New York State Museum Bulletin

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CHARLES C. ADAMS, *Director*

GEOLOGY OF THE COXSACKIE QUADRANGLE, NEW YORK

BY WINIFRED GOLDRING D.Sc.

State Paleontologist, New York State Museum

WITH A CHAPTER ON GLACIAL GEOLOGY

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LIST OF ILLUSTRATIONS

GEOLOGY OF THE COXSACKIE QUADRANGLE, NEW YORK[1]

By Winifred Goldring D.Sc.

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By John H. Cook

PREFACE

The area covered by the Coxsackie quadrangle (latitude 42°15′ to 42°30′; longitude 73°45′ to 74°) lies in the Hudson valley between the Albany quadrangle on the north and the Catskill quadrangle on the south and includes parts of Albany, Greene (in large part), Rensselaer and Columbia counties. The work was undertaken in order to continue the mapping of the Devonian formations, particularly, and to fill in the gap between the already mapped Capital District area and the Catskill quadrangle mapped by Doctor Ruedemann and Dr G. H. Chadwick. The work was started in June 1934 and practically completed in the fall of 1937.

In order to draw the boundary lines correctly along the eastern border of the quadrangle, it was found necessary to study the same formations on the western border of the Kinderhook quadrangle, where the majority of the outcrops were located. The results are embodied in a black and white map accompanying the geological map of the Coxsackie quadrangle. An overprint to indicate masking glacial deposits has only been used where large areas are covered, as in the broad belt between Urlton and Newrys and the Cambrian-Ordovician belt bordering the Hudson. A third map, printed in black and white, shows enlarged (three times) the complicated geology of the limestone belt from the vicinity of Climax southward. It is suggested that the formations on this map be colored, preferably with colored pencils.

The writer wishes here to express thanks to Dr Charles C. Adams, Director of the State Museum, for his unfailing interest in the work as it progressed and to her colleagues on the Museum staff: Dr Rudolf Ruedemann, former State Paleontologist, Dr D. H. Newland, former State Geologist, and C. A. Hartnagel, State Geologist, for assistance of various kinds. Doctor Ruedemann accompanied the writer on a large number of the trips in the area underlain by

[1] Including a short discussion of the new Stony Hollow member (p. 247) of the Hamilton beds and a note on the restricted Berne member (p. 249) by Dr G. Arthur Cooper, U. S. National Museum, Washington, D. C.

the Cambrian and Ordovician beds and visited with her, toward the close of the work, some critical localities in the limestone belt south of Greens lake. To him especial acknowledgment is here made. Thanks are also due T. Y. Wilson who on a few occasions accompanied the writer and Dr Ruedemann on field trips. The writer has had assistance, helpful suggestions and information in the field from Dr G. H. Chadwick and Dr G. A. Cooper of the U. S. National Museum. Doctor Cooper also kindly consented to write a chapter on his new Stony Hollow member of the Hamilton beds. The glacial chapter was written by John H. Cook who has for years studied the glacial geology of eastern New York and already produced similar chapters for the bulletins on the Berne quadrangle, Capital District and Catskill quadrangle. To Walter J. Schoonmaker, Assistant State Zoologist in the New York State Museum, the writer is indebted for faunal lists.

To Professor Charles P. Berkey acknowledgment is made for permission to use a portion of the block diagram of the Mid-Hudson Valley region.

The writer wishes to acknowledge here also the many courtesies received, while in the field, from the residents, permanent and summer, of the area covered by this quadrangle. Interest, understanding and kindness were met with on all sides. In particular, acknowledgment is made to the Rev. Delber W. Clark, former rector of Christ Episcopal Church in Coxsackie, local historian and amateur geologist, from whom many facts of interest, historical and otherwise, were gleaned. Because of the local interest expressed in this work and because of the large number of summer residents, especially in the southern part of the area, an effort has been made to make the information in this bulletin useful to the layman as well as to the scientist. For the various formations discussed are given the relations with neighboring areas and in the State as a whole. A short discussion of each period has been thought advisable as an introduction to the discussion of the formations of that period and the historical chapter is therefore less detailed.

The photographs used in this bulletin were made by the late staff photographer and draftsman, Edwin J. Stein, to whose skill is due a number of the pen and ink sketches of fossils. After his death this work was completed by the technical assistant in paleontology, Clinton F. Kilfoyle. Except for the Cambrian (Schodack) fossils, which were taken from C. D. Walcott: Cambrian Faunas of North America (U. S. Geol. Surv. Bul. 30, 1886), all the drawings of fossils were taken from various museum publications.

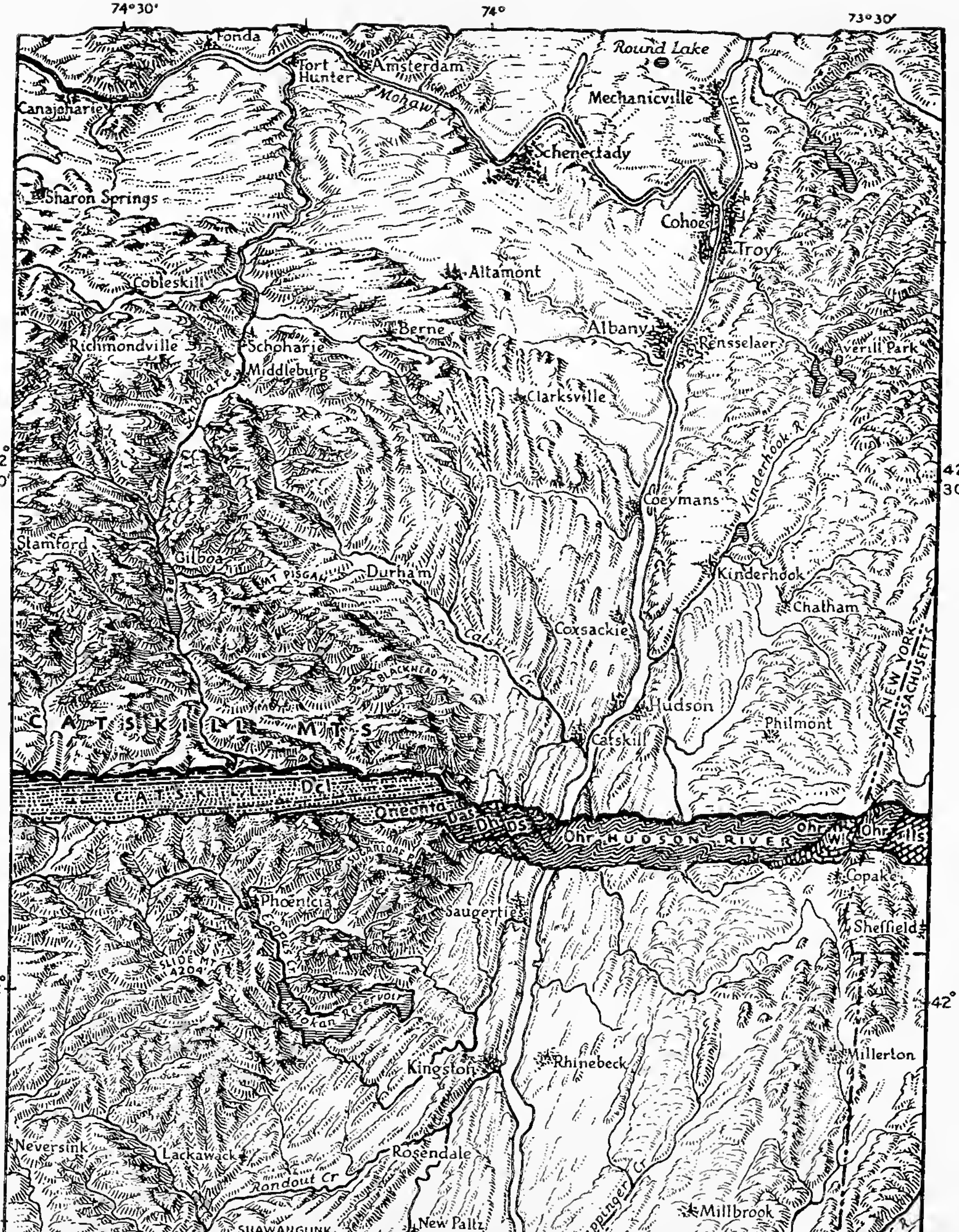

Figure 1 Block diagram of the Mid-Hudson Valley region. *Ils*, Inwood limestone (Precambrian); *Wls*, Wappinger limestone (Cambro-Ordovician); *Ohr*, "Hudson River" (Cambro-Ordovician) shales; *DS*, Upper Silurian and Lower Devonian beds; *Dh*, Hamilton beds (Middle Devonian); *Das*, Ashokan beds (Hamilton age); *"Oneonta"*, Kiskatom beds (Hamilton age); *Dcl*, "Catskill" beds (Upper Devonian). Scale, five miles to seven-sixteenths of an inch. (After Berkey)

INTRODUCTION

PHYSIOGRAPHY

The Coxsackie area may be roughly divided into three belts: the Hudson Valley lowland developed upon the Cambrian and Ordovician beds, into which the present Hudson River trench has been cut; the folded and faulted limestone belt known here and in the region to the south as the Kalkberg (lime hill), and west of this the broad belt of the Hamilton sandstones and shales, occupying about half of the area covered by the quadrangle (figure 1). All of these belts are, however, a part of the Hudson valley which stretches in width from the eroded Catskill escarpment on the west to the Taconic Mountains area on the east which is distinguished from the Hudson valley chiefly by the fact that the Cambrian and Ordovician formations composing it are highly metamorphosed and therefore resistant. The coarser features of the topography have resulted from the general erosion of the country, controlled by the rock structure; details have been added during the advance or retreat of the ice in the Glacial Period and by postglacial erosion. The differences of level are considered to "arise from (1) the presence of more than one peneplain, (2) the imperfections of peneplains, especially where the rocks have been strengthened by metamorphism, (3) glaciation, (4) crustal movements associated with the Pleistocene ice" (Fenneman, '38, p. 209). Ruedemann in his bulletin on the Capital District ('30, p. 19-21) distinguished three peneplain levels: the broad inner lowland designated as the Albany (Somerville) peneplain and regarded as an incipient peneplain of late Tertiary age; the Helderberg peneplain of early Tertiary (Eocene) age, correlated with the Harrisburg peneplain, which rises to a height of about 2000 feet southwest of Albany but descends gradually southward around the Catskills due to the southwest dip of the beds; the Catskill peneplain of Cretaceous age, at or near the top of the Catskills, known as the Schooley or Kittatinny peneplain, which rises to a height of about 4000 feet. It has been suggested that these peneplains may be much younger than supposed (Ashley, '35).

The lowland, or incipient peneplain, embracing the river is generally five to eight miles wide south of Albany. It is now quite flat as much of it is covered by clay or sand laid down during the last stages of the Ice Age in a lake (known as "Lake Albany") or series of lakes and in delta deposits. On the Coxsackie quadrangle these flats lie between elevations of 100 feet to 200± feet and are in process of dissection by the small streams joining the Hudson which is practically at sea level. In most places the descent to the entrenched river is by steep bluffs of clay (usually) or rocks, 100 feet or more high. On the west side a few low hills or ridges of rock peek through the clay and sand flats, on the east side they are more numerous; but it might more accurately be stated that these flats were built around and between rock hills or ridges which they had failed to cover, a feature strikingly displayed south of West Coxsackie. An occasional glacial hill also rises above the general level of the flats, such as Lampmans hill, south of Coxsackie, and the Klinkenberg (Echo mountain) two miles south of this (located by School No. 10). The lowland on the west side of the river was developed almost entirely upon the intensely folded Normanskill beds, striking generally N. 20° E., and the resistant grit and chert interbedded with the shale have given rise to the ridges. One such ridge forms the cliff at the lighthouse at Fourmile point, known as Echo cliff. An interesting example is Flint Mine hill (Minneberg, or Mine hill, of the old settlers), located about a mile and a half south of West Coxsackie road junction. To the east lies a ridge formed entirely by grit (Spoorenberg); to the west, another grit ridge (Berg Stuyffsink) with a fertile flat between (figure 2).

Flint Mine hill, composed of grit and white-weathering chert (*see* page 117), has become well known as the site of the great Algonkin flint mines described by Clarke ('22, from information given by Parker) and Parker ('24). This quarry site was known as early as 1900, but thorough investigation was not made until the years 1921-24. Two hundred flint pits and three large quarries, one of them 150 feet long and 40 feet wide were discovered. The question has been raised whether the quarries were made by the Indians or the early Dutch settlers and it has been stated that traces of old cart roads leading to the quarries have remained into recent times. In places on the hill were found sites of sorting stations, clipping stations, workshops and refuse dumps, some of which were 10 or more feet thick and several hundred feet long. Hundreds of stone maul heads and hammers were found in the pits and the dumps were full of them. Numerous clippings and partly finished blades were found in the various stations, but the largest workshops where the blades were finished were on the flats below the hill. From this locality were obtained for the State Museum by Arthur C. Parker, then State Archeologist, 3000 flint implements, 500 hammers, 50 disks, 3 gorgets, unique in form, a fine mortar and a copper chisel (Clarke, *ref. cit.*, p. 47). Parker, after examination of the hill, be-

Figure 2 Flint Mine hill (Minneberg) and the valley to the west of it, looking south and southeast from the grit ridge to the west (Berg Stuyffsink). Such flats between grit and chert ridges are characteristic of the Normanskill belt. (Photograph by E. J. Stein)

lieved (*ref. cit.*, p. 124) that 50 to 100 Indians worked here for at least 1000 years and states that others considered that intermittent work had been going on for over 5000 years. He also points out (p. 123) that, with the possibility of the "demon" of failure lurking in every cranny to cause fracture of the material worked upon, strange amulets were made, usually depicting a serpent devouring some animal, and suggests that the name Coxsackie may thus have originated from the Indian words *ahgooks* (or skooks) and *aki*, meaning *serpent place*.

The occurrence of the clay and sand-covered rock terrace along the river indicates post-Harrisburg uplift and the inner gorge or trench a further uplift, just as uplift of the Schooley peneplain preceded the development of the Harrisburg peneplain suggested in the more or less concordant tops of the Hamilton hills. Above this early Tertiary peneplaned surface Cairo Round Top rose as a hill of more resistant rock, a monadrock.

The limestone belt, the Kalkberg, shows very interesting topographic features, due to folding, faulting (or a combination) and dissection, some of which are mentioned below. The general north-northeast strike of the belt follows the strike of the folding. The escarpment at the east is a striking topographic feature, especially during the fall and winter after the leaves have fallen. It forms a wall, broken only south of Ravena and north of Climax, which rises quite abruptly from the clay plains to heights between 100 and 300 feet, with occasional summits rising above. The cliff is mainly composed of the Manlius and Coeymans limestones; but, as seen on the geologic map, lower and higher formations are more or less involved. On the topographic sheet long straight lines are seen, instead of curves, and contours crowded closely together in this belt. This is due to the fact that the underlying rocks, mainly shale and limestone have been so folded by great pressure from the east that they are crumpled and crowded together in north-south lines. The rocks are also highly jointed across the folds and blocks broken from the parent ledge tend to split off along roughly north-south and east-west lines. This is well shown both on the topographic map and in the topography itself, particularly in certain places along the escarpment, as in High Rocks and west of Flint Mine hill.

Interesting features of the limestone belt are the small but conspicuous swells or anticlinal hills seen on the Onondaga flats (Aquetuck flats) west of Aquetuck and north and south. Anticlinal hills and synclinal valleys are common topographic features of the area, sometimes seen in an unbroken series as in the Esopus-

Schoharie belt north of the Aquetuck-Coeymans Hollow State road. A north-south anticlinal valley or glade (figure 3) has been developed between Roberts Hill and High Rocks by dissection along the axis of a pitching anticline. The conspicuous hill north of Climax is a domed anticline the eastern half of which has been removed by erosion. One-half mile south of the Climax hotel, along the cliff, the hill capped by Coeymans limestone owes its height to faulting along the cliff. South of the Coxsackie-Bronks Lake road, in the vicinity of the State reservoir, a narrow valley or glade, extending southwestward, has developed along a faulted anticline on the east. Greens lake is located in a roughly east-west synclinal basin developed across the north end of a pitching anticline and complicated by faulting. Black lake lies in a north-south synclinal basin faulted at the east (figure 34). The north-south canoe-shaped valley (the "Canoe"), located west-southwest of Black lake is a sharp syncline, faulted or broken at the east (figure 53). In the spring, after the snows have melted, and during a rainy season the bottom of the "Canoe" is covered with water for more than half its length and has the appearance, looking north from the southern end, of a small river with steep banks. The high ridge extending beween Leeds and Limestreet is a broad anticline, with steep western arm, modified by dissection. The ridge immediately south of the west end of Greens lake is the axis of the dissected anticline, the higher beds forming ridges on the east and west along the two north-south roads. In the domed southern end of this anticline (figure 4) the Catskill has developed the beautiful Leeds gorge. (*See* pages 212, 221-22, 232, 303 and figures 54-56).

In the southern third of the quadrangle a rather noticeable, narrow, flat valley has been developed on the soft black shales (Bakoven), between the Onondaga belt and the Potic mountain. This valley continues northeastward, but north of Hollister lake is obscured by glacial deposits, and in the northern third or more of the quadrangle these soft shales constitute the lower portion of the Hamilton escarpment above the Onondaga flats. Potic mountain is probably the most conspicuous feature in the belt of Hamilton sandstones and shales. It is the northward extension of the range of Mt Marion, Mt Airy, Timmerman hill and Vedder hill on the Catskill quadrangle, known as the Hooge Berg (high hill). This range is less conspicuous north of the Climax-Urlton road and about a mile and a quarter north of the Roberts Hill-Medway road ends in a 200-foot cliff. Features of the Hamilton belt conspicuously shown on the map and in the topography, particularly in the northern area

Figure 3 Notch between High Rocks and Roberts Hill due to dissection of an anticline pitching north. View looking north from a point on the state road two miles north of West Coxsackie junction. (Photograph by E. J. Stein)

Figure 4 The Leeds gorge, looking south-southwest. The south wall is formed by an anticlinal fold in the Esopus shale (see figures 54, 55); the Schoharie and Onondaga limestones form the falls. (Photograph by E. J. Stein)

and in the southwest corner of the quadrangle, are the steps or terraces developed upon the harder beds. They are shown on the topographic map by contour lines closely grouped. These terraces, with dip slopes, are most strikingly exhibited on the east and northeast sides of Cairo Round Top.

A factor that has largely influenced the shaping of the surface is the great glacier that moved over this area from north to south. In a broad belt extending from Urlton (spelled Earlton by the village) north-northwest to Newrys may be seen numerous small hills or mounds crowded together and constituting a conspicuous and characteristic feature in the topography (figure 64). Some of these hills contain huge boulders. The ice acted as a great rasp, scouring the rock over which it passed, and the material it picked up was dropped by the overloaded ice, probably in its "melt" stages.

Between the mounds are depressions which have given rise to ponds or, as they became partly filled, to swamps. There are very few rock outcrops in this area. The ice plucked the cliffs to the north and east and exposed many north-south rock ledges. In the limestone belt, where the rock is broken up by numerous joint cracks the ice has plucked and carried away huge blocks. This feature is well shown along the east side of the road running north from Limestreet and along the Climax-Roberts Hill road north of the junction with the Medway road. Both areas are underlain by the Onondaga limestone.

The large elliptical hills, seen in numbers in the vicinity of Gayhead and northward to the Surprise-Sanfords Corners road, are also a conspicuous element of the topography. These are drumlins or drumlinoids (with rock core) deposited during the late stages of glaciation and are composed of unstratified materials picked up by the glacier (*see* figure 71). The longer axis of these hills roughly indicates the direction of advance of the ice. A number of drumlins may also be seen between the Urlton-Climax road and Medway, and there are scattered ones elsewhere.

