocks are determined as follows:

Kaaterskill sandstones	Tully (perhaps also Geneseo)
Kiskatom red and green beds	Moscow Ludlowville Skaneateles plus Mottville
Ashokan sandstones Mount Marion shale and sandstone	Pecksport } Cardiff Solsville } dark Bridgewater } shale Chittenango black shale
Stony Hollow sandstone	Cherry Valley
Bakoven shale	Union Springs

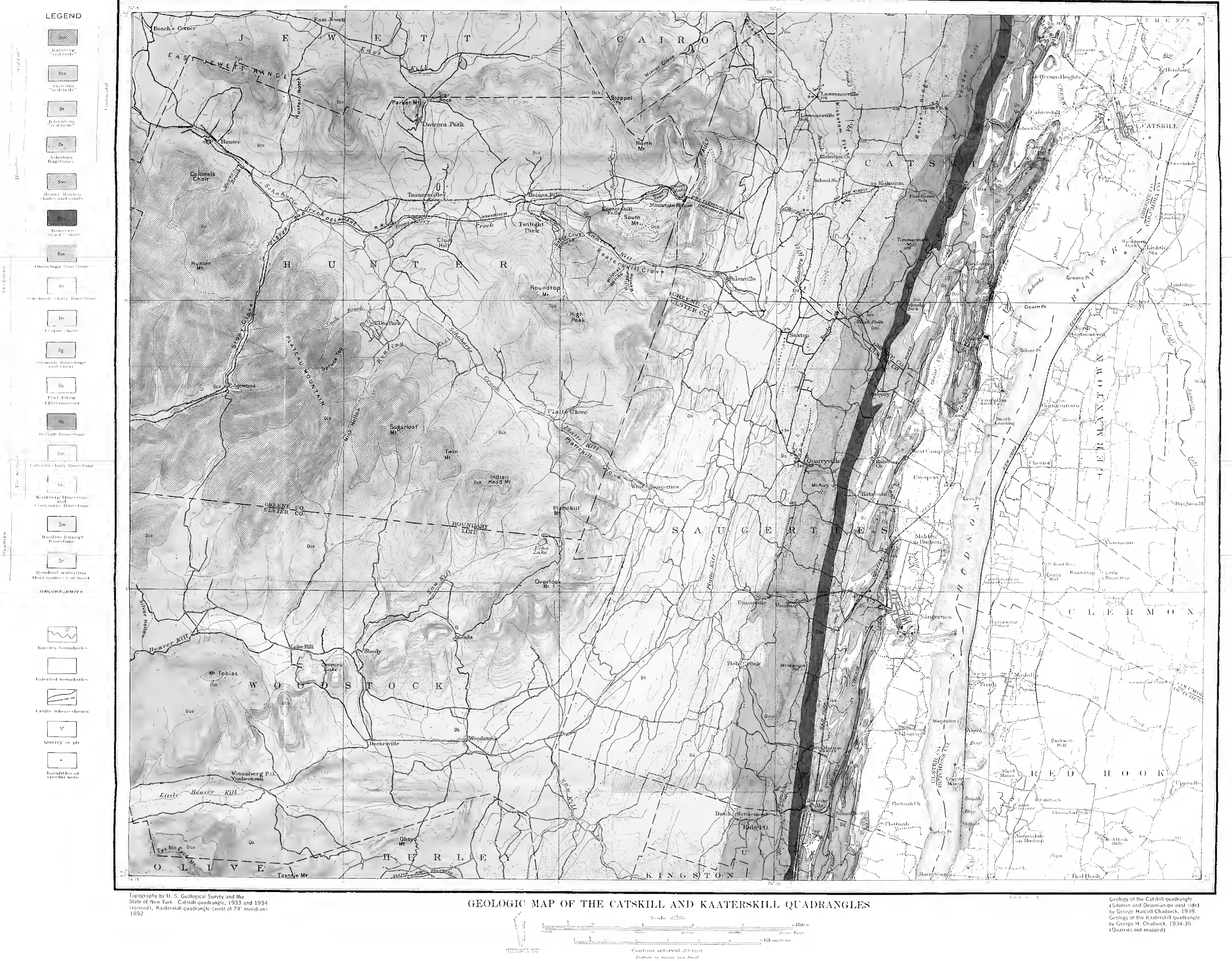
On our map the Stony Hollow sandstone is included (as originally) in the Mount Marion beds and is the lower 100 feet or so (our page 107 and figure 41) that has distinct topographic expression and that overrides the "coal" at Houck's (page 171; see also 191). Both Tully and Geneseo are made Middle Devonian by Cooper (see our page 122).

For the higher (Senecan) strata, Cooper accepts our correlations, awaiting the more refined tracing that these beds unquestionably require.

Condensation may have left undetected errors in references that the reader can doubtless solve. Most of the many less important titles cut from the bibliography may easily be found in the U. S. Geol. Surv. bibliographic bulletins; those that might confuse are (*in Bul. 746:*) Chance 1880 (G4); Clarke 1884 (1885b), 1885(*a*), 1901 1902*a*), 1930(*a*); Conrad 1842(*a*); Eaton 1823(*a*), 1824 (Erie Canal); Hall 1851(*b*), 1862(*m*), 1863(*i*), 1873 (23d St. Cab.), 1878(*b*), 1893(*a*) 1894(*a*); Lesley 1882 (G6); Jules Marcou 1855(*c*); Merrill (1906(*c*); Mitchill 1798; H. S. Williams, 1900(*c*), 1910(*b*); (*in Bul. 823:*) Ernst Antevs 1; Chadwick 20; Fairchild 24; Grabau 6; G. F. Wright 2; (*in Buls. 834, 869:*) Bassler 221; Chadwick 465; Cooper 562, 751 [1934, see 1933*a*]. Chadwick 1907 is a master's thesis deposited in University of Rochester and State Museum.

INDEX

Map 1 Silurian and Devonian Geology of the Catskill and Kaaterskill Quadrangles



Topography by U. S. Geological Survey and the State of New York. Catskill quadrangle, 1933 and 1934 (revised); Kaaterskill quadrangle (west of 74° meridian) 1892.

GEOLOGIC MAP OF THE CATSKILL AND KAATERSKILL QUADRANGLES

Geology of the Catskill quadrangle (Silurian and Devonian on west side) by George Halcott Chadwick, 1938.
Geology of the Kaaterskill quadrangle by George H. Chadwick, 1934-35.
(Quarries not mapped)