The hills on the north side of the Catskill are heavily banked with glacial deposits which have given them a smooth rounded appearance. Outcrops are only found along the roads and in the stream beds. This is in contrast to Cairo Round Top and the terraces to the north and east of it which have been plucked of their covering exposing rock ledges. In general a mantle of drift covers the whole area, sometimes a thin veneer, again heavy as in the above-mentioned area, in the area north of the Hannacrois creek between Alcove and Coeymans Hollow (figure 5) and in the northwest corner of the quadrangle.

The clays and sands which have leveled off the dissected surface of the inner valley or lowland of the Hudson river have been mentioned above. They have to a certain extent been reworked by the small streams so that the flats, particularly noticeable north and south of Coxsackie and north and south of West Athens (figure 6), are underlain by a mixture of alluvium and the glacial sands and clays. The clays forming the flats show a distinct varved structure, an alternation of lighter and darker layers indicative of seasonal deposition in quiet, fresh water. It was formerly supposed (*see* Woodworth, '05) that a single large body of water, known as Lake Albany, occupied the Hudson valley between Kingston on the south and Saratoga and Schenectady on the north; but the more recent work of Cook ('30) indicates instead a series of smaller lakes held at slightly different levels in the river valley by residual tongues of ice ("dead" ice). Wells in the vicinity of Coxsackie have been driven 80, 135 and 175 feet through the clays before reaching rock (information from the Rev. Delber W. Clark). The clay and sand of these flats also control the character of the stream valleys which show a striking dendritic character on both sides of the river and divide the area into numerous more or less flat-topped hills.

Small deltas and terraces formed by streams during the latest stages of the glacial period are in places noticeable features in the landscape. A delta, now being excavated, is well shown at the mouth of the Hannacrois creek on the east side of the State road east of New Baltimore (figures 67, 68). Three terraces, in various stages of dissection, are quite noticeable topographic features in the valley of the Catskill on the north side of the creek: north of Cairo in the vicinity of the bridge across the Catskill, north (Sandy Plain) and east of South Cairo and north-northeast of Leeds at the south end of Potic mountain.

For the details of glaciation the reader is referred to the chapter on glacial geology by John H. Cook (page 321).

DRAINAGE

The drainage in its present form is the result of glaciation. Old stream courses have been filled in and are being reexcavated by the present streams; or streams have been turned away from their old courses. Small lakes or ponds were formed in the depressions in the midst of glacial deposits and through draining or partial filling many of them have become swamps. The entire area is drained by the Hudson river and its tributaries, large and small. In this part of its course the Hudson carries a large amount of debris, brought in

Figure 5 The Hamilton hills north of Coevmans Hollow as seen from the hill above (south of) the cemetery. Such hills, heavily covered with glacial deposits, are characteristic of this area. (Photograph by E. J. Stein)

Figure 6 West Athens flat, looking north-northeast from the Kings road. (Photograph by E. J. Stein)

by its tributaries, and as the river is here at tide level much of the material is dropped in the channel in the form of islands, producing a "braided" stream. The rocky Barren island has in recent years been connected by a sand flat with the mainland at Coeymans in the course of dredging operations. The name should be Barent's or Baerent's island, after Barent Pieterse Coeymans who received a patent starting from this island, as the county line now does. Across the river from Coxsackie two other rocky islands are connected with the mainland by alluvium, Nutten hook and Little Nutten hook (properly Noetten hoek: "nutty" corner).

The Hudson river existed long before the Glacial Period, at least as far back as Cretaceous time, over 75,000,000 years ago. At the close of the Paleozoic this section of the continent was elevated and after eons of time was worn down to a low plain, the Cretaceous peneplain over which the streams wandered regardless of structure. Subsequent elevation, which continued into Tertiary time rejuvenated the streams which again reduced the area from the Catskill mountains on the west to the Taconic mountains on the east to a low-lying plain (*see* pages 318-20), the present broad valley of the Hudson and its tributaries. The enormous amount of work involved can be grasped if one remembers that the river and its tributaries have not only removed the rock between the tops and bases of these ranges but also the continuation of these formations that once extended farther north and lapped upon the Adirondacks. Even at the end of Tertiary time the country stood much higher than now. The Hudson had a course, now buried under the ocean, nearly 100 miles beyond the site of New York. The gorge which the river had cut for itself extended from Albany to its mouth. Near Albany the rock surface is now more than 100 feet below sea level. At the Highlands the canyon is more than 700 feet deep, while beyond New York it goes down, according to Veatch and Smith ('39, plate 1) about 8000 feet at a place about 50 miles beyond Sandy Hook, the buried Grand Canyon of the Hudson. All these facts indicate not only a much greater elevation but an extension of the coastal section of the continent eastward. (*See* Ruedemann, '32, '39, 42*b*: Catskill bulletin; Johnson, '31; Meyerhoff and Olmsted, '36, for history of the Hudson river.)

The Hudson river held its preglacial course through the various glacial and interglacial periods and is now entrenching itself within the clay flats which are in process of dissection by the small streams tributary to it (figure 7). Since the new gorge in the clay is narrower than the rock gorge the bluffs of the river in many places consist of clay. Where both the Hudson and the tributaries are working in the soft clays they meet at grade, but in a few places the tributaries have encountered rocks and descend to the level of the river by falls, thus forming "hanging valleys." Examples are seen in Coeymans creek at the north outskirts of the village, in the stream just south of the Rensselaer County line on the east side of the river and in the stream south of Poolsburg just east of the Castleton cutoff. On the east side of the river the tributaries are of small sizes and, because their courses are in large part in the deep clays, have developed the characteristic dendritic type of drainage. Mill creek, three-quarters of a mile due east of its mouth, has encountered the rock of the old valley floor. Stockport creek which with its two tributaries, Claverack and Kinderhook creeks, drains much of the northern and western area of the Kinderhook quadrangle, empties into the river three and one-half miles north of the city of Hudson. At Columbiaville, where the highway bridge crosses, the creek has been forced to cut down through Cambrian shales and sandstones, producing a gorge where once there must have been a falls, since base level and would have been reached comparatively quickly by the stream in that portion of the valley, underlain by clays, between this point and the river.

The west side of the Hudson river on the Coxsackie quadrangle is drained largely by the Hannacrois, Coeymans, Coxsackie and Murderers creeks, and the Catskill, with their tributaries. Coeymans creek at the north and Murderers creek (Modder or Mordaener kill= Muddy creek) north of Athens are confined to the clay flats in the Ordovician and have the same character as the streams on the east side of the river. The courses of the other three creeks, with their tributaries, are confined largely to the area underlain by the Devonian rocks, the limestone belt and the belt of the Hamilton shales and sandstones. The Hannacrois (correctly Haanekraaie or "Cock Crow" creek, from Dutch *haan,* cock; *kraai,* to crow) is characterized in the vicinity of Coeymans Hollow, and east and west, by tributaries with steepsided valleys extending north-northeast and south-southwest. From the topographic map one has the impression of valleys gouged out by the ice; but no evidence for this was found in the field and the indications are these valleys are controlled by one set of the master joints found in the Hamilton beds. The Hannacrois has developed two broadly open valley sections in its upper course, one controlled by the falls developed on resistant beds at Dickinsons falls (Dormansville); the other by a similar falls at Alcove, an area now the site of the Alcove reservoir,

Figure 7 The Hudson river from a point about one mile north of Stuyvesant, looking southwest toward the Catskills. The steep banks of the entrenched river are formed by the Normanskill beds or glacial sands and clays; the Hamilton hills appear in the middle distance merging into the Catskills. (Photograph by E. J. Stein)

the water supply of the city of Albany. The deep, steepsided valley in the Hamilton beds between Coeymans Hollow and Alcove is in strong contrast to the broadly open valley on the Onondaga between Aquetuck and Coeymans. At Deans Mills the Hannacrois turns southeasterly in a gorge through its previously built glacial delta (page 20), at the head of which is a falls on the Manlius, Coeymans and Kalkberg limestones. Apparently the stream here is reexcavating its own preglacial valley. Instead of continuing in a southeasterly direction to the Hudson, as is usual, it turns abruptly to the northeast, emptying into the river south of Coeymans after passing through a deep ravine cut in the clay flat. This course probably has no significance other than that direction was initiated by the slope of the original surface. Coxsackie creek follows a similar course over the clay flat, and also Mill creek north of Stuyvesant. The Coxsackie creek, which empties into the Hudson at Bronk island has a north branch, Sickles creek (Diep Clove kill on the 1913 edition of the topographic sheet) which is entirely confined to the clay flat in the Ordovician belt. Of the tributaries of the south branch, the Kleine kill has its source south of Roberts Hill and drains the glade west of High Rocks; the Diep kill or Diep Clove kill heads one and one-quarter miles north-northeast of Medway in the Hamilton belt, and supplies the Coxsackie reservoirs south-southeast of Roberts Hill. The main south branch has its source in a spring under the Manlius limestone and its course is confined to the clay flats between Normanskill grit ridges and the escarpment. The largest branch (Murderer kill; probably originally Mordaener kill or Muddy creek) heads in a swamp two miles north of Medway and joins the main stream near West Coxsackie. At Climax, in the meadow southwest of Jerry's hotel, the stream disappears in a sinkhole through the Kalkberg and reappears under the Manlius one-quarter of a mile to the east. A young lad of Coxsackie, Joseph H. Edwards, informed the writer that this sinkhole was the entrance to a cavern containing a deep lake, but that it was dangerous to enter. The Steene kill or Stony creek drains Bronks lake. Hollister lake and Black lake are drained by the headwaters of the Hans Vosen kill which has established its very meandering course in the clay flat between the Kalkberg escarpment and the broad grit ridge to the east. Greens lake drains southward into the Catskill through the swamp at the southwest corner, but this can only be at times of high water. There is indication of underground drainage through the Onondaga limestone at the extreme west end and thence to the Catskill by way of the stream (Lake brook or Willow brook) that occupies the broadly open valley, excavated on the Marcellus black shale, between the Potic mountain and the Onondaga ridges at the east.

The greater area by far, is drained by the Catskill and its tributaries, which in the southwest corner are small and often intermittent. The two largest tributaries from the north are the Jan de Bakkers kill, heading northwest of Place Corners in the vicinity of Greenville Center and in the swamp just east of Sanfords Corners, and the Potic creek. The former drains little area but the Potic with its tributaries drains an area bounded on the east by Urlton and Medway (West Medway creek), on the west by Newrys, East Greenville and Result (Cob creek). Cob creek supplies the water for the Potic reservoir (Catskill village water supply), two miles south of Urlton near the junction with the Limestreet-Gayhead road. The West Medway creek heads as far north as the Stanton Hill-Newrys road, only two miles south of Coeymans Hollow, and another branch, Grapeville creek, has its source about a mile south of Alcove. The Catskill proper is not only the largest stream in our area but has a long course and a large drainage basin. It has its source far to the northwest close to the Schoharie valley (four miles south-southeast of Middleburg) and, with its tributaries, drains the greater part of the Catskill quadrangle east of the river and north of Saugerties and the Catskill front north and west of Palenville (Kaaterskill quadrangle); about two-thirds of the Durham quadrangle west of our area, including the Catskill front here and on the Gilboa quadrangle, and the southeast corner of the Schoharie quadrangle. Broadly open valley sections have been developed at intervals between Cairo and Oak Hill on the Durham quadrangle, but these alluvial flats are best displayed between the "gorge" north of Cairo and the Leeds gorge. While in general the postglacial valley of the Catskill in this section has been carved out of glacial deposits, rock has been encountered (figure 65) as in the south bank of the "gorge" north of Cairo (at the bridge) and in the south bank east of the Valje Kilje (one and one-quarter miles east of South Cairo). At Leeds the creek crosses the limestone belt forming the Leeds gorge (figure 4) and its continuation on the Catskill quadrangle, Austin's glen. The broadly open flats above Leeds were excavated while this gorge was being carved out of the limestone, and their local base level today is the top of the falls at the old dam at Leeds. The millpond, developed in the Onondaga limestone above the falls (*see* page 232) apparently is a plunge pool developed beneath a falls that in an earlier stage of development of the creek, must have existed at the "narrows" at the west side of the pool and has since been cut through.

VEGETATION

According to Bray ('30) the Coxsackie area, as part of the Hudson valley region, belongs to zone B of the vegetation zones of New York, "the Hudson Valley region and adjacent highlands (Westchester hills, Highlands of Hudson, Lower Catskills), especially dissected channels, *e. g.,* Kaaterskill clove, becoming 'thinned out' by disappearance of many species" (*ref. cit.,* p. 69). This is a much favored zone with a long growing season (160 to 180 days), only surpassed in length of growing season (190 to 200 days) and more favored climate by zone A which includes Staten Island and southern Long Island, especially coastward (p. 67). Zone B, which includes the morainic region of Long Island and Staten Island and extends up the Hudson valley, westward through the Mohawk valley to the Oneida Lake region and northward, "thinning out" toward the St Lawrence valley, is also found in the Delaware, Susquehanna and Allegheny drainage valleys and is characterized by a dominance of oaks, hickories, chestnut, tulip-tree etc. As indicator species Bray (p. 68, 69) lists red cedar (*Juniperus virginiana*), black walnut (*Juglans nigra*), butternut (*Juglans cinerrea*), the hickories: bitternut or swamp hickory (*Hicoria cordiformis*), shag-bark or shell-bark (*H. ovata*), king-nut or big shag-bark (*H. laciniosa*), white-heart hickory or mocker-nut (*H. alba*), small-fruited hickory (*H. microcarpa*), pignut-hickory (*H. glabra*); the oaks: red oak (*Quercus rubra*), swamp or pin oak (*Q. palustris*), scarlet oak (*Q. coccinea*), gray oak (*Q. borealis*), black oak (*Q. velutina*), white oak (*Q. alba*), post oak or iron oak (*Q. stellata*), mossy-cup or burr oak (*Q. macrocarpa*), swamp white oak (*Q. bicolor*), rock chestnut oak (*Q. prinus*), chestnut oak or yellow oak (*Q. Muhlenbergii*); sweet birch (*Betula lenta* [*populifolia*]), chestnut (*Castanea dentata*), hackberry (*Celtis occidentalis*), red mulberry (*Morus rubra*), cucumber tree or mountain magnolia (*Magnolia acuminata*), tulip tree or yellow poplar (*Liriodendron tulipifera*), paw paw (*Asimina triloba*), sassafras (*Sassafras sassafras*), wild hydrangea (*Hydrangea aborescens*), American crab-apple (*Malus* [*Pyrus*] *coronaria*), sycamore (*Platanus occidentalis*), red-bud (*Cercis canadensis*), Kentucky coffee-tree (*Gymnocladus dioica*), honey locust (*Gleditsia triacanthos*), prickly ash (*Zanthoxylum americanum*), tupelo (*Nyssa sylvatica*), flowering dogwood (*Cynoxylon* [*Cornus*] *floridum*), great laurel (*Rhododendron maximum*), mountain laurel (*Kalmia latifolia*).

It is the above variety of trees and bushes that gives charm and interest to the woods of zone B and their brilliance of color in the fall, particularly where maples are also abundant. There is a richness, too, among the small herbaceous species and for this zone Bray cites the following indicator species: white dog-tooth violet (*Erythronium albidum*), lizard's tail (*Saururus cornuus*), lotus (American) or water chinquapin (*Nelumbo lutea*), golden-seal (*Hydrastis canadensis*), wild sensitive-plant (*Chamaecrista* [*Cassia*] *fasculata*), shooting-star (*Dodecathion meadia*), Virginia cowslip or bluebell (*Mertensia virginica*).

On the Coxsackie quadrangle the clay plains of the inner lowland on both sides of the Hudson river furnish level rich farm lands, with patches of forests here and there indicating the once rich tree flora that covered this land. Orchards are characteristic of this area and also of areas in the uplands to the west where the glacial till is heavier. The small islands of flinty rocks rising above the clay plain, more characteristically developed to the north of our area on the Albany quadrangle and to the south of our area on the east side of the river, have a distinct flora of which Ruedemann writes ('30, p. 15):

It is interesting to note in this place that, as Doctor House informs me, this small island of flinty rocks in the clay plains is distinguished by a little flora of its own, the most notable members of which are the fragrant sumac (*Rhus aromatica*), the yellow chestnut oak (*Quercus Muhlenbergii* [*acuminata*]), the big-flowered chickweed (*Cerasteum arvense*), the early scorpion grass (*Myosotis virginica*) and a fern ally, the rock selaginella or festoon pine (*Selaginella rupestris*), and the ferns, *Woodsia ilvensis* and *Woodsia obtusa.*

Juniper, popularly known as red cedar, is a dry soil plant. It is found on ridges of chert or grit in the Normanskill belt and grows in great numbers where pastures on these rocks are returning to woodland. The areas of Oriskany sandstone and Esopus grit, that is, belts of sandstone and gritty shales, may be recognized by the prevailing red cedar trees. The low bushy form of juniper, the erect juniper (*Juniperus communis* var. *depressa*) is common in the dry belt along the escarpment of the limestone belt (the Kalkberg). The Esopus grit area may show stands of hemlock (*Tsuga canadensis*) and white pine (*Pinus strobus*) both of which grow where the soil is poor; but frequently it is marked by open fields and poor vegetation, even the grass being sparse. The aromatic sumac (*Rhus aromatica*) has also been found in abundance on Esopus ridges. The yew (*Taxus canadensis*) and the hemlock seek shady places where the atmospheric temperature is more constant, so both these species occur in the stream gorges, and although found in the Hamilton gorges are particularly characteristic of those in the

Esopus shale, where the sides are often heavily covered with rich, dark-green mats of yew. Hardwood forests are found very generally in the limestone belts and also occur in the Hamilton shale belt. In the broad belt between Urlton and Newrys the numerous glacial hills usually bear hardwood forests, sometimes with pines or hemlocks; but in some places they are entirely covered with stands of pine or hemlock. Sassafras trees are abundant in the hardwood forests and contribute much to the brilliancy of the fall coloring, as do the red maple (*Acer rubrum*) found in swamps and wet soil and the soft or white maple (*A. saccharium*) frequent or common along streams. The pitch pine (*Pinus rigida*) occurs in dry, sandy or rocky soil. Stands of it occur in the Hamilton belt, noticeably along the summit of Potic mountain, where it is associated with scrub oak, (*Quercus ilicifolia*), chestnut oak (*Q. prinus*), sassafras and maples, among other species, and on the summit of Cairo Round Top where the soil is poor and sparse. Here are found also chestnut oak, gray or American white birch (*Betula populifolia*), which is abundant on the slopes that carry the hardwoods, huckleberries and the shad bush or common Juneberry (*Amelanchier canadensis*) which lightens up the woods in the spring. Large stands of blueberries (*Vaccinium*) and huckleberries (*Gaylussacia*) are supported by the thin, acid soil of the Hamilton belt, both in fields and in open woods.

The American bladdernut (*Staphylea trifolia*) is a small tree characteristic of our area. It is abundant in limestone regions and considerable stands are found in places under the escarpment of the Kalkberg. The aromatic or prickly ash (*Zanthoxylum americanum*) is abundant on all limestones, including the Schoharie formation, but is particularly characteristic of the Onondaga and Becraft limestones. Some of the stands are so thick that it is almost impossible to pass through the area. There are some lime-loving plants that deserve mention. One is the mossy stonecrop or wallpepper (*Sedum acre*). This plant grows in large patches and with its numerous yellow flowers is very striking. It is very abundant in the Onondaga and Schoharie areas between Aquetuck and Coeymans Hollow and to the north and south. The fringed gentian has been found growing on the Schoharie and Onondaga limestones in moist places. Among the lime-loving ferns is notably the walking fern (*Camptosorus rhizophyllus*), which grows on shaded rocks and cliffs, usually limestone, often covering fallen limestone blocks with a rich green blanket. This fern is rather abundant on exposed limestone formations from the Catskill region northward. Other ferns growing on rocks and cliffs and preferring limestone are the purple-stemmed cliff brake

(*Pellaea atropurpurea*), the maidenhair spleenwort (*Asplenium trichomanes*) and the wall-rue spleenwort (*A. Ruta-muraria*). The hart's tongue (*Phyllitis scolopendrium*) which occurs only in Onondaga and Madison counties, on shaded limestone cliffs and in depressions, has been introduced into Greens lake area by a Miss Bogardus of Catskill.

Another fern, the rusty woodsia (*W. ilvensis*) is found on shale ledges. This fern is characteristic on exposed rocks and ledges southward in the Hudson valley to the Catskills. Another species, the blunt-lobed woodsia (*W. obtusa*) occurs on moist rocky ledges, rocks, banks and sometimes in open woods and is found in the Hudson valley as far south as Westchester county (House, '24). Another plant frequent on dry, rocky exposures in the Hudson valley, or sometimes on sandy soil, is the rock selaginella or festoon-pine (*Selaginella rupestris*). Characteristic of rocky gorges in shale and sandstone is the pale touch-me-not or jewel weed (*Impatiens pallida*), of which extensive stands were found in the Hamilton shale belt.

In the limestone region the New Scotland shaly limestone belt is usually the area under cultivation, and rich farms are found on the broad Onondaga flats, as those between Deans Mills, Aquetuck and Coeymans Hollow. The broader stream valleys and the slopes heavily covered with till are under cultivation regardless of formation.

FAUNA

The writer is indebted to Walter J. Schoonmaker, Assistant State Zoologist in the State Museum, for lists of the animals to be looked for in the area covered by the Coxsackie quadrangle. For the mammals he lists the white-tailed deer, red fox, gray fox, cotton-tail rabbit, snowshoe rabbit, woodchuck, raccoon, red squirrel, gray squirrel, flying squirrel, chipmunk, muskrat, mink, New York weasel, field mouse, white-footed mouse, Brewer's mole, short-tailed shrew, big brown bat, little brown bat. The deer are so abundant in this region that Greene county has been opened to hunters in the season; gray squirrels are abundant and chipmunks numerous. The writer saw two red foxes in one day southeast of Coeymans Hollow in woods along ravines.

Among the land birds are the robin, bluebird, song sparrow, tree sparrow, chipping sparrow, meadowlark, phoebe, indigo bunting, house wren, red-winged blackbird, purple grackle, bronzed grackle, flicker and game birds such as the ring-necked pheasant and the ruffed grouse. The writer has found the ruffed grouse or partridge abundant in the woods of this area, but particularly so east and south of the Greens lake region and north and south of Black lake. Among the hawks are to be seen the duck hawk and the red-tailed and red-shouldered hawks. A great variety of river birds visit the Hudson Valley region and ducks are seen by the thousands on the river during their fall migration. The wild black ducks live and breed in great numbers along the river where the river swamps supply them with plenty of food. Schoonmaker has listed the following: black duck, mallard duck, green-winged teal, blue-winged teal, pintail duck, horned grebe, Holboell grebe, pied-billed grebe, American merganser, red-breasted merganser, hooded merganser, great blue heron, American bittern, coot, Florida gallinule, greater yellowlegs, lesser yellowlegs, spotted sandpiper, belted kingfisher, American egret and, rarely, the Canada goose. The American egret, one of the most striking members of the heron family, has recently been described for the Albany region by Doctor Stoner, State Zoologist with the New York State Museum ('38). This bird, which usually breeds from Florida to North Carolina in eastern United States, has in recent years extended its breeding range into Maryland and southwestern New Jersey. The breeding season in the more northern range lasts through mid-June, and later both adult and immature birds wander far north of their breeding grounds. In the Albany region, according to Stoner, they are most likely to be seen in the early autumn and he has records of their visits to the vicinity of the Stockport railroad station on the Coxsackie quadrangle, from August to the middle of October 1937, with a maximum of 25 birds recorded on one day during a two-hour period. Doctor Ruedemann and the writer, while mapping in this area in a previous year, counted at least 20 birds at one time in a group in the river swamp. Seven of these birds were observed, in passing, by the writer in the vicinity of the Basic reservoir about one mile west of the northwest corner of our area.

The reptiles are represented by five snakes: the three commonly known forms, the garter, milk and water snakes, and the copperhead and black snakes. Black snakes are harmless and kill the copperheads and for that reason, if for no other, should be allowed to live. Copperheads have been reported nearly as far north as Ravena along stream valleys. A number of times the writer's attention was called by residents to their presence in stone walls or in grass along roads bordering swamps but in all the years of mapping none were encountered. August is the only month in which they are at all active and at no time are they vicious. Among the amphibians are nine salamanders (red, purple, two-lined, red-backed, dusky, slimy, spotted, Jefferson and the mud puppy), two toads (American and Fowler's) and seven frogs (leopard, pickerel, green, wood, bullfrog, spring peeper and tree toad).

Among the fish found in the streams, lakes and the river in this region are listed the brown trout, brook trout, common sucker, dace, sunfish, bullhead, large-mouthed bass, yellow perch, white perch, pickerel, wall-eyed pike, carp, shad (river), herring (river, spawn in side streams).

Special mention should be made of two forms that have been found in the Hudson river, the sturgeon and the dolphin. The sharp-nosed pelican or sea-sturgeon was so abundant in the past (but within the memory of older inhabitants of the Hudson valley) that it was sold and known as "Albany beef." The pollution of the river waters has made the occurrence of this fish in the river very rare. A specimen of this species was caught in the Highlands and the short-nosed sturgeon in the vicinity of Rhinecliff in May 1934. Dolphins, which are marine mammals belonging in the same group (cetaceans) as the whale, seem to be starting an upstream movement (Stoner '38*a*). In the fall of 1936, within a period of three weeks two fresh carcasses of the common dolphin were found on the banks of the Hudson river, one at Van Wies point about four miles south of Albany, the other at Blue point (Ulster county), one and one-half miles south of Highland (75 miles north of New York City). At the former locality, "no school or other indication of the presence of dolphins in the river" has been observed, but a school of dolphins was reported in the Highland section of the Hudson on the day previous to the discovery of the dead specimen.

Another item of interest might be mentioned here in connection with the fauna of this area. In 1706 mastodon remains were found in the town of Coxsackie (Hartnagel and Bishop, '22, p. 26). This was the second mastodon found in America; the first specimen found by white settlers had been discovered at Claverack (Columbia county) the year before, in 1705. A second mastodon occurrence for our area is reported by Howell and Tenney ('86, p. 74). The remains were found in Coeymans Hollow "on the farm of Mr Shear a few years since." New York State has proved particularly rich in remains of both mastodons (*Mastodon* [*Mammut*] *americanus*) and mammoths (*Elephas primigenius*), which roamed the region during Pleistocene time after the retreat of the ice sheet.

SETTLEMENT

No attempt will be made here to give a history of the settlement of this area. Much has been written and is available in libraries. Those interested might consult Howell and Tenney: History of the County of Albany; Parker: Landmarks of Albany County; Beers: History of Greene County; Fiske: Dutch and Quaker Colonies in America, and the recent book by Carl Carmer: The Hudson, which contains an extensive bibliography of books, pamphlets, manuscripts, periodicals and newspapers. Two publications deserve special notice. One, Ye Olden Time, written by Robert Henry Van Bergen for the Coxsackie News of 1889, was reprinted in 1935 by the Coxsackie Union-News, under the editorship of F. A. Hallenbeck, with notations and additions by the Rev. Delber W. Clark, then rector of Christ Church, Coxsackie. This is a series of articles about people, places and happenings of local interest. A more ambitious piece of work was undertaken by the Rev. Mr Clark, the story of the life and work of Justus Falkner which was printed under the title of Justus the Blessed, in the Coxsackie News, in weekly instalments 1936-38. This is an account of the settlement of the Hudson valley and the community in the Upper Hudson in which Justus Falkner took up his ministry. Consideration is also given to the conditions in Europe which impelled the settlers to seek a new country. The following short discussion has been drawn from the above sources and information from the Rev. Mr Clark.

After the discovery of the Hudson by Henry Hudson in 1609, this "Great River of the Mountains" (so termed by Hudson) was visited by a few Dutch vessels that returned to Holland. The New Netherlands Company, which was organized in 1614, had a monopoly of the river trade and sent out successful fur expeditions. This company was succeeded by the West India Company, a monopolistic stock company founded in 1621. They, too, found fur cargoes more profitable and agriculture did not thrive along the river. It was difficult to get worthy farmers and craftsmen to leave their prosperous, safe Holland. French was the natural language of the first white settlers to the high-walled valley of the Hudson claimed for the Dutch by Henry Hudson. In the spring of 1624 thirty families of Walloons, Protestant refugee farmers from South Netherlands, landed at the mouth of the river. Some went to the Delaware river, some to the Connecticut, and eight men stayed to begin the permanent settlement of Manhattan Island, Fort Amsterdam; but 18 families sailed up the river to the present location of Albany, calling their settlement Fort Orange.

In 1629 the Patroon system was established. Great river estates were granted to members of the company, each of which could extend 16 miles along one shore of the river or eight miles along both shores, with an indefinite extent inland. The title must be purchased from the Indians and then was held as a "perpetual fief of inheritance." One of the original six (two on the Delaware, two on the Connecticut, two on the Hudson), and the only one surviving after six years, was that of Killian Van Rensselaer of Amsterdam who claimed all the land on both sides of the river from Barren island (at Coeymans), 11 miles below Albany to the mouth of the Mohawk nine miles above, with an indefinite limit inland. A feudal sort of tenant system was established, which finally, after the death in 1839 of Stephen Van Rensselaer, the last holder of the Manor of Rensselaerwyck under the British crown, ended in the famous antirent war, echoes of which were heard down through the Civil War and even into the middle eighties. Lured by the prospect of prosperity there came to this colony and to the settlement of Fort Orange a rough, tough and quarrelsome, mixed crew of Irishmen, Swedes, Danes, Germans and Englishmen. The colony on Manhattan showed an equally mixed society. Eighteen different languages were represented by 1643. Law and order came with Pieter Stuyvesant of New Amsterdam. In 1651 he laid out the boundaries claimed for the West India Company and established Beverwyck on land beneath the fort at Fort Orange. In 1664 the British took over the Dutch colony of New Netherlands for James, Duke of York, and abolished the duties and taxes levied by the greedy West India Company. New Amsterdam became New York, Rondout was Kingston, Beverwyck was Albany and the "River of the Prince Mauritius" named for Maurice of Orange became the Hudson. The rights of the Van Rensselaers to their patroonship was confirmed. The Van Rensselaers never successfully established claim to any part of Greene county.

In 1674 Robert Livingston, son of a poor Presbyterian minister and exiled from Scotland to Holland, came to the upper Hudson. He acquired an estate extending for a distance of 12 miles along the east bank of the Hudson, south of Rensselaerwyck. This was one of several extravagant grants made by the British government and soon regretted. The feudal system of permanent leases, such as used by the Van Rensselaers, was adopted at once in all such holdings. War, rising taxes and failure of crops had reduced the inhabitants of the Rhineland to a desperate condition. Some of these Palatinates, augmented by other German recruits, lured by the promises held forth of prosperity in this faraway land sailed for New York in the fall of 1708 and in the following spring, on lands granted by Governor Lovelace, settled on the west bank of the river at a place they called Newburgh. In the early summer of 1710 the first of the "Wonder Fleet" of 10 ships that started out with about 3000 Germans sailed into New York harbor, and in the fall they were settled in the mid-Hudson area on both sides of the river, on the east side on the less desirable of his acres sold by Livingston. East Camp's three towns now comprise the village of Germantown; the inclusive name West Camp for the west bank's four towns is retained today (Catskill quadrangle). Living conditions were very hard; Livingston cheated the settlers and after two years of waiting for promises to materialize the Germans were thrown upon their own resources. Some stayed on the Livingston manor lands and accumulated heavy debts that finally ended in the usual rebellion; about 500 marched northwest into the fertile Schoharie valley, spreading later on into the Mohawk valley; others spread up and down the river, settling in places such as Hackensack and Rhinebeck; some went back to New York. Like the Palatinates the English too were part of the trend of immigration to the new land in the first half of the eighteenth century and they settled in great numbers along the Hudson. The later assumption that all life of the valley not English was Dutch is not true as German and Dutch ways were intermingled along the Hudson.

By the late 1760's not only the tenants and freeholders but the manor lords themselves had begun to feel the strained relationship between the British rulers and the Hudson River people. This feeling was aggravated and increased and a few lean years added to the discontent. When the news of Lexington was brought to Albany on April 20, 1775, it took the English-haters—Dutch, Swedes, French Huguenots and Palatine Germans—just one month to gather at Coxsackie and sign the *Coxsackie Declaration of Independence,* more than a year before the Philadelphia Declaration of Independence. There were 255 signers.

After the Revolution, in the latter part of the eighteenth century, refugees from the French Revolution came to the Hudson valley, many of distinguished birth, and the river families found them congenial and desirable. "As the eighteenth century ended," writes Carmer, "the Hudson ran through a smiling, free land of peace to a flourishing free city. To the west lay lands of incalculable wealth, awaiting development. Now a man might take his wages, buy a farm and in a land where the only ruler was the people become as independent as any foreign king" ('39, p. 183).

In his preface to Ye Olden Time the Rev. Delber W. Clark divides the history of Coxsackie into seven ages, and these may be applied in general to the entire region. According to his view, "the history of Coxsackie is best divided by thinking of the history of transportation," and he elaborates as follows:

The prehistoric age of Coxsackie was that of the Indian Foot path which followed the cliffs from Leeds to Coeymans.

The second age came, first with saddle horses and later with coaches. This is the Colonial period, its great memorial is the King's road. The center of our community was then where the road crossed the creek in West Coxsackie.

The third age may be called the river and road age. It began about 1800. At this time the river landings and the turnpikes with their toll gates began to be important. The development of this period was toward the export of agricultural products which were fairly plentiful. The sloops on the river handled the freight and the stage coaches on the turnpikes handled the mail and passengers. During this period the numerous river villages developed. New Baltimore, the three landings of Coxsackie, Athens and Esperanza at old Loonenberg, and Catskill village—which finally took over the name away from Leeds—all grew up in this period.

The fourth age came with the steamboat. The survival of the fittest reduced the river villages of Greene county to three and centered the trade near the steamboat dock. This period in Coxsackie was marked by the development of the brick industry and the growing size of the landing village. From this time, date the Second Reformed and Methodist churches and the defunct Baptist church.

The fifth age was that of the "White Elephant" railroad from Athens to Schenectady. It was during this period that the brick business passed its height and the ice business began to develop. During this time came the Civil War. It was then that the present Episcopal church and the Roman Catholic church began their regular life.

The sixth age was that of the West Shore railroad. It was the height of the ice business. The high school was built and the industries in the metal business began to assume a large importance.

The seventh period of the life of Coxsackie came with the development of motor transport. The hard surfaced road and the automobile changed the whole course of village life. Technology destroyed the ice business. The local store was brought into competition with the city. The new 9-W which takes the traffic around the town is the distinctive and probably the most permanent structure of this age.

The first known settlement in Greene county was at Catskill (1649), probably because the equally desirable great flats of Athens and Coxsackie were not visible from the river. One of these colonists was Hans Voos (John Fox), after whom the Hans Vosen kill was named. About 40 years before Justus Falkner, the German Pietist, came to the upper Hudson (1703) the white settlers had purchased from the Indians in two instalments, within a period of three years, all the land from the mouth of the Coxsackie creek to the Athens shipyards and from the river to the limestone cliffs to the west. Coxsackie was purchased by Pieter Bronck in 1662, the same year that his stepfather Arent Van Curler or Van Corlear bought Schenectady. Bronk island was Martin Gerritsen's island in the boundaries described in the patent. The price was 150 guilders in beavers, to be paid in goods, about $60 in modern money. The land called Caniskeek (possibly "great flats") by the Indians, including the area from south of Lampman's hill to Athens and from the river to the Catskill Indian path, was purchased in 1665. It was called Jan Cloet's (Clute's) land for 20 years, but when a John Van Loon became a principal shareholder it was changed to Loonenburg. The land to the north of the mouth of Coxsackie creek was considered less desirable. Barent Pieterse Coeymans, often called Barent de Molinaer (the Miller) after whom Barren island (Barent's island) was named, established himself at the present site of Coeymans village and in 1673 was granted by Governor Lovelace title to six miles north and south of Coeymans and twelve miles westward from the river (the Coeymans old patent).

In these settlements life was primitive and travel was by the Indian footpaths. There was no real road from Albany to Kingston in the period of 1663-73. An Indian footpath followed the line of cliffs up from Saugerties to the Mohawk. Settlers at Catskill used the Indian footpath for travel by foot or by horse; grain was hauled to Albany by boat when the river was open, by sledge over the ice in winter. The course of the Catskill Indian path is described by the Rev. Delber W. Clark (March 19, '37):

The Catskill Indian Path crossed the Catskill at a point near Jefferson Heights and followed up the limestone cliffs to a point near the Chapel cemetery east of Limestreet. It followed the same line of cliffs down the valley of the Coxsackie creek to Climax, thence it struck across the flat to the mouth of the Roberts Hill road and followed under the High Rocks to the Hanne Kraahe kill very near the old line of the 9-W highway. Except for the bit between Climax and the Roberts Hill road, there is either a trail or highway near its course through the whole town of Coxsackie.

The "old Dutch road" or trail of the settlers in the 1680's "was to become the line of a strategic highway a decade later and to supplant the Catskill footpath as a means of travel" (*ref. cit.,* June 25). This "old Kings road," whose ancient course is practically followed today by the new 9-W road, was almost forgotten after the Revolution when the turnpikes and toll gates directed traffic along new routes, but it brought great changes into the life of the settlers.

Lateral and crossroads were developed. Most of the old roads follow the ridges of Ordovician rock (Normanskill grit). One such road was the road from Leeds to Kaaterskill of which trail the Greens Lake road, which joins the old Indian footpath at Chapel cemetery, is a northern extension. Near the cemetery a short cut, now Mud lane, meets the Kings road where was the site of the original Black Horse Inn (*ref. cit.*). Travel was by stage when the old King's road or Post road was in its prime and taverns were located every two or three miles. The Black Horse Inn derived its name from the swinging wooden sign, shaped like a horse and painted black (Van Bergen, '35, p. 80). Jerry's Hotel in Climax was also one of these inns and the site of another tavern is the Brae Burn cottage opposite Jerry's (Clark in *ref. cit.*).

There are a few other matters of interest that might be brought to the reader's attention here, among them the history of the city of Hudson to which the name Claverack Landing was changed by salt-water folk, Nantucket Quakers, who settled there in the spring of 1783. In two years the incorporated city had a fleet of 25 sailing boats, more than New York had, and had developed a thriving whaling business. By 1790 it was an official seaport with custom officers and government seals. Whaling died out as a Hudson river industry after the great panic of 1837 and the whaling captains became traders. In 1797 Hudson lost by just one vote the honor of being the capital city of the State. Livingston, viewing the success of Hudson, planned a city, Esperanza, on the opposite bank of the river which was to rival Hudson in sea commerce. Athens sprang up alongside and soon eclipsed it. This village was built up by Yankee real estate promoters early in the nineteenth century on the site of the older Dutch community of Loonenberg. At this time when the use of classical place names was sweeping the country the village of Coxsackie almost became Carthage. Clark (March 19, '37) gives the origin of the name Coxsackie as from the Indian *Mak-kacks-hacking* or place of many owls. At the time of its purchase the recording clerk spelled it *Koxhackung* and Justus Falkner usually *Kockshagki*. New Baltimore was settled by Friends with the orthodox meeting place at Stanton hill (Clark). The name Priming hook, one and a half miles northeast of Hudson, is a corruption of Preuwen hoek (Plum point or Plum corner). Here in 1720, Justus Falkner established his last home from which he still carried out his work and this place was soon dubbed Gospel hook or Gospel point. Stottville, about one and a half miles north-northeast, was named after the Staats. Major Abraham Staats built at the mouth of Stockport creek in the

1650's a house which still stands and is one of the landmarks of Columbia county.

Among miscellaneous items of interest is the Forrestville commonwealth, a Robert Owen experiment in communism. This community was located one and one-quarter miles northwest of Urlton (Earlton). The commonwealth lasted only a year, the members apparently unable to live up to its program of simple living and working together for the good of each other. The portion of the Athens-Schenectady ("White Elephant") railroad between Athens and Coxsackie, built in the late 1860's, located its right of way through the saddle between the Klinkenberg and Lampman hill, near the first crossroads north of School No. 10. Between Leeds and Cairo on the south side of the Catskill in many places may be found traces of the proposed (1831) Catskill-Canajoharie railroad which stopped at Cooksburg in 1839 and extinguished Rensselaerville's (Berne quadrangle; Helderbergs) ambitions to become a metropolis of the forest. Attention might also be called to the old Hallenbeck house on the river at Four Mile point, about one-half mile north of the lighthouse and Echo cliff (Klinkenberg). The house, also called the Klinkenberg, was Tory headquarters during the Revolution. Klinkenberg landing was probably used by numbers of settlers on the flats, variously referred to as the Coxsackie flats, the Klinkenberg flats and the Loonenberg flats. The flats constituting the triangle of land between Murderer's creek and the Hudson, north of Athens, were known as the Krost Verlooren which, Clark points out (March 16, '37), literally would be "Lost Crust," probably a corruption of "Lost Coast." One branch of the Murderer's kill rises at a marshy place near the West Athens railroad station, known as the Beer Gatt, which "means bear hole and refers to Bear Wallow, where the bears in the early days went to refresh themselves from the summer heat with a cool mud bath" (*ref. cit.*).

The old Bronk house, an important landmark of Greene county located near the junction of the Bronks Lake road and the new 9-W (opposite the New York State Vocational Institution) is now the headquarters of the Greene County Historical Society. In Bronk's mill at the Steenekill, now in the watershed of the Vocational Institution reservoir, flour was ground for the continental army at Saratoga (Clark, letter). Another old grist mill of slightly later date (erected in 1790) may be seen at the bridge in Alcove (formerly Stephensville). A landmark of the old days which has disappeared within the memory of those now of middle age or older is the old Aquetuck fort (figure 8) which stood on the Aquetuck flats on the

Coeymans patent. It was built in 1759 of the Onondaga limestone on which it stood and was demolished about 1897. The fort was located on the Shear farm (now in the possession of Mrs Susan Shear) opposite the house on the south side of the Aquetuck-Coeymans Hollow road near its junction with the road to Stanton Hill (east fork). Aquetuck, spelled Ache-que-tuck (after the Oneida Indians of that name) in the old records, was locally known as Peacock's Corners in the past; the very fertile farm land between here and the eastern extremity of Coeymans hollow was described in the old deeds by the Indian name Hagh-a-tuck. Landmarks of a once flourishing industry are the survivors of the old lime kilns in which limestone was burned for both agricultural and building purposes. One of these kilns may be seen on the west side of the road about one-quarter of a mile south of Limestreet; a second is located one mile east-southeast of Roberts Hill, on the west side of the road, south of the junction with the road to Medway. A conspicuous landmark, still standing, is the old four-arch bridge that spans the Catskill on the Catskill-Cairo road at Leeds (figure 9). This old dry rubble bridge, built in 1760, has stood for nearly two centuries. In the spring of 1936 a great flood rendered the bridge unsafe. It was planned to replace the old bridge with a modern structure; but Colonel Frederick Stuart Greene, then State Superintendent of Public Works, took the stand that this would be "an outrage to the history of American engineering." The bridge was taken apart, stone by stone, foundations strengthened, cemented and put together as it was originally.

DESCRIPTIVE GEOLOGY

There are 22 recognizable formations (or members) on the Coxsackie quadrangle extending from the Lower Cambrian into the Middle Devonian. They are as follows in descending order:

Devonian system

22 Hamilton: Kiskatom beds
21 Hamilton: Ashokan shales and flags
20 Hamilton: Mount Marion beds
19 Hamilton: Bakoven shale (Marcellus "black shale")
18 Onondaga limestone
17 Schoharie grit and limestone
16 Esopus shale
15 Oriskany sandstone (Glenerie limestone in south)
14 Port Ewen beds
13 Alsen limestone
12 Becraft limestone
11 New Scotland beds: Catskill shaly limestone
10 New Scotland beds: Kalkberg limestone
9 Coeymans limestone

Figure 8 Old Aquetuck fort which formerly stood on Aquetuck flats on the Coeymans Patent (Shear farm). Built about 1759; demolished about 1897. Photograph loaned by Mrs Susan Shear, Coeymans Hollow.

Figure 9 The old four-arch bridge over the Catskill creek at Leeds, looking north-northwest. Two eastern arches built in 1760; the two western in 1792. (Photograph by E. J. Stein, April 27, 1936)

Silurian system
- 8 Manlius limestone
- 7 Rondout limestone

Ordovician system
- 6 Rysedorph conglomerate
- 5 Normanskill formation

Canadian system
- 4 Deepkill shale

Cambrian system
- 3 Schodack shale and limestone
- 2 Bomoseen grit
- 1 Nassau beds

These 22 formations (or members) represent two series, one belonging to the eastern and the other to the western trough of the Capital District. The geological structure of the Capital District has been fully discussed by Cushing and Ruedemann ('14) and later by Ruedemann ('30). Ruedemann's discussion, in brief, is as follows ('30, p. 130, 132): The first period of folding occurred in Precambrian time producing several long barriers which extended in north-northeast to south-southwest direction across the district forming two or more troughs. Two of the troughs have been positively recognized and designated as the eastern and western troughs, each characterized by their entirely different geologic series of formations. The formations of the two troughs are now in close contact, due principally to the fact that folding and faulting along numerous fault planes has carried the rocks of the eastern trough westward. The eastern trough has been termed the Levis trough (Ulrich and Schuchert, '02) from Port Levis in Canada, and in this trough occur the Lower Cambrian beds and the long series of graptolite shales, the Schaghticoke, Deepkill and Normanskill shales of Canadian and Ordovician age. The western or Chazy trough, to the southern extension of which has been given the name Lower Mohawk trough (Ruedemann, '14), contains the "normal series" of beds, the Devonian ones listed above and below them, in descending order, the Manlius, Rondout and Cobleskill limestones of Upper Silurian age; the Brayman shale of the Ordovician-Silurian interval (Upper Silurian: Salina of authors), present only locally; the Indian Ladder beds of Upper Ordovician age, present only locally; the Schenectady beds, Canajoharie shale, Glens Falls limestone and Amsterdam limestone of Middle Ordovician age, and the Little Falls dolomite, Theresa formation and Potsdam sandstone of Upper Cambrian age (Lower Ozarkian of authors). It is thus seen that no formation up to the Silurian is common to the two series or troughs, which, according to the records left in sediments and fossils, persisted through Ordovician time. In the Cambrian, Canadian and Ordovician periods this was due to oscillating movements which alternately drained and submerged the two troughs, the one being drained while the other was submerged; in the Silurian and Devonian periods this was brought about partly through an hiatus of nondeposition and partly through extensive erosion of the formations outside of the Helderbergs and their extension southward. The formations of the two troughs are shown in the table on page 47 (adapted from Ruedemann, '30, p. 27, in Goldring, '35, p. 56).

On the Coxsackie quadrangle the formations of the western trough begin with the Rondout waterlime.

Formations of the Chazy and Levis troughs

SYSTEMS	WESTERN TROUGH (CHAZY)	EASTERN TROUGH (LEVIS)
Upper Devonian........	....	Rensselaer grit (?)
Middle Devonian.......	Hamilton beds Onondaga limestone Schoharie grit and limestone	
Lower Devonian........	Esopus shale Oriskany sandstone (or Glenerie limestone) Port Ewen beds Alsen limestone Becraft limestone New Scotland beds Coeymans limestone	
Upper Silurian.........	Manlius limestone Rondout waterlime Cobleskill limestone	
Ordovician-Silurian interval.............. Upper Ordovician.......	Brayman shale Indian Ladder beds	
Middle Ordovician......	Schenectady beds Canajoharie shale........ Glens Falls limestone.... Amsterdam limestone....	Snake Hill shale Tackawasick limestone and shale Rysedorph conglomerate Magog shale
Lower Ordovician.......	....	Normanskill shale (Bald Mountain limestone)
Canadian.............	....	Deepkill shale Schaghticoke shale
Upper Cambrian........ (Lower Ozarkian of authors)	Little Falls dolomite Theresa formation Potsdam sandstone	
Lower Cambrian.......	....	Schodack shale and limestone Troy shales and limestones Diamond Rock quartzite Bomoseen grit Nassau beds
Precambrian..........	Precambrian rocks.......	Precambrian rocks

CAMBRIAN SYSTEM

The name Cambrian was first proposed (1835) by the Rev. Adam Sedgwick, professor of geology in Cambridge University, England, for the oldest stratified rocks of North Wales. The name was derived from the Roman name for the region, the province of Cambria. The *Cambrian* is the oldest period of the Paleozoic era (Gr. *palaios,* ancient; *zoe,* life), and the rocks of this system are generally separated from the older rocks by the most marked unconformity, representing a very long interval of erosion. Except for the few fossils found in the Precambrian, this is the oldest fossiliferous system yet known. At the opening of the Cambrian all known continents were dry land and subject to erosion and it was during this period that the first great transgression of the seas over the continent occurred. The deposits of residual sands, the product of long-continued erosion, were reworked by the transgressing seas and formed the first deposits, which were generally a pure quartz sand. In eastern North America the Lower Cambrian is restricted to the Appalachian geosyncline, or sinking area, and these rocks have been called the *Taconian series* because they were first studied and recognized as a system in the Taconic mountains of eastern New York by Professor Ebenezer Emmons of the New York State Survey. This series was previously termed Georgian from Georgia, Vermont, where Lower Cambrian beds occur. The Lower Cambrian deposits stretch from eastern Canada to Alabama, but are confined to the eastern part of the geosyncline. These sediments of the Appalachian trough show great thicknesses in places. Through Pennsylvania, Maryland and Virginia there is a total thickness of approximately 10,000 feet, about half sandstones and shales and half limestones. In Vermont and northeastern New York there are about 3000 feet, more than 1500 feet consisting mainly of slates and quartzites and more than 1200 feet of marble and dolomite. During the Middle Cambrian the eastern or Appalachian geosyncline was largely drained of Atlantic waters and here Upper Cambrian beds, where present, rest as a rule upon Lower Cambrian (southern Appalachian region). Middle Cambrian deposits with Atlantic fauna occur in Newfoundland, Nova Scotia, New Brunswick, Cape Breton, northern Vermont and eastern Massachusetts. Once or twice during this epoch marine waters teeming with life common to the western (Cordilleran) geosyncline spread eastward into the Appalachian trough and passed south from east Canada to Alabama in more western troughs, now doubtless buried under overthrusted deposits in most of the St Lawrence valley and all of eastern New York but exposed from Pennsylvania southward. Middle Cambrian beds in the east are particularly well developed in the Acadian region of eastern Canada and hence this series of beds is known as the *Acadian series.* In eastern America the absence of transition faunas between Middle and Upper Cambrian indicates a break in deposition. The Upper Cambrian is known as the *Croixian epoch* from its occurrence in the St Croix River region of Wisconsin. These beds and their equivalents were considered to be of lower Upper Cambrian age and followed by a higher series of formations the *Ozarkian series* (from the Ozark uplift in southern Missouri), considered by some as uppermost Cambrian, by others as belonging to another system, the *Ozarkian.* Evidence derived from later studies in field and laboratory indicates that formations referred to the Ozarkian are Upper Cambrian and of *Croixian age* and this view has wide acceptance. These Upper Cambrian ("Ozarkian") deposits have been found outcropping from New York and Vermont south through New Jersey and Pennsylvania to Alabama, in the Mississippi basin (Missouri, Iowa, Wisconsin, Minnesota, Oklahoma), central and western Texas, Colorado, Idaho, Nevada, and also British Columbia. It is believed with good reason that they are represented in western Quebec and possibly northern Newfoundland. This Upper Cambrian (early Ozarkian) sea invaded the central part of the continent from the south, and at about the same time spread into the Appalachian trough extending northward into New York and Vermont and thence through the St Lawrence area of Canada. Later (late "Ozarkian" time) the seas were greatest in the Mississippi valley and in the southern Appalachian trough where deposits, chiefly dolomites and relatively pure limestones, aggregate about 8000 feet.

In New York the *Little Falls, Hoyt, Theresa* and *Potsdam,* in outcrops bordering the Adirondacks, represent the Upper Cambrian (Lower Ozarkian). The Potsdam and Hoyt horizons are represented in the *Wappinger Terrane,* a large development of dolomitic limestones consisting of several members, separated by gaps in deposition. These limestones occur in Dutchess, Orange and Ulster counties and have also been traced into Columbia county. The beds lie above the *Poughquag quartzite* (Lower Cambrian) and represent Lower Cambrian to Trenton time. The Middle Cambrian has but little representation and that is the *Stissing limestone* which occurs in Stissing mountain in northern Dutchess county. It has been suggested (Ulrich) that the somewhat doubtful Middle Cambrian sediments occurring in Stissing mountain originally belonged farther to the east and were moved westward to their present position by a thrust fault. The Lower Cambrian is represented by the basal *Poughquag quartzite* (quartzite and conglomerate) occurring in Dutchess and Orange counties and the *Taconian series* (Georgia beds) in the counties bordering southern Vermont and Massachusetts in the Capital District.

Excepting a very narrow belt along the river, Walcott (1888, pl. 3) referred to the Lower Cambrian the entire belt of rocks north of Hudson and as far east as the limestones, extending the belt south to the northern boundary of Columbia county. On the latest State Geological Map (Merrill 1901) the Lower Cambrian rocks (Georgia beds) are shown ending abruptly at Stockport (Coxsackie quadrangle) with a strip of Cambrian extending southward from Elizaville on the Catskill quadrangle. The area from north of Hudson south to the Highlands and east to the limestone belt of the Harlem valley is marked as "Hudson River" and "Hudson River metamorphosed," except for the narrow belt of Wappinger limestone in Dutchess and Orange counties. The same distribution is shown on the map (Plate I) accompanying Guidebook 1 of the XVI International Geological Congress (Longwell, '33), with the "Hudson River" marked as Ordovician and the strip south of Elizaville as Lower Cambrian. Mapping on the Coxsackie and Catskill (R. Ruedemann) quadrangles has shown a much wider distribution in the Capital District for the Lower Cambrian rocks (Nassau beds and Schodack formation) than was expected. These formations, unaltered, extend south of Stockport to Hudson and then form a belt of unaltered and metamorphosed rocks along the eastern border of the Catskill quadrangle and eastward, with scattered patches within the belt of Ordovician shales to the west. This Lower Cambrian belt continues southward. From observations made in the field in the fall of 1937, on an excursion in connection with the New England Geological Association, the writer is inclined to believe that this belt continues south as far as the Highlands and eastward to the limestones of the Dover valley. The rocks observed on this occasion in the vicinity of Poughkeepsie and eastward, while much altered, appeared still to show the characteristics of the unaltered Nassau beds and Schodack formation of the Capital District. More extensive field study of this problem is needed.

Ruedemann ('14, p. 69, 70; '30, p. 25) proposed for the recognizable larger units of the Lower Cambrian of the Capital District the following formation names, in descending order:

5 Schodack shale and limestone
4 Troy shales and limestones
3 Diamond Rock quartzite
2 Bomoseen grit
1 Nassau beds

As a result of his study of the Lower Cambrian series as exposed in Rensselaer county and part of Columbia county, Dale distinguished beds A to J ('04, p. 29) and it was to these beds that the above names were given. In the following table the formation names are given at the left of the serial letters of Dale's table; as adapted by Ruedemann ('14, p. 68).

The Lower Cambric series as exposed in Rensselaer county and part of Columbia county, N. Y.

FORMATION	SERIAL LETTER	DESCRIPTION OF STRATA	FAUNA	ESTIMATED THICKNESS IN FEET
Schodack shale and limestone	J	Greenish shale	....	50
	I	Thin-bedded limestone, or dolomitic limestone, in varying alternations with black or greenish shale and calcareous quartz sandstone. Some of the limestone beds brecciated within the sandstone or shale and forming brecciation pebbles, in places, however, beach pebbles	*Olenellus* fauna	20[a]–200
Troy shale	H	Greenish, reddish, purplish shale, in places with small beds of more or less calcareous quartzite At Troy, in upper part a 2½ foot bed of calcareous sandstone	*Oldhamia*, annelid trails *Hyolithes* and *Hyolithellus*	25?–100+
Diamond Rock quartzite	G	Granular quartzite, in places a calcareous sandstone	....	10–40
Bomoseen grit	F	Olive grit, metamorphic, usually weathering reddish, absent at south	Traces of?	18–50
Nassau beds	E	Greenish, or reddish and greenish, shale with small quartzitic or grit beds	Casts of impressions, *Oldhamia*[b]	65–535
	D	Massive greenish quartzite, in places very coarse	....	10– 50
	C	Reddish and greenish shale with small beds of quartzite or grit (rarely up to 5 feet thick)	Casts of impressions, *Oldhamia*	30– 80
	B	Massive greenish quartzite, in places very coarse	....	8– 40
	A	Reddish and greenish shale with small beds of quartzite or grit, from 1 to 12 and, rarely, 24 inches thick	Casts of impressions, *Oldhamia*	50– 80

[a] Usually 50 [b] *Oldhamia* occurs in A, C or E and quite possibly in all three. Minimum, 286. Maximum, 1225+

In a paper on the "New York-Vermont Slate Belt" Dale established a series of divisions for the Lower Cambrian of Washington county and Vermont ('99, chart opposite p. 178). There are four divisions here, A to E. Division A (olive grit, 50-200 feet) is the Bomoseen grit of Ruedemann; division D (Cambric black shale, 50-250 feet) represents the Schodack shale and limestone. In Washington county and Vermont the olive grit is overlain by a great mass of colored slate, the "Cambric roofing slates" of Dale (division B, 200-40 feet) to which Ruedemann (*ref. cit.* p. 69) has given the name *Mettawee slate.* Above this is found the "Black patch grit" (division C of Dale, 10-40 feet) to which Ruedemann has given the name *Eddy Hill grit.* Again, above the Schodack shale and limestone is a ferruginous quartzite and sandstone (division E of Dale, 25-100 feet) which Ruedemann has named the *Zion Hill quartzite* (*ref. cit.*). These three formations are absent in the Capital District, but in his bulletin on the Catskill quadrangle Ruedemann ('42*b*, p. 64) notes the occurrence of the Zion Hill quartzite. He has distinguished here in descending order

Zion Hill quartzite
Schodack shale and limestone
(Burden conglomerate Grabau)
Bomoseen grit
Burden iron ore
Nassau beds

The Zion Hill quartzite, the Schodack shale and limestone and the Bomoseen grit were not mapped separately as they are so intimately connected and infolded in this area.

Dale ('99, p. 178) estimated the maximum thickness of the Lower Cambrian at Mt Hebron and east of North Granville, N. Y., as about 1400 feet. In the Green Mountain region of Massachusetts 1500 feet (*ref. cit.* footnote) of Lower Cambrian quartzite were measured and 470 of Lower Cambrian limestone, giving a total of nearly 2000 feet with the thickness of the basal member, the olive grit or Bomoseen unknown. In Rensselaer and Columbia counties Dale ('04, p. 29) estimated a maximum of 1225+ feet, 785 feet of Nassau beds and 440 feet of Schodack formations (*see* Table, page 51). No total measurements were given for the Capital District "since it was obvious that the conditions were not favorable to finding reliable guide beds, the quartzite being repeated and the beds being too similar to each other to be clearly identified in different outcrops" (Ruedemann, '30, p. 78). The Nassau beds for this district have a thickness of 150 to 800 feet; the Diamond Rock quartzite, 10 to 40 feet; the Troy shales and limestones, 25 to 100 feet. For the Catskill quadrangle Ruedemann gives no total thicknesses, because the beds are so involved by folding ('42*b*, p. 38). He thinks possibly only Dale's uppermost division (E) represents the Nassau beds in that area; the Bomoseen grit does not exceed 20 feet and the Zion Hill quartzite has about the same measurement. For the Schodack shale and limestone as a whole he estimates more than a hundred feet of greenish gray and black shale and nearly a hundred feet of limestones and shales, a total of over 200 feet. On the Coxsackie quadrangle, even allowing for duplication by folding several thousand feet of Cambrian must be present, the bulk of the thickness belonging to the Nassau beds.

In the section dealing with the Lower Cambrian formations in his Catskill bulletin (*ref. cit.*, p. 58, 60-62) Ruedemann gives a full discussion of the correlations of the Nassau beds and the Schodack formation, as follows:

An attempt at the correlation of the Lower Cambrian formations of the entire Appalachian geosyncline from Newfoundland to Alabama brings out the fact, as was pointed out to the writer by Dr Charles E. Resser, a leading student of the American Cambrian faunas and stratigraphy, that the base is everywhere formed by quartzite beds, pure quartzite or quartzite and shale and that this is later followed by Lower Cambrian calcareous beds or frequently by limestone and shales.

It thus appears that the quartzites and shales which we have called Nassau beds and Diamond Rock quartzite (Troy quadrangle) and the limestones, dolomites and limestone breccias with shales which we have termed Schodack and Troy beds . . . may well be continued as Cheshire quartzite at the base and the overlying Plymouth marble and Plymouth breccia in southeastern Vermont, or Cheshire quartzite and Rutland dolomite and Cheshire quartzite with overlying Monkton quartzite (fossiliferous), Winooski marble and Mallett dolomite above in northwestern Vermont. We do not cite in this connection the smaller members of less wide distribution, as the Bomoseen grit, Eddy Hill grit and the Mettawee slate which will be considered as members of the Schodack formation in a later chapter [*see* below]. The Cheshire quartzite extends to Vermont (see Wilmarth correlation table of Vermont) and the series can be recognized in Canada and Newfoundland, where the Nassau beds are represented by the Random terrane of Walcott (1900, p. 3-5) as of Algonkian age and is still placed with the Precambrian. The importance of this correlation will be understood when it is remembered that the Nassau beds, as well as the Cheshire quartzite and other basal quartzites have thus far utterly failed of affording any fossils save the Oldhamias in New York, which are but feeding trails of soft-bodied animals (supposedly worms) and might equally well occur in Precambrian beds of Beltian type. T. H. Clark ('21) has also found barren beds (slate, dolomite and graywacke) below the Cheshire quartzite in southern Quebec and north of Vermont. It is possible that these beds also are Precambrian in age.

Also, southward from the Hudson valley the sequence of the basal quartzite and shale and superjacent limestones and shales is preserved, the Nassau quartzite being continued southward in the Poughquag quartzite of the Highlands and the Cheshire quartzite of the Taconic range which there is followed by the lower Stockbridge limestone. South of New York in New Jersey the base is formed by the Hardyston quartzite with the Lower Cambrian (Olenellus) fauna in the upper part that is overlain by the Kittatinny limestone which has upper Cambrian fossils above the middle and is barren in the lower part. The Hardyston series of quartzites (with various members: Loudoun formation, Weverton sandstone, Harpers schist with Montalto quartzite member) and the overlying Antietam sandstone in central southern Pennsylvania and the corresponding basal Chickies quartzite with Hellam conglomerate member at bottom in northeastern Pennsylvania are followed by Lower Cambrian limestones (Tomstown dolomite). In Maryland and northern Virginia we find again the Loudoun, Weverton, Harpers, Antietam quartzite and shale series overlain by the Tomstown dolomite, while in central and southwestern Virginia these formations appear in slightly different character but the same general succession in ascending order as Unicoi sandstone, Hampton shale, Erwin quartzite, Shady dolomite and Watauga formation or shale (Rome formation in west, upper part middle Cambrian), while in the Blue Ridge province of North Carolina the typical Unicoi formation (a 1500-2500 foot massive white sandstone, feldspathic sandstone and quartzite with interbedded shales in upper part and conglomerate arkose and graywacke in lower part) is followed by the Hampton shale, Erwin quartzite and Shady dolomite and their differently named correlatives, and the Piedmont Plateau contains corresponding metamorphics (Kings Mountain quartzite, Blackburgs schist and Gaffney marble). The succession can be followed to Alabama, where the barren Weisner quartzite, Shady limestone and Rome formation (shales) represent the Lower Cambrian series.

If in the Lower Cambrian of the Appalachian geosyncline a general succession of basal quartzites and shales and overlying limestones and shales can be established, as is indicated by the preceding survey, it is equally probable from information the writer has received from students of the Lower Cambrian, as Dr C. E. Resser, and of its economic products, as Dr D. H. Newland and Professor A. F. Buddington, that the siderite-limonite iron ores are usually found in the quartzite-limestone interval of the formation. . . .

We may add that this work may receive still greater significance by the possibility that the iron ore horizon may mark the end of the Precambrian era. This is suggested by several facts; first of which is the absence of fossils in the Nassau quartzite and corresponding basal quartzites; further, the apparent transition of undoubted Precambrian beds into the basal quartzite series, as in the Random terrane, and finally the fact that wide-spread iron ore deposits are beginning to be considered as evidence of long preceding continental emergence and erosion, which furnished the iron-solutions to the continental and littoral waters. This view is especially prevalent among European students of sedimentation problems, as Johannes Walther (1893) and Hermann Schmidt (1935).

In a conference of the writer and Doctor Ruedemann with Dr Charles E. Resser of the U. S. National Museum, it was decided that it was more practicable to extend the term Schodack formation to include as members all the beds that occur, associated or interbedded, from the Bomoseen grit through the Zion Hill quartzite, since it permits a correlation of the larger upper units of the Lower Cambrian north and south of New York, which also consist of limestones and shales. Ruedemann's discussion of these correlations continues (*ref. cit.*, p. 65):

Prindle and Knopf (1932, p. 277) have been able to distinguish on the Taconic quadrangle (including the Berlin and Hoosick quadrangles east of the Capital District) the Mettawee slate, the Schodack formation and the Eagle Bridge quartzite which they consider as probably identical with the ferruginous quartzite (horizon C) of Dale (Ruedemann's Zion Hill quartzite), but name separately as the correlation is not certain. Doctor Resser would unite Ruedemann's Mettawee slate, Schodack shale and limestone and the Eagle Bridge quartzite (Zion Hill quartzite) into the Schodack formation and correlate this with the ever present upper limestones or dolomites and shales of the Lower Cambrian, that is with the Parker shale and Mallett dolomite of Vermont, the lower Kittatinny limestone of New Jersey, the Tomstown dolomite of Pennsylvania and northern Virginia, the Shady dolomite and Watauga formation (Rome formation in west) of North Carolina, known as the Shady limestone and Rome formation of shales as far as Alabama.

Doctor Resser would also correlate the Bomoseen grit and Diamond Rock quartzite with the Antietam sandstone and Erwin quartzite of the south. In his last publication ('38, p. 6) the Antietam quartzite is considered as represented in New Jersey by the Hardyston quartzite and in New York by the Poughquag quartzite and the Bomoseen grit of the Hudson valley. We have already pointed out . . . the importance for general paleogeographic conclusions that this uniform series of shales and quartzites, followed by shales and limestones, has in the Appalachian geosyncline.

It is worth noting that the Shady dolomite of Georgia and Virginia, as well as the Mallett formation of Vermont are remarkable for the beautifully developed reefs of Archaeocyathinae with which is usually associated a rich fauna. No such reefs were clearly seen in the Schodack formation of the Catskill district, but they may well be present and only have failed to be exposed as a result of the scanty outcrops.

Nassau Beds

The name *Nassau beds* was proposed by Ruedemann ('14, p. 70) for divisions A to E of Dale's Lower Cambrian series in Rensselaer county and part of Columbia county (*see* page 51). The beds are especially well exposed in the village of Nassau. The Lower Cambrian formations are arranged in ascending order from east to west, the lowest division, the Nassau beds, being farthest east.

Dale ('04, p. 16, 17) has given a detailed description of the petrography of the Nassau beds. He describes them as consisting of "a greenish shale, occasionally slightly reddish or blackish," and continues:

> Under the microscope it is a very fine-grained aggregate of muscovite and chlorite scales, angular quartz grains, rarely plagioclase grains, with brownish dots which are probably limonite. . . . The microscopical composition and structure of this shale indicate that it would probably not have required a vastly increased amount of compression to transform it into schist.
>
> This shale is very frequently interbedded with quartzose beds, weathering rusty-brown, from one-half inch to 2 inches thick. These little beds, when examined microscopically, prove to range from an almost pure quartzite to a dolomitic quartz grit. . . .
>
> There remain to be described certain greenish coarse and fine quartzite beds interbedded with the red and green shale bearing *Oldhamia occidens*. These differ little from those just described except in the occasional abundance of chlorite or chlorite-schist areas or fragments. Belonging to the same series are beds of massive quartzite from 8 to 50 feet thick, of similar character, but including here and there small beds of quartz conglomerate, in which pebbles measure up to one-fourth and even one-half inch in diameter and occasionally a pebble of dark-greenish slate.
>
> The reddish shale associated with all these quartzite beds varies much in the amount of its hematite and, therefore, in the intensity of its color. . . . The green shales owe their color to chlorite, the purplish ones probably to chlorite and hematite, and the blackish ones, naturally, to carbon.

In the Capital District bulletin ('30, p. 83), Ruedemann describes the Nassau beds as consisting of "a series of reddish and greenish shales, alternating with small beds of quartzite, mostly one or two inches thick." He found, as did Dale, "three groups of these alternating reddish and greenish shales and quartzite, the uppermost of which is more than 500 feet thick in places," separated by two massive beds of greenish quartzite reaching 40 to 50 feet in thickness.

On the Coxsackie quadrangle the Lower Cambrian is found along the river, stretching from about a mile and a half south of Schodack Landing almost to the city of Hudson. This belt, which is located farther east in the Capital District (Troy quadrangle), has been brought farther west in a block overthrust (figure 52) along the Logan fault plane. The belt of Schodack formation outcrops from this point south of Schodack Landing almost to Nutten hook. From here the Nassau beds continue south along the river, swinging to the east of Hudson. The northern boundary, north of Nutten hook swings to the northeast passing just west of Niverville on the Kinderhook quadrangle, then north-northeast one mile west of North Chatham onto the Troy quadrangle. From a mile north of Stuyvesant Falls to Stockport on the Kinderhook quadrangle, stretching along the Kinderhook creek and east and west, are a number of outcrops of Normanskill grits and shales forming a fenster of the normal series in the overthrust belt of Nassau. This fenster forms a narrow four-mile strip along the east border of the Coxsackie quadrangle north of Stockport creek (*see* map 2). The Normanskill in normal sequence appears to the east of the Nassau belt on the Kinderhook quadrangle. The most northern outcrop of the Nassau beds was found on Barren island where it represents the core of a pinched anticline, exposed by erosion. One patch occurs within the western part of the Schodack belt, exposed by erosion, in the deep valley of Mill creek, two miles north-northeast of Stuyvesant. Within the belt of the Nassau beds there are two excellent exposures, one at Nutten hook and the other in the triangular area extending from Stockport station east to the Columbiaville bridge and north along the New York Central tracks to the brickyards, a distance of two miles. The outcrops in these two miles are almost continuous. The other outcrops in the Nassau belt are usually small, scattered and few in number on the Coxsackie quadrangle.

Nutten hook is a rock island consisting of a north and a south hill, which has been joined to the mainland by alluvial deposits. This is an excellent place in which to study the Nassau beds, particularly in the south hill (figure 10). In the southern end of this hill about 150 feet north of the docking flat a fault may be seen in the cliff along the river, with a secondary break a little to the south. North of this in the cliff, as the beds approach the fault, a broad, shallow syncline is seen with the south arm raised; south of the fault is a broken anticline with east-west axis. Southward from the fault zone (secondary break) the section in descending order is as follows:

20	feet	alternating quartzites and shales, the quartzites from 2 to 6 inches thick
1½	feet	ferruginous quartzite
1½	feet	thin-bedded quartzite
3	feet	ferruginous quartzite with edgewise conglomerate in middle produced by breaking up of thin quartzite bands
1½	feet	thin-bedded quartzite
10	feet	slightly brownish quartzite with edgewise conglomerate, as above
1½	feet	greenish shale
3	feet	brownish quartzite
10	feet	greenish shales and thin quartzites
5	feet	heavy quartzite, thinner bedded in middle
15	feet	alternating shales and thin-bedded quartzites
3	feet	rusty weathering quartzite
2	feet	thin-bedded quartzite and shales
10	feet	quartzite in several beds
15	feet	largely covered; mostly shale
10	feet	greenish quartzite, fine-grained and very compact
40	feet	greenish gray shales, nearly vertical and more or less contorted
20	feet	greenish gray shales and thin quartzites; nearly vertical, dip slightly to north
30	feet	greenish shales and thin quartzites; vertical, with crumpling
15	feet	shales and thin quartzites (crumpled)
—		broken anticline with repetition of shales and thin quartzites; all contorted to southern end of hill, with brownish weathering thin quartzites
65 to 70	feet	greenish shales (practically whole thickness) with grit at top, in south end of hill; steeply dipping to north due to contortion

At the north end of the south hill is seen an east-west section in the Schodack formation. In the cliff here are seen 10 feet of shale with thin limestone bands representing the lowest Schodack beds. Between these beds and the heavy quartzite bed (Nassau) beneath is an erosion plane marking some interval of time, since there is an important change in conditions between the deposition of the quartzite and the shale and limestone. The section going from north to south, in descending order follows:

4	feet	quartzite in several bands. Dip N. 48° E., angle 21°
1½	feet	shale and thin quartzites
4	feet	quartzite in two beds; cross-bedding well shown, indicating shifting currents
25	feet	alternating shale and thin quartzite, 1 inch to 1 foot in thickness, ferruginous
10	feet	quartzite showing plunge structure, first bed 4½ feet; thin bands of quartzite. Strong currents indicated by plunge structure.

The section above apparently overlaps the first section, beginning with the uppermost 10-foot quartzite bed, and adds about 10 feet to the total section of about 300 feet. The two heavy quartzite beds may represent Dale's divisions B and D which would mean the larger part of division E is missing, or the whole section may be in division E, where, however, such heavy beds of coarse quartzite are usually not to be expected. The quartzite breccia or edgewise conglomerate may have been formed in connection with the folding and faulting (*see* pages 57, 291). The Schodack beds shown above the erosion plane will be discussed later. They are cut off on the east, with a reappearance of the Nassau beds, by a fault running south-southeast; on the south by the north-northeast trending fault seen in the cliff along the river. On the west side of a knoll just east of the southerly-trending fault is an outcrop of Schodack too small to be mapped.

The northern hill of Nutten hook, at the south end, shows in the cliff along the river the thin-bedded quartzites and shales typical of the Nassau beds, and with the normal dip and strike. Along the river, about 700 feet south of the northern end are 20 feet of thin-bedded limestones and breccia of the Schodack formation following in normal position the Nassau beds to the north and east and cut off on the south by a fault running south-southeast and roughly paralleling the one that cuts off the Schodack beds in the south hill. To the north of this fault the beds dip steeply almost due east, the Nassau beds forming the crest of the hill and the Schodack in part duplicated by a small thrust fault. In the Nassau beds 50 feet south of the north end a belt of shale and thin-bedded quartzite is changed into a crush breccia varying from one to four feet in thickness in 15 feet. On the east side of the hill are seen heavy quartzite beds with quartz breccia, striking almost due south and standing nearly vertical. Farther north these beds dip slightly to the southwest at a lower angle. At the northeast end is found a small wedge (15 feet) of Schodack limestone in contact with 25 feet of heavy quartzite beds at the east and on the west separated from the typical Nassau shales and thin quartzite of the west side by a fault. The quartzites and limestone beds stand practically vertical and strike due south. All of Nutten hook, particularly the north hill, is folded and faulted. The faults and the relation of the Schodack outcrop to the Nassau beds, together with the dips, suggest faulting of a recumbent syncline with the arms open to the west followed by a pinched anticline overturned to the west, complicated at the southern end by cross-folding and faulting. The lower arm of the syncline forms the south hill and the repeated Nassau brought up on the east through faulting; the north hill represents the anticline with axis trending south-southeast.

Another good section in Nassau beds is seen in a road cut east of Judson point, extending from the top of the hill down to the level of the house some 20 feet above the junction with the road to the south. Without counting small contortions, there is an estimated exposure of 200 feet of Nassau quartzites and shales, standing almost vertical and dipping northeast. At the top of the section is brownish weathering grit with breccia beneath, too contorted to measure. Near the top is a one-foot bed of greenish quartzite, between which and a quartzite bed eight feet thick at the bottom of the section are the typical Nassau beds with abundant thin quartzite bands. One-eighth mile to the east on the top of the flat a ridge showing olive grit and thin-bedded quartzites strikes southeast along a short lane. The section continues in the railroad cut along the river, south of Judson point (figure 11). Heavy quartzite beds are shown in the cut immediately south as follows, in descending order from north to south:

1½	feet	quartzite
1½	feet	thin quartzite bands and shale
2	feet	quartzite
1	foot	shale
5	feet	quartzite
3	feet	shale and thin quartzites
5	feet	quartzite
½	foot	thin quartzites and shale
2	feet	quartzite
1½	feet	alternating thin quartzites and shale
1¼	feet	quartzite
3	inches	shale
1½	feet	quartzite
1½	feet	shale
15	feet	alternating thin quartzites and shale with a 2-foot bed of edgewise conglomerate in the middle (thin quartzite beds broken up)
15	feet	alternating shale and quartzite
3	feet	quartzite bed
3	feet	shale
3	feet	shale and thin quartzite bands
3	feet	quartzite
25	feet	alternating shale and thin quartzites with 2-foot quartzite beds at bottom

The section ends at the south with a thick bed of breccia which forms the point at the north end of the swamp or embayment and follows to the end of the swamp as a low bank. In this section are seen 26 feet consisting almost entirely of heavy-bedded quartzites. This might well represent Dale's division B and the section in the road cut, a part of division C. The section along the railroad continues south to Stockport station and east to the Columbiaville state highway bridge. Above and below this bridge is an exposure of over a quarter of a mile of greenish shales and thin quartzites, largely downstream. Between Stockport station and the bridge a road leads north showing outcrops of Nassau for over a quarter of a mile. In a small stream east of this road a considerable thickness of heavy bedded quartzite above greenish shales and thin quartzites forms a falls. The beds have a strike N. 13° E. and dip at an angle of 45°. The dip of the beds here has changed to east-southeast from

Figure 10 Nassau beds in the southern end of Nutten hook near the dock and ferry landing, look north-northeast. The heavy quartzite beds are well shown at the left (north); at the right the fault that extends through the hill in a north-northeast direction. (Photograph by E. J. Stein)

Figure 11 Nassau beds just south of the Judson Point crossing, looking south-southeast. Heavy quartzite beds are conspicuous here, but thick shale beds appear to the south in the east bank of the New York Central railroad tracks. (Photograph by E. J. Stein)

the northeasterly dip at Judson point; and at the bridge one mile east of Stockport station it becomes easterly. The quartzite beds at the falls may represent Dale's division D and the outcrop at the bridge his division E. An enormous thickness of the Nassau beds is represented here, but how much of the mile of thickness is due to isoclinal folding can not be estimated.

In the valley of Mill creek, one and one-half miles north-northeast of Stuyvesant is an inlier of greenish Nassau shale with thin-bedded quartzites. The bank of the stream is formed by a heavy bed of ferruginous weathering quartzite and immediately above is the Schodack formation with a three-foot breccia bed at the base, followed by thin-bedded limestones with black shales and thin quartzite beds. Unless the ferruginous quartzite bed represents the Bomoseen grit here it is absent in this section.

Barren island, south-southeast of Coeymans along the west shore of the river, is evidently an inlier of the Nassau beds, the core of a pinched anticline. They consist of green shale with numerous bands of green quartzites up to two inches in thickness. At the north end the beds dip steeply to the west, on the south steeply to the east, and they are much contorted at the northwest. It would be difficult to make any measurements here, nor is there a full representation of the beds. There is room between the island and the two shores to accommodate the thickness of the Schodack formation and the Deepkill shale. The Normanskill shale occupies both banks.

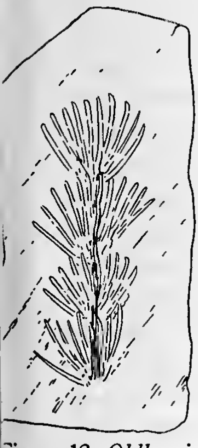

Figure 12 *Oldhamia occidens* (Walcott). A characteristic fossil (worm trail) of the Nassau beds. (After Walcott)

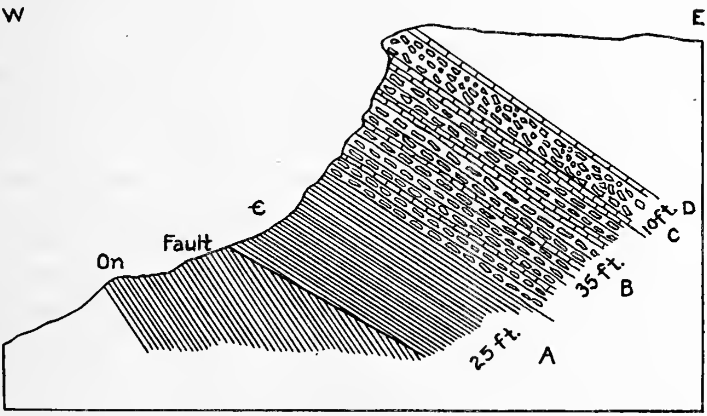

Figure 13 Diagrammatic section showing the relation of the Lower Cambrian limestone (*B, C, D*) and shale (*A*) to the Normanskill shale (*On*) as exposed at two localities near Schodack Landing. *B*, bedded limestone and nodular limestone in shale. *C*, conglomerate with brecciated limestone stratum below. *D*, coarse-grained limestone bed. (After Dale)

No fossils have been found in the Nassau beds except the *Oldhamia* (figure 12) impressions described originally by Walcott ('94, p. 314) from the beds of the Troy quadrangle as a calcareous alga, *Oldhamia occidens*. "This absence of preservable organic life," according to Ruedemann ('42*b*, p. 42), "is to some extent in favor of the view that this formation may be very late Precambrian or a transitional one from the Precambrian to the Cambrian."

The organic nature of *Oldhamia* was denied by Roemer ('80), Sollas ('86) and the paleobotanists Solms-Laubach ('91), Seward ('98) and Potonié and Gothan ('21). More recently, in a paper on *Oldhamia occidens,* Ruedemann ('29, p. 50) brought forward evidence that apparently pointed to an algal origin for this species. Since then recent collections of fine material of this species has led to a restudy of the whole *Oldhamia* problem and the resultant discovery that all these impressions both in the shale and the quartzite are radiating feeding trails of worms (Ruedemann, '36, p. 383, abstract).

Schodack Formation

The Schodack formation is here used as extended by Ruedemann to include all members associated or even interbedded with it from the Bomoseen grit through the Zion Hill quartzite (*see* page 51). On the Troy and Cohoes quadrangles it includes in ascending order the Bomoseen grit, Diamond Rock quartzite, Troy shale and limestone, Schodack shale and limestone; in Washington county and Vermont Bomoseen grit, Mettawee slate, Eddy Hill grit, Schodack shale and limestone and Zion Hill quartzite; on the Catskill quadrangle (Ruedemann, *ref. Cit.* p. 64), Bomoseen grit, Schodack shale and limestone, Zion Hill quartzite. The *Zion Hill quartzite* member (Ruedemann, '14, p. 69), the ferruginous quartzite of Dale ('99, chart, p. 178), does not appear on the Coxsackie quadrangle. On the Catskill quadrangle, to the south, Ruedemann has found it exposed in many localities as a deep iron-red quartzitic sandstone, constituting one of the most striking of the Lower Cambrian rocks there. This member is more often 10 to 30 feet thick, but may reach a thickness of 74 feet (Ruedemann, '42*b*, p. 65). Dale (*ref. cit.* p. 184) found it occurring in the central and southern part of the slate belt of Washington county and Vermont, in some places as a massive quartzite identical in composition and appearance with the Bomoseen grit; in other places as a bluish calcareous sandstone, traversed by quartz veins, which upon weathering crumbles into a rusty-colored quartz-sand, leaving the quartz veins. Outside of the

Catskill quadrangle, just south of the village of Claverack, Ruedemann (*ref. cit.*, p. 67) has found a coarse conglomerate containing numerous ferruginous quartzite pebbles and other limestone pebbles and incorporated in greenish gray siliceous slates with black worm-tubes. This bed represents a horizon above the Zion Hill quartzite, which therefore is not the top of the Schodack formation but only a member near the top.

Bomoseen grit. This name was proposed by Ruedemann ('14, p. 69) for Dale's reddish weathering "olive grit" (division F). The type locality is on the west side of Lake Bomoseen, Vermont. For this member Dale gives a thickness in Rensselaer county of 18-50 feet ('04, p. 29; see page 51); but in the Lower Cambrian series of Washington county and Vermont it is a very prominent member and here Dale records 50 to 200 feet ('99, p. 178) with associated quartzite beds, 12 to 55 feet thick in places. Ruedemann ('14, p. 70) found it still a striking formation along the eastern edge of the Schuylerville quadrangle where it is easily recognized by the pale brick-red color of the weathered crust that forms on it. It is little exposed in the Capital District and always, in the western portion of the belt, in association with the Troy and Schodack beds (*auth. cit.*, '30, p. 83). On the Catskill quadrangle the "occurrences are repetitions of the same beds in an east-west succession produced by folding. The full thickness of the Bomoseen beds or olive grit has not been obtained, but is apparently not more than 20 feet. . . . In all these localities it outcrops close to the Schodack thin-bedded and brecciated limestones, ferruginous quartzite, etc." (*auth. cit.* '42*b*, p. 43).

On the Coxsackie quadrangle there is just one place where typical Bomoseen grit is seen. One-half mile north of Stockport station, just before the road turns abruptly east, there is a road cut in the hill at the east exposing 10 feet of dark olive grit weathering rusty This is within the belt of Nassau beds and is probably infolded. One-half mile to the northeast along the lane to the south olive grit with Nassau quartzites and shales forms a low ridge. At Nutten hook where the Schodack beds are seen in normal position above the Nassau beds there is no evidence of Bomoseen grit, unless the heavy quartzite beds immediately below the Schodack beds are here a representation of the grit, which the writer believes is unlikely. A number of outcrops of olive grit occur from one mile south of Schodack Landing to three-quarters of a mile south of Poolsburg, in the area to the northeast of this and east to Kinderhook lake (map 2). This grit does not weather like typical Bomoseen and moreover is found in several sections interbedded with the Schodack breccias and limestones which would indicate that it should be considered as belonging to this member. This will be discussed in the section devoted to the Schodack shales and limestones (*see* pages 69, 72).

Dale ('99, p. 179) gives a detailed petrographic description of this rock, as follows:

A greenish, usually olive-colored, very rarely purplish, more or less massive grit, generally somewhat calcareous, and almost always spangled with very minute scales of hematite or graphite. Under the microscope it is seen to consist mainly of more or less angular grains of quartz, with a considerable number of plagioclase grains, rarely one of microcline, in a cement of sericite with some calcite and small areas of secondary quartz. There are large scales of muscovite and of chloritic mineral, scarcely dichroic. . . . More conspicuous and typical of the rock are scales from 0.043 to 0.130 by 0.020 millimeter, frequently bent, pale green, markedly dichroic and under polarized light olive or slightly bluish green. . . . Finally there are grains or crystals of a muddy yellow under incident light, probably limonite and that after hematite. The scales of hematite, sometimes graphite, can be made out with a magnifying glass.

This characteristic rock can usually be identified at a distance by the peculiar pale brick-red color of its weathered surface, and, on closer inspection, by the minute spangles and the olive color of the fresh surface.

Ruedemann did not report fossils either from the Schuylerville quadrangle or the Capital District area, and no special effort was made to find them on the Catskill or Coxsackie quadrangles as they are extremely rare. The only record that can be found of a fossil occurrence in the Bomoseen grit is the *Obolella crassa* reported by Walcott ('12, p. 188) from Lower Cambrian reddish sandstone about one mile east of Lansingburg, north of Troy, Cohoes quadrangle (U.S.G.S.), Rensselaer county, N. Y. (Cooper Curtice, 1883).

The brick-red weathering Bomoseen grit is of especial interest because of the small, but steady iron (hematite) content it carries and because it holds the same horizon, between the Nassau and Schodack formations, as the Burden iron ore beds in Columbia county. The *Burden Iron ore* formation (Ruedemann, '42*b*, p. 43) is found south of Hudson on the Catskill quadrangle and consists of "limonite and siderite iron ore between the Nassau and Schodack beds in a belt extending from the southern base of Mt Tom (Mt Thomas) to Church hill, about four miles in all. Here ore was mined until 1901 in the Burden mines at Mt Tom and in other mines on Plass hill (now Church hill)." The typical outcrop of the ore is at the old adit of the Burden mine where the 25-foot iron bed, a breccia with limestone pebbles, rests upon the shale and thin quartzites of the Nassau beds and is followed by thin-bedded and heavy-bedded quartzitic limestones of the Schodack formation.

The Burden iron ore is fully discussed by Ruedemann in his bulletin on the Catskill quadrangle (*ref. cit.* p. 43-61), as to occurrence, age, origin and relationships and the views expressed in earlier writings are given (Dana, '84; Smock, '89; Kimball, '90; Eckel, '05; Hobbs, '07; Ruedemann, '31; Newland, '36). Some of Ruedemann's views on relationships are expressed in the following quotations:

It is thus apparent that the Burden iron ore is a bedded layer holding a horizon near or at the base of the Schodack formation and above the Nassau beds. Its thickness is variable, partly because of the slip-planes . . . and partly perhaps due to rapid variation of original deposition. Smock reported a thickness of 41 feet including a thin bed of sandstone at the Burden mines (mines No. 3 and 2) southeast of Mt Tom; on Cedar hill a thickness varying from 8 to 30 feet; in the Livingstone mine east of Cedar hill 18 feet and in the Plass hill openings ore ranging between 10 and 16 feet with a footwall of drab-colored shale.

The Burden iron ore is, as was early recognized by Dana (1884) and his successors in the study of the iron ores of eastern New York, of the same type as the iron ore of the great belt in the Harlem and Stockbridge valleys along the New York-Massachusetts line in the Taconic area. . . . A hasty survey of the mines on the New York side with Dr D. H. Newland gave evidence that the schists close to at least some of the mines are metamorphosed Nassau beds and the limestones metamorphosed Schodack beds, in part at least, the iron ore holding a place approximately between the two. This is especially apparent at Amenia, N. Y., "one of the few places where the ore and wall rocks are well exposed. . . ." (Newland, 1936, p. 146). . . . Furthermore, accurate age determination of the eastern metamorphosed beds will therefore probably prove that the Burden iron ores and the eastern iron ores . . . are parts of an identical horizon . . . The eastern iron ore belt is interrupted north of Copake exactly opposite or directly east of the Burden-Church Hill belt by a stretch of about the same length as the latter that has no iron pits and apparently no iron. It is then quite possible that the Burden-Church Hill belt is a sector torn out of the eastern belt and carried farther west by about 15 miles on the overthrust plane that is exposed along the western slope of the ridge. . . ." (*ref. cit.* p. 46, 49, 50).

Ruedemann also remarks (*ref. cit.,* p. 58) that "it is very probable that the appearance of the iron ore between the Nassau and Schodack beds has a much greater significance." Newland ('36, p. 155) in his discussion of the Mineralogy and Origin of the Taconic Limonites, in this same connection, writes: "The relation of the Taconic district to the rest of the Appalachian district from the standpoint of the origin of the limonites is a subject for future examination. The outcome may be important for stratigraphy as well as economic geology. For the present it suffices to refer to the many striking comparisons between Taconic and other ore occurrences available in the published records, suggestive of a community of physical and chemical features hardly realizable from the operation of mere chance." In his discussion of correlation of the Lower Cambrian beds Ruedemann adds the following remarks on the iron ore question (*ref. cit.*, p. 62).

If the Nassau beds, like the supposedly correlated Random beds of Newfoundland [*see* page 53], should prove to be of Precambrian age (Resser) the Burden Iron Ore horizon would be on the actual boundary of the Precambrian-Cambrian eras (Lipalian interval) and in a true position to be regarded as the result of the washing out of the regolith [residual soil] of the widely emerged continent. In case the Nassau beds should prove, however, to be of earliest Lower Cambrian age, it would still be possible to consider the iron ore of a like origin, as also in Lower Cambrian time the largest proportion of North America was still widely emergent.

It is in this connection important to remember that the Bomoseen grit, which holds about the same horizon as the Burden iron ore is a peculiar arkosic rock, a coarse grit, full of hematite scales and with a considerable number of plagioclase grains. . . . This rock with its iron and feldspar content points also to a continental surface with much granite as the source of the material, presumably also a Precambrian surface, and suggests even the character of a continental regolith similar to the Brayman shale.

Schodack shale and limestone. Ruedemann ('14, p. 69) proposed this name for Dale's "Cambric black shale" ('93, chart facing p. 178) of Washington county and Vermont, a formation of "black shale or slate, sometimes pyritiferous, with thin bands of limestone and less frequently limestone breccia." The name was suggested by the "fine exposures two miles south of Schodack Landing, N. Y., on the bank of the Hudson river and the belt of these rocks in the town of Schodack, N. Y." (Ruedemann, *ref. cit.*). This formation is also typically Dale's division I of the Lower Cambrian series as exposed in Rensselaer county and part of Columbia county ('04, p. 29) and Ruedemann has added his division J, the neutral greenish shale usually associated with it ('30, p. 80).

For Washington county and Vermont Dale ('93, p. 178) records a thickness of 50 to 250 feet for the "Cambric black shale"; in Rensselaer and Columbia counties ('04, p. 29) 20 to 200 feet for the thin-bedded limestones, shales and breccias (division I) and 50 feet for the greenish shale (division J). In his Capital District bulletin Ruedemann has made no estimates as to thickness because of "the difficulty, or rather the impossibility, of determining exactly the thickness of these beds" (*ref. cit.*, p. 78). Of this formation on the Catskill quadrangle he writes ('42*b*, p. 78):

The full thickness of the Schodack formation on the Catskill quadrangle has not been ascertained. As usually only the limestone beds or the alternating limestone beds and shales are exposed, while the greenish-gray and black shales which reach considerable thickness remain hidden, the thickness of the formation is undoubtedly greater than would appear by piecing the various outcrops together. Outcrops of 25-50 feet of limestones with intercalated shales and representing different horizons . . . indicate nearly a hundred feet of limestones with shales. To this can be added more than a hundred feet of greenish-gray and black shales, which are seen in several places, especially on the quadrangles north of the Catskill quadrangle.

Ruedemann cites 75 feet of Schodack limestone, breccia and conglomerate in the Greendale section ('42*b*, p. 68) and elsewhere he records beds of conglomerate and breccia up to 10 and 12 feet in thickness (*ref. cit.* and p. 76).

On the Coxsackie quadrangle an excellent exposure of the Schodack shale and limestone is seen on both sides of the road and along the railroad spur (Castleton cutoff), extending from a point one and a half miles south of Schodack to Poolsburg. A second very accessible exposure, suitable for study, is located in the north end of the south hill forming Nutten hook (figures 16, 17). Small exposures are seen at the north end of the hook, but they are less accessible for study. Both these sections will be discussed in detail. Elsewhere the exposures are few and scattered. East of the Schodack Landing-Poolsburg section along the eastern margin of the sheet are several exposures of olive grit that, however, does not represent the Bomoseen grit which holds a position at the base of the Schodack formation. One mile south-southeast of Poolsburg a small stream lies to the south of an east-west road. In this stream the Schodack limestone caps a small falls with the black shale below and the olive grit above. The black shales are well exposed in a road cut on the east side of the state highway, one mile below Stuyvesant and also in the valley of Mill creek two miles north-northeast of Stuyvesant. In the first locality black slate is shown alternating with two-inch wide limestone bands in a 20-foot exposure which strikes N. 12° E. and dips south of east at an angle of 62°. In the second locality a three-foot breccia bed is followed by thin-bedded limestones with black shales and thin quartzite bands. Heavy breccia beds are exposed in a ridge in the field west of the airport about a mile north of Columbiaville and immediately north of the junction of the two state highways. In descending order the section here is: 3 feet of thin-bedded limestones; 3-foot heavy breccia bed; 2-foot quartzite bed; 3-foot heavy breccia bed. Three and a half miles north-northeast, just over the edge of the Coxsackie quadrangle, a heavy breccia bed is found outcropping in the strike of the airport exposure. In the Schodack formation belt north and east to Kinderhook lake, on the Kinderhook quadrangle (map 2), have been found only outcrops of the olive grit which holds a position above the heavy breccia beds. At Stuyvesant Falls, on the Kinderhook quadrangle, the Schodack beds are exposed in the stream bed within the area of the Normanskill fenster, below the falls and a short distance downstream; another exposure is found capping a Nassau ridge east of the Normanskill fenster, south-southeast of Stockport and one-half mile north of the junction with the West Ghent road.

The section south of Schodack Landing (*see* figure 13, page 63) is discussed by Dale ('04, p. 16) in his paper on the Geology of the Hudson Valley between the Hoosic and the Kinderhook, as follows:

A limestone conglomerate deserves notice. Two miles south of Schodack Landing (Coxsackie quadrangle) or 7 miles west-southwest from North Chatham, the Cambrian shale and limestone form a cliff about 70 feet high. . . . Near the top is a bed about 10 feet thick, the lower part of which is a brecciated limestone, but the upper resembles a conglomerate, and it looks as if the brecciated limestone had for a while been exposed to wave action. The pebbles are limestone carrying Lower Cambrian fossils, but the cement is shaly. Some of the pebbles have pitted surfaces. This bed is capped by a few inches of coarse-grained limestone also carrying Lower Cambrian fossils. At Ashley Hill, a mile northeast of Riders Mills, in Chatham, the brecciated Cambrian limestone seems also to pass into a conglomerate, and the pebble-like nodules are likewise pitted from the impression of the quartz grains of the matrix [See Dale '93, p. 313]. . . . Foerste traced similar pebbles in the Cambrian shale at Troy to small limestone beds which had undergone a process of brecciation, slip cleavage, and partial solution [see Dale '96, p. 569]. . . .Such "pebbles" might also be accounted for by a concretionary process taking place in sediments which were partly calcareous and partly argillaceous, or, finally, by a slight crustal movement exposing the limestone to wave action during a brief period and then submerging it again. The applicability of the first two theories should be carefully tested before resorting to an explanation involving geographical changes. It is, however, quite possible that such changes did occur here in Lower Cambrian time and that in some localities there are true conglomerates (Walcott, 1894), in others autoclastic ones.

In discussing intraformational conglomerates Walcott ('94) distinguishes between these and intraformational breccias, the latter having a wide geographic distribution and owing their origin to local disturbance within the beds affected, without presupposing elevation above sea level and erosion (p. 192). He defines an intraformational conglomerate as "one formed within a geologic formation of material derived from and deposited within that formation" and among the numerous occurrences recorded for the United States and Canada cites "the old limestone quarries on the east shore of the Hudson, below Schodack landing." His discussion continues:

The section is formed of thinly bedded limestone, carrying the typical Olenellus fauna. Toward the summit of the quarry a band of conglomerate limestone rests conformably on the bedded limestone. Pebbles and fragments of several varieties of limestone occur, in which fragments of typical species of the Olenellus fauna were found. The conglomerate band varies in thickness from 2 to 6 feet, and it is capped by thinly bedded limestones that carry the same species of fossils as the limestones beneath the conglomerate and the bowlders in the conglomerate (p. 192).

The writer has studied in detail the sections south of Schodack Landing. Three-quarters of a mile north of Poolsburg and two and a half miles south of Schodack Landing the state highway approaches close to the edge of the cliff along the New York Central tracks, and one may descend at this point without risk (figure 14). The Lower Cambrian Schodack beds are well-exposed overthrust on the Ordovician Normanskill shales. The Ordovician beds dip at an angle of 55°, the Cambrian beds 40°. The strike of the Cambrian beds here is almost due north, the dip almost due east. The section obtained by the writer is given below, in descending order:

1 foot	limestone bed with fossils
2 feet	green slaty shale with limestone pebbles ("nodular" limestone)
6 inches to 1 foot	coarse crystalline, fossiliferous limestone
20 feet	greenish slaty shale with rounded limestone pebbles ("nodular" limestone); 4 feet at top with no limestone bands or pebbles
10 feet	thin-bedded limestones, including a 6-foot bed of limestone breccia and a 2-foot shale belt at the top
15 feet	alternating shales and a few thin limestone bands; greenish, slaty shale
15 feet	dark gray Schodack shale
25 feet	Normanskill dark gray shale

Dale ('04, p. 28) gives a combined section at these cliffs (*see* Ford, '85) in which the Ordovician dip is given as 55° and the Cambrian as 50°. The diagram (figure 13), shows 25 feet of Lower Cambrian shale, 35 feet of bedded limestones and "nodular" limestone in shale (*Olenellus* fauna) and 10 feet consisting of conglomerate (pebbles with *Olenellus* fauna), with a brecciated limestone stratum below it and a capping of coarse-grained limestone with *Olenellus* fauna. The brecciated pebble beds are Walcott's intraformational conglomerate, the pebbles produced by the separation of thin limestone layers by successive plication and cleavage, but, as noted by Dale ('04, p. 29), there are also true beach pebbles.

Three-eighths of a mile north of the above section on the east side of the road near old School No. 6, is a splendid cut showing 12 feet of thin-bedded limestone and above this a five-foot bed of breccia or intraformational conglomerate (figure 15). Greenish shales are seen below the limestones in the road ditch. To the west in the cliff above the New York Central tracks are 20 feet of thin-bedded limestones underlain by 25 feet of greenish, slaty shale. A short distance north along the road is a cut in olive grits and shales. Along the Castleton cutoff above (east) is the following section in descending order (with a possible fault at the southern end):

4 feet	ferruginous-weathering limestone with sandy surfaces and thin bands of shale
15 feet	dark shales with thin beds of siliceous limestone
4 feet	conglomerate bed with abundance of sand; ferruginous-weathering
5 feet	shales with 2 and 3-inch bands of siliceous limestone
8 inches	siliceous limestone band
44 inches	siliceous limestone band
25 feet	thin siliceous limestone and shale alternating
5 feet	breccia bed
18 feet	bluish gray slate with limestone pebbles
12 feet	breccia bed
25 feet+	olive grit

The beds here dip S. 42° E. This section, taken into consideration with the cut at the main tracks and the road cuts near the old schoolhouse, gives a thickness for the Schodack beds here of at least 85 feet, if the road cut in thin-bedded limestones, with the greenish shales below, and the thin-bedded limestones in the cliff above the railroad tracks represents the alternating siliceous limestones and shales seen in the cutoff section above. If the five-foot breccia bed in the cutoff corresponds to the five-foot breccia bed in the road cut, as appears, then there is a thickness of over 100 feet. These sections also indicate that olive grits or gritty shales, sometimes containing limestone pebbles, are interbedded with the thin-bedded limestones and limestone breccias and therefore do not necessarily represent the Bomoseen grit. The olive grit exposures found to the north, east and northeast (on the Kinderhook quadrangle) have been interpreted as representing these beds in whole or in part. The olive grits and olive shales are well shown to the north of the cutoff section in a road cut in the hill just east of the railroad tracks, along the east-west

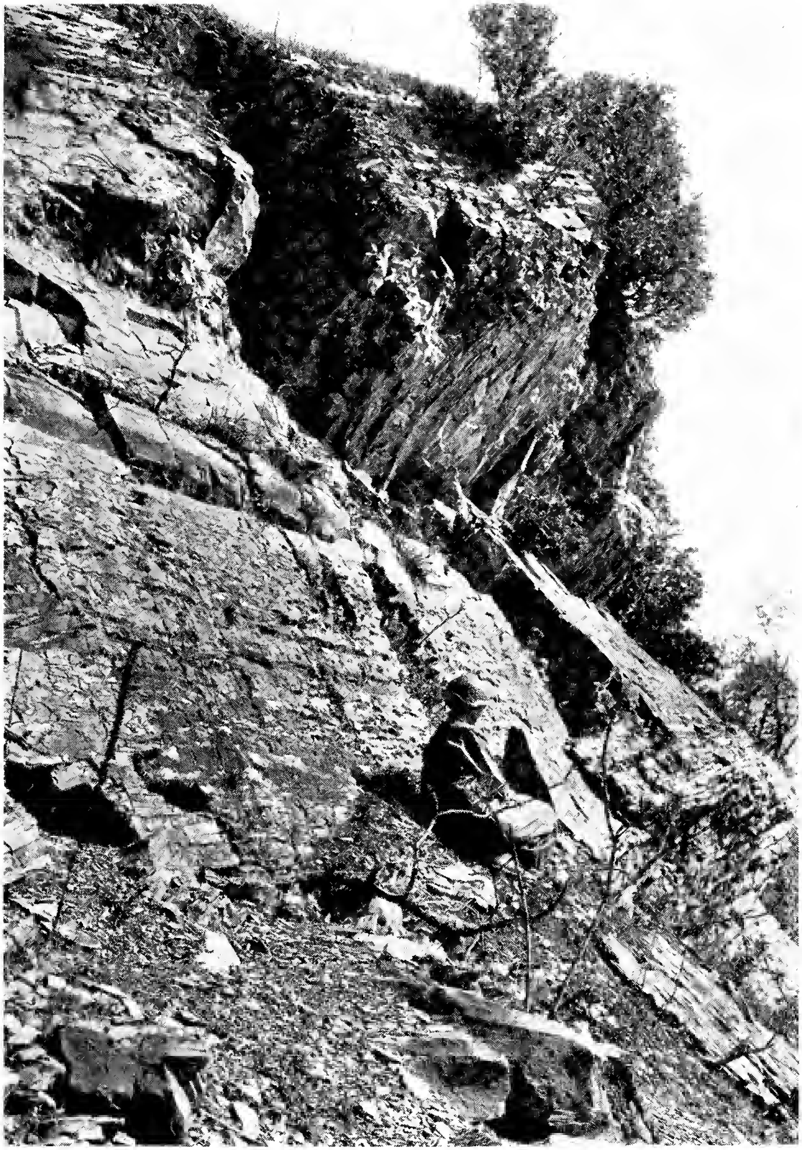

Figure 14 Schodack beds above the thrust zone in the east bank of the New York Central railroad tracks. The brecciated limestone bed is well shown near the base of the cliff at the right. See figure 52.
(Photograph by E. J. Stein)

Figure 15 Schodack brecciated limestone in a cut along the east side of the state road in the vicinity of School No. 6, two miles south of Schodack Landing. (Photograph by E. J. Stein)

road. There is a suggestion of the Bomoseen grit in these beds, as they weather rusty, but they are not typical.

The section in Schodack beds at Nutten hook at the north end of the south hill is very accessible as it may be reached by a farm road branching off the highway one-quarter of a mile north of the ferry road from the village of Newton Hook. Here also the relation with the Nassau beds below is well shown. As pointed out above (page 58) between the heavy grit bed at the top of the Nassau section and the shales and limestones of the Schodack formation is an erosion plane representing some interval of time, since there is an important change from conditions permitting deposition of grit and those resulting in deposition of shales and limestones. In a cut over 200 feet in length a thickness of over 100 feet of Schodack beds is exposed (figures 16, 17). At the west end near the river dark gray quartzitic shales with thin-bedded limestone bands follow the Nassau beds. Eastward and higher in the section the limestone bands become more numerous and have developed a striking wavy character. At the east end of the cut, in the upper portion of the section are three breccia beds with thin-bedded limestones and shales between. The uppermost breccia bed has a thickness of about 3 feet and is followed by 4 feet composed almost entirely of thin-bedded limestone, above which are 15 feet of thin-bedded and heavier bedded quartzitic shales with some thin-bedded limestones. The succession from dark gray shales through thin-bedded limestones with some shale to heavy limestone beds, followed by shales again, indicates a slow change from muddy water to clear water with an abrupt return of muddy waters again. Toward the east end of the cut a small fault may be seen with a displacement of 8 to 10 feet. This fault probably accounts for some of the crumpling of the limestone bands, as well as the fault of greater magnitude immediately to the east. The wedge-shaped outcrops of Schodack beds at the north end of Nutten hook show alternating shales and thin-bedded limestones in contact with the Nassau beds. In both localities the Schodack beds are cut off by faults; the section at the northwest shows wavy and crumpled, thin limestone bands and a thin limestone breccia. The Nutten Hook section does not correspond to those south of Schodack Landing, so that the thickness of the Schodack shale and limestone on the Coxsackie quadrangles totals well over 200 feet.

The limestone breccia beds of the Schodack formation attain considerable thickness. As pointed out above (page 69), beds 10 to 12 feet thick have been observed on the Catskill quadrangle and still greater thicknesses are recorded for Vermont and northeastern New York. According to Walcott ('94, p. 197, 198):

The relation of the bedded limestones to the superjacent conglomerates proves that the calcareous mud which was subsequently consolidated into the limestones solidified soon after deposition. This is shown by the presence in the conglomerate of rounded pebbles and angular fragments of limestone with sharp clear cut edges. The presence of the conglomerates above the limestone beds, from some portion of which they were derived, leads me to believe that the sea-bed was raised in ridges as domes above the sea level and thus subjected to the action of the seashore ice, if present, and the aërial agents of erosion. From the fact that the limestones upon which the conglomerates rest rarely if ever show traces of erosion where the conglomerates come into contact with them, the inference is that the débris worn from the ridges was deposited in the intervening depressions beneath the sea.

These edgewise conglomerates or breccias are also interpreted to indicate submarine slumping at the bottom of a gently sloping seacoast which involved recently hardened calcareous mud beds. In this connection Ruedemann writes ('42*b*, p. 70, 76):

The presence of these lenses repeatedly at the same horizon, viz. at the top of the heavy limestone, followed by black shale, points to the repetition of more violent interruptions by storms, earthquakes or other agents that caused the slumping and new inrush of muddy water. . . .

Identical lenses of edgewise conglomerate are also known from the Deadwood formation (Upper Cambrian) of the Black Hills. It is considered by Schuchert and Dunbar ('33, p. 157) as made up of the shingled-up fragments of mud-cracked layers. The more extensive beds of edgewise conglomerate described before by Dale and Prindle and by the writer from the Schodack limestone beds in Albany and Washington counties may in part at least have originated on tide-flats where such beds are seen forming today when partly consolidated thin limestone beds are again broken up, as shown along the German coast of the North Sea (Häntzschel, '36, p. 350).

On the other hand, the lenses of edgewise conglomerate, as those in Fischers quarry and south of Becraft mountain, that clearly represent a slipping at times on a firmer bed, if they can be found over a wider area at the same horizon as those at the two mentioned localities, may suggest seismic activity that caused sudden slipping of portions of the slanting sea bottom that were in more labile condition.

Grabau ('03, p. 1034-36) described these breccias or conglomerates in his paper on the stratigraphy of the Becraft Mountain region, south of the city of Hudson and gave to them the name *Burden conglomerate*. Davis in an earlier paper ('83, p. 382) assigned to it an age "apparently younger than the Helderberg series and certainly much older than the drift." Grabau believed that it belonged to the Hudson River series, but could not ascertain whether older or younger than the Normanskill shales, though areal relations indicated an age older

Figure 16 Schodack shale and limestone in cut at north end of south hill of Nutten hook. West end of section showing the thin, wavy limestone beds. (Photograph by E. J. Stein)

Figure 17 Schodack beds. East end of section shown in figure 16. Three thick, brecciated beds may be seen, one marked by the head of the figure; thin, wavy limestone bands appear lower in the section. (Photograph by E. J. Stein)

than the Normanskill beds of Mt Merino (Moreno). He also thought the conglomerate might correspond in age with the Trenton conglomerate of Rysedorph hill, described by Ruedemann ('01, p. 3) from Rysedorph hill, east of Rensselaer. This Rysedorph conglomerate (*see* page 119), seen in a few outcrops on the Coxsackie quadrangle (*see* page 123) is well represented on the Catskill quadrangle where it outcrops in great thickness north of Elizaville. It is of Middle Ordovician age, overlying the Normanskill shale. Grabau's description taken into consideration with later field work indicates that he has united under the name Burden conglomerate beds of earliest Schodack age, as at Burden iron mine, with beds of later Schodack age, as at Claverack creek and north of Becraft mountain. All these beds are of Schodack age and Burden conglomerate, as a formation name, has no standing.

The Schodack limestone is distinguished, not only by the lenses and beds of breccia, but also by the frequent occurence of well-rounded, frosted sand grains evenly distributed in the limestone and also present in the breccia. The sand grains are nearly always smoky or black (*see* Ruedemann, 42*b*, p. 76, 176; Dale '93, p. 313). According to Dr D. H. Newland, State Geologist, such gray quartz is prevalent to the east in the Green mountains and New England, but does not occur in the Adirondacks. "These floating sand grains have all the appearance of having been blown into the sea from land. As one rarely observes them in later limestones, they give a fair indication of the desert conditions that have prevailed on land and the power of the storms that raged over it. . . . It may properly be concluded that these storms came from the north and east" (Ruedemann, *ref. cit.*). These quartz grains, through pressure and solution fit into the limestone pebbles of the Schodack conglomerate as though pressed into it, which gives a finely pitted appearance to the pebbles when the cement has been eroded (Dale '93, p. 313).

The *fauna* of the Schodack formation has been fully discussed by Ruedemann in his bulletin on the Capital District ('30, p. 80, 81) and the fossils listed with Walcott's locality numbers ('12, p. 162, 183, 200, 212, 266, 277) for the various localities in that area. The conglomerate is the main carrier of the fossils; specimens found in the shales and limestones are rare and fragmentary. The fauna (figure 18) consists almost entirely of small and primitive forms and is the oldest fauna as yet known, except for some scattered, mostly doubtful Precambrian fossils. The most common species are *Obolella crassa, Botsfordia* [*Obolella*] *caelata, Hyolithellus micans, Microdis-*

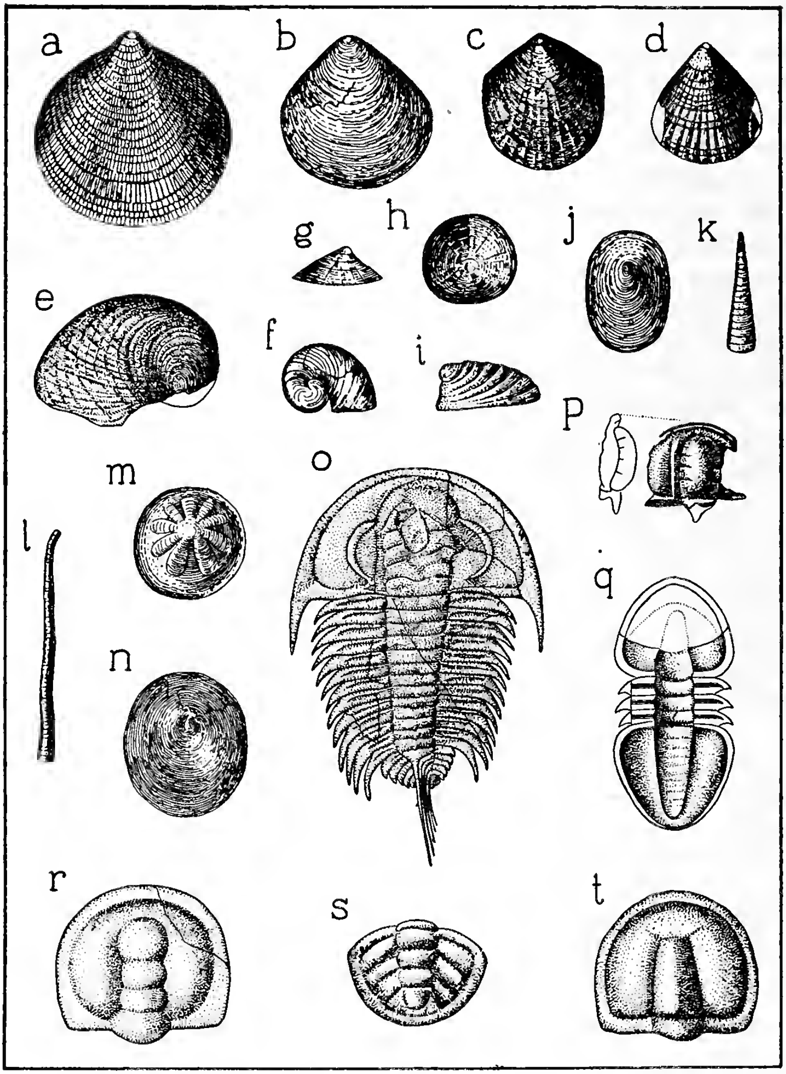

Figure 18 Schodack limestone fossils. (Brachiopods, *a-d;* gastropods, *e-j;* conularids, *k-n;* trilobites, *o-t*). *a, b Obolella crassa,* ventral valve, x 3; dorsal valve, x 2. *c, d Botsfordia caelata,* dorsal valve, x 3½; ventral valve, x 2. *e, f Straparollina primaeva,* left (x 7) and right (x 4) sides. *g, h Scenella retusa,* lateral (x 3) and summit (x 3) views. *i, j Helcionella rugosa,* x 2. *k Hyolithes communis. l-n Hyolithellus micans: l* terminal portion of tube, x 3; *m, n* interior (x 5) and exterior (x 4½) of operculum. *o Elliptocephala asaphoides,* x ⅓. *p Solenopleura nana,* x 1½. *q Microdiscus speciosus,* x 2. *r-t M. lobatus: r,* head, x 13; *s,* pygidium, x 9; *t,* head variation, x 9, (After Walcott)

cus [*Goniodiscus*] *lobatus* and parts of the somewhat larger trilobite *Elliptocephala asaphoides*. The full list follows:

Sponges

Archaeocyathus rarus (Ford)
A. rensselaericus (Ford)

Brachiopods

Acrothele nitida (Ford)
Acrotreta saggitalis taconica (Walcott)
Bicia gemma (Billings)
B. whiteavesi Walcott
Billingsella salemensis (Walcott)
Botsfordia [*Obolella*] *caelata* (Hall)
Lingulella schucherti Walcott
Micrometra (*Paterina*) *labradorica* (Billings)
Obolella crassa Hall
Obolus prindlei Walcott
Yorkia washingtonensis Walcott

Gastropods

Helcionella [*Stenotheca*] *rugosa* (Hall)
Scenella retusa (Ford)
Straparollina [*Platyceras*] *primaeva* (Billings)

Conularids

Hyolithellus micans Billings
Hyolithes communis Billings
H. communis emmonsi Ford
H. impar Ford

Trilobites

Elliptocephala asaphoides Emmons
Microdiscus connexus Walcott
M. (*Goniodiscus*) *lobatus* (Hall)
M. schucherti Walcott
M. speciosus Ford
Olenoides fordi Walcott
Protypus hitchcocki (Whitfield)
Solenopleura nana Ford

Fossils may be collected from the cliffs along the New York Central railroad tracks south of Schodack. Species of *Obolella, Hyolithes* and *Microdiscus* have been seen by the writer in the limestone at the top of the cliff two and a half miles south of Schodack Landing (page 71). Walcott (*ref. cit.*, p. 189, 265) lists from the "limestone 1 mile (1.6 km) below the New York Central Railroad depot at Schodack Landing" the following fossils collected by himself and S. W. Ford:

Brachiopods

Acrotreta sagittalis taconica (Walcott)
Bicia gemma (Billings)
Botsfordia [*Obolella*] *caelata* (Hall)
Obolella crassa (Hall)

Conularids

Hyolithellus micans (Billings)
Hyolithes americanus (Billings)

Trilobites

Microdiscus (*Goniodiscus*) *lobatus* (Hall)
Microdiscus speciosus Ford
Elliptocephala asaphoides Emmons

Ruedemann in his paper on Cambrian and Ordovician fossils ('42, p. 21) cites a new fossil from the black, calcareous Schodack shale underlying the Manlius limestone at the northern extremity of the Becraft Mountain plateau, south of Hudson. Since this fossil, which he considers a seaweed (*Schodackia biserialis* Ruedemann), was found by him nearly 40 years ago occurring quite commonly in the black Mettawee slate at the Mettawee river, Ruedemann suggests the possibility that the shale is a southern representative of the Mettawee slate of Vermont and northern New York.

Trilobites were the dominant form of life of the Cambrian and make up the largest element of the fauna, the brachiopods holding second place. So characteristic are the trilobites that their names have been used to indicate the divisions of the system. The Lower Cambrian rocks of Vermont and Pennsylvania have yielded such striking trilobites as *Olenellus thompsoni,* similar to species which have been observed in beds of the same age in other parts of the world. From these forms this division of the Cambrian has become known internationally as the *Olenellus* beds and the fossil content as the *Olenellus* fauna.

CANADIAN AND ORDOVICIAN SYSTEMS

The rocks of Ordovician age in Wales were classed by Sedgwick as a part of the Middle and the whole of the Upper Cambrian, but Murchison made the type of his Lower Silurian rocks of the same geological age in South Wales. The Silurian system was divided into two parts by Murchison (1835), which were called the Lower and Upper Silurian, a classification that is followed by some even to the present day. Some followed Sedgwick, others Murchison and it was not until after the proposal by Professor Lapworth (1879) of the name Ordovician for the Lower Silurian that geologists in general came to an agreement. The name was taken from the *Ordovices,* an ancient Celtic tribe which at the time of the Roman conquest occupied the territory now included in northeastern Wales and the adjoining parts of England. Great Britain, Sweden, Norway, Denmark and the United States have accepted this classification, but in other European countries the name Silurian is retained as defined by Murchison. In America the name Champlainian for this broad system is also used, a name proposed in 1842 by the geologists of the New York State Survey because of the occurrence of rocks of this system in the Lake Champlain region (New York-Vermont). Nowhere in the world are the Ordovician rocks preserved in such completeness and with so little alteration as in North America, especially in the eastern section. The formations were first studied in greatest detail in New York State, which is therefore regarded as the standard section, and the current names of the formations are those used in New York. In the northern Appalachian region the rocks which consist more often of sandstones and shales have been intensely folded, as seen in the Upper Hudson valley and slate belt country of New York and Vermont and are similar in appearance.

The name *Canadian* was first used as a group name (Dana, 1874) for a series of formations (Lower Ordovician) which were well developed in northern New York and Canada, from which country the name was taken. The separation of this group from the Ordovician as a distinct system has been recently proposed (Ulrich, 1911) and appears to have wide acceptance. The name of the group was retained for the system, which is set off from the Cambrian (or Ozarkian of authors) by a complete break and is also marked at the top by a complete break throughout North America. The waters withdrawn from present land areas at the close of the preceding period returned with a different arrangement in the Canadian period, and the transgressions of the sea, at least in two stages during this period, were more extensive than the transgressions that occurred later in the Ordovician (Lowville and Trenton seas). The period as a whole was one of emergence with deposition over wide areas at certain stages, and it was also a period essentially of dolomite making. The aggregate thickness of Canadian deposits is somewhere around 7000 feet, mostly limestones and dolomites. The greatest thickness in the East is found in the middle and southern Appalachian areas; in central United States, in Oklahoma; in the West, in the Rocky Mountains region of Nevada and Utah. There are also more than 2000 feet of these dolomites and magnesian limestones in western Newfoundland.

In New York State the earliest Canadian (Beekmantown) rock, the Tribes Hill limestone, overlies the Upper Cambrian (Lower Ozarkian of authors) Little Falls dolomite nearly everywhere in the Mohawk valley, but not so far west as Middleville and Newport. The Tribes Hill also does not extend so far north as Saratoga and the exact equivalent of the formation has not been found in the Champlain valley. Depression in the west lasted only a short time. The uplift following tilted the land to the east giving rise to a long-continued submergence in the Champlain valley. The remaining divisions of the Beekmantown limestone are confined to this trough with its prolongations north and south and the Ogdensburg area on the northwest side of the Adirondacks. Upper Canadian beds have been found at intervals in southeastern New York (Wappinger terrane) New Jersey and Pennsylvania, in the last-named state having a thickness of 2000 to about 4000 feet. The strata of Canadian (Beekmantown) age in New York have an aggregate thickness of 1500 to 2000 feet. In the Hudson valley near Albany occurs the Schaghticoke shale (Rensselaer county), graptolite shales constituting the lowest beds of the Canadian, which are not found farther west and are regarded by some as marking the closing stages of the Cambrian. Here, too, the Beekmantown (Canadian) limestone is replaced by a series of shales and sands (Deepkill) of the same age, characterized chiefly by graptolites belonging to the Atlantic realm and similar to or identical with species of Great Britain, Norway and Sweden. A narrow body of water connected with the North Atlantic, called the Levis channel (*see* pages 280, 307) and believed to be distinct from the other seaway, extended from Newfoundland into New York State, entering from the northeast. In this trough thick formations of graptolite shales were deposited.

The *Ordovician system* is separated from the Canadian by a complete break throughout North America due to a withdrawal of the sea at the end of Canadian time. After its return, at several times during the course of the Ordovician period, the retreat of the marine waters was so nearly complete that if any remained it could be only in certain of the now deeply covered basins. The oscillatory movements, that is, the submergence and emergences, throughout the Ordovician were slow and gentle, so that it may be regarded as a period of quiet, with epicontinental seas gradually increasing in size to their greatest expansion in the middle epoch (Lowville and Trenton seas) when the greater part of the southeastern quarter of the continent was submerged. The transgressions were, however, less extensive, certainly, than the Upper Cambrian (Upper Ozarkian) sea and probably also less widely spread than two of the Canadian stages (page 85). During this period, as during the preceding, North America was little above sea level and uplands occurred only along the margins of the continent. These periods, therefore, were characterized to a large extent by limestone building since the seas were receiving less sediments because of the low relief of the surrounding lands. In the Lower Ordovician in several places (as in the Hudson valley in the vicinity of Albany) only deposits of muds and sands that contain characteristic graptolite faunas were laid down. As in the case of similar Beekmantown (Canadian) shales, the fossils of these Ordovician shales indicate a connection with the Atlantic. The Middle Ordovician was a time of limestone-making on a wide scale, the dominant rocks being thin-bedded limestones and shales. During the Upper Ordovician, while the thin-bedded limestones are common, more muds (shales) are found with them, and these sediments occurred in increasing amounts toward the close of the Upper Ordovician with a prevalence of sandstones. The Upper Ordovician of the East consists largely of a thick mass of shales and minor thicknesses of sandstone, representing clastic sediments spread widely over the sea floor. The increase in deposits of muds and sands of this epoch is due probably to elevation of the land, allowing the streams to carry increased loads, and to accompanying shallowness of the sea. These shales and slates extend from the St Lawrence to Tennessee along the Appalachian area and are thickest toward the east. Ordovician deposits have a maximum thickness of several thousands of feet with a limestone value of about 8000 feet, that is, limestones plus the equivalence in limestone of the clastics which are more rapidly deposited. The greatest thickness of limestones is in the southern Appalachian area.

At the end of the period the lands were again drained leaving the outlines of the continent much as they are today. The close of the Ordovician is marked by a time of widespread disturbance and mountain-making, known as the *Taconic Emergence, Disturbance* or *Deformation,* traces of which are found in North America and Europe, especially along the Atlantic slope of each continent. The great masses of sediments that had accumulated in the northern part of the Appalachian trough were subjected to lateral pressure and folded. The Taconic range along the line between New York and New England was upheaved at this time and has given its name to the period of deformation. Its rocks were greatly compressed, folded and metamorphosed and sedimentary beds from the Cambrian to and including the Ordovician were involved. Evidences of this disturbance have been found as far south as Alabama and in Nova Scotia and New Brunswick to the north, but the upheaval does not appear to have extended to the northern part of the Gulf of St Lawrence. In the Hudson valley of New York and in parts of Pennsylvania the strongly folded and eroded Ordovician beds are overlain in some places by Upper Silurian strata, in other places by Middle or Upper Silurian or even Lower Devonian beds and everywhere the unconformity between the two systems, marking the old erosion surface or plane, is well shown although later disturbance has taken place. Metamorphism of the sediments involved in this disturbance was brought about by the heat generated by the folding and by the intrusion of igneous material in many parts of New England and in eastern Canada. The limestones of Vermont were changed into marbles; the mudrocks or shales of Vermont and eastern New York became roofing slates; sandstones were altered into quartzites.

There is no positive evidence that the entire Adirondack area was ever submerged during Ordovician times so the central Adirondacks must have persisted as an island in the Ordovician sea. There were a number of oscillations through the period bringing the land around the island now above sea level, again below. Except for this island formed by the Adirondacks and alternating conditions in its vicinity, New York State was entirely or almost entirely submerged practically throughout Ordovician time after the Lower Ordovician (Chazyan). Some even believe that the Middle Ordovician (Trenton) sea submerged the entire Adirondack area. Limestones characterize the deposits of the earlier Ordovician when the neighboring lands were of low relief. At the same time thick deposits of graptolite shales (Normanskill) were being laid down in the Levis trough farther east. During the latter part of the period when lands were high and erosion more active, forming muds and sands to be washed into the sea, deposits were shales and sandstones. In southeastern New York the so-called "Hudson River" shales and sandstones overlie the Wappinger terrane and in the northern part of the State Canajoharie, Utica and Lorraine shales and sandstones overlie the Chazy, Black River and Trenton limestones.

The Ordovician strata in New York have an aggregate thickness of about 5000 feet, mostly deposited in a shallow sea, even the limestones. These formations were first studied by Ebenezer Emmons, geologist of the Second New York District, and grouped together as his Champlain System, which then included Canadian and some Upper Cambrian (Lower Ozarkian). In Vermont and in the Taconic range of mountains forming the New York-Massachusetts boundary line the rocks are very strongly folded and metamorphosed and very difficult to distinguish. Most American geologists of Emmons' time referred this whole series to the Ordovician. Emmons regarded them as belonging to an older system which he called the Taconic (*see* pages 87, 280) ; and he was in part correct though it is now known that besides the older rocks there are infolded and faulted strata of Canadian and Ordovician age. The discussion that arose over the age of these folded and metamorphosed rocks has been termed the "Taconic Controversy."

In the eastern shale belt or eastern (Levis) trough of the Appalachian geosyncline in New York, the Canadian system is represented by some limestone, the Bald Mountain limestone, and the Deepkill and Schaghticoke shales. Only the Deepkill shale is represented on the Coxsackie quadrangle and the area to the south of it. The Bald Mountain limestone was named (Cushing and Ruedemann, '14, p. 78; Ruedemann, '30, p. 75) from its occurrence in the fine quarries at the foot of Bald mountain in Washington county, and it is suggested (*auth. cit.* '14; '30, p. 96) that this limestone continues through the eastern slate belt and may form a part of the Wappinger terrane in southeastern New York. The only occurrence in the

Capital District is a small outcrop on the top of Rysedorph hill, exposed by erosion (*auth. cit.*, '30, p. 95). The formation has a thickness up to 100 feet. The Schaghticoke shale (Ruedemann, '03), formerly included in the "Hudson River" group, is typically exposed along the Hoosick river at and in the vicinity of Schaghticoke, Rensselaer county, and constitutes the lowest beds of the Canadian in New York State, which do not occur farther west. Lithologically they are similar to the Deepkill beds and are thin, equally bedded, alternating greenish and black shales, with intercalated thin barren limestone bands. Of its occurrence southward, Ruedemann remarks ('42*b*, p. 79): "The horizon has not been observed on the Catskill quadrangle, which, however, by no means indicates its absence there, as the relatively small thickness of the beds (minimum measured 30 feet at Schaghticoke, probably considerably more) will serve to obscure their presence in the much folded mass of shales." This shale is characterized by the presence of the graptolites *Dictyonema flabelliforme* Eichwald var. *acadicum* Matthew and *Staurograptus dichotomous* var. *apertus* Rued. The fauna characterized by *D. flabelliforme* also occurs in Canada and in Europe, where it is considered by some as belonging to early Ordovician (*sensu lato*), by others (as authors in Great Britain) as marking the closing stages of the Cambrian.

The Ordovician system is represented in the eastern (Levis) trough by the Snake Hill shale (at top), Tackawasick limestone and shale, Rysedorph conglomerate and Normanskill shale, the last two formations alone being present in the Coxsackie and Catskill areas. In the Hudson valley the Snake Hill beds form a broad belt of shales between the Normanskill shales and the Wappinger limestone at the bank of the river to the Skunnemunk mountains and has a computed thickness in Orange county of 1500 to 2000 feet which is regarded as a minimum figure considering the width of the belt. These shales, also part of the old "Hudson River" group, received their name from the very fossiliferous exposures at Snake hill (Ruedemann, '12) on the east side of Saratoga lake. In the Capital District there is an estimated thickness of 3000 feet (Ruedemann, '30, p. 118). These beds are lithologically similar to the Normanskill shales but are without the strong development of grits and white-weathering chert beds; argillaceous shales prevail. The black carbonaceous, graptolite-bearing bands occur more frequently than in the Normanskill formation, but the graptolite fauna, comparatively, is much impoverished. The Tackawasick limestone and shale (Ruedemann, '30, p. 115) forms a narrow belt of calcareous shale with Trenton fossils along the southern edge of the Rensselaer grit in the Capital District, where only three outcrops of the formation have been reported. To the south it connects with the "Hudson schist," a broad belt of metamorphosed shales and grits possibly of Normanskill and Snake Hill ages (Ruedemann, '30, p. 116). Kimball ('90) reports outcrops of thin belts of similar limestone in "Columbia county, and they may continue intermittently as far as the Poughkeepsie quadrangle" (Rued., *ref. cit.*, p. 117).

Deepkill Shale

The Deepkill shale is for the most part equivalent in age to the Beekmantown limestones, but the uppermost graptolite zone carries a Chazy fauna (Ruedemann). These deposits were laid down in the Levis trough farther east. The shales, formerly included in the "Hudson River" group were named and described by Ruedemann ('02; '03) from the typical exposure in Rensselaer county, along the Deepkill, a tributary of the Hudson from the east. The Deepkill shales here are exposed in a continuous series of rocks, beginning a quarter of a mile above the hamlet of Grant Hollow in the creek bed and extending to the dam of the reservoir of the Troy waterworks in the Deep Kill gorge. The occurrence, an inlier in the Lower Cambrian rocks, "is the only complete section through the Beekmantown graptolite shale known as yet south of that at Point Levis, near Quebec" (Ruedemann, '30, p. 87; full section given). The rocks of this section have been estimated to have a total thickness of 200 to 300 feet (*ref. cit.*). Dale ('04, p. 33) recorded other Deepkill exposures in the Capital District and gave a rough estimate of the thickness as about 50 feet; but he states that this estimate should be taken as a minimum, "as there is a possibility that some of the green shale without banded quartzites and without fossils belongs to this formation."

The Deepkill shale shows an alternation of limestones with shaly intercalations, sandy shales and grits, thin-bedded shales, grits and limestones and limestones with greenish siliceous shales and black graptolite shale. The deep black, soft graptolite-bearing mud shales are always inclosed in the greenish gray, very hard and thin-bedded siliceous layers. The calcareous bands are very characteristic of these beds. The Deepkill shale and its faunas were fully described by Ruedemann in 1904; the outcrops and faunas of the formation in the Capital District in 1930.

The graptolite shales of the Canadian and Ordovician in New York have been divided into 20 graptolite zones, and the Deepkill shales carry five of these zones with seven subzones. In 1902 Ruedemann divided the Deepkill graptolite shales at the type locality into three zones, as follows, in descending order:

c Zone of *Diplograptus dentatus* and *Cryptograptus antennarius.* Graptolite beds 6 and 7.
b Zone of *Didymograptus bifidus* and *Phyllograptus anna.* Graptolite beds 3, 4, 5.
a *Tetragraptus* zone. Graptolite beds 1 and 2.

Later ('21, p. 119; *see* '30, p. 88), taking into consideration with the Deep Kill section an occurrence near Defreestville and the section at the Ashhill quarry at Mt Merino (Moreno), near Hudson, he found it advisable to make additional zones and divide most of the zones into two or more subzones, since the graptolite faunas of the graptolite beds of each zone show differences in faunal composition that correspond to those recognized elsewhere, notably Great Britain and Sweden. Along the road between Defreestville and West Sand lake, L. M. Prindle discovered (Dale, '04, p. 30) a graptolite zone below the deepest zone exposed at the Deep Kill section which contains forms of the *Clonograptus* zone of the Point Levis series, Quebec (*see* Raymond, '14, p. 523) and Europe. At the Ashhill quarry Ruedemann found ('21, p. 121) an horizon of the zone of *Diplograptus dentatus,* that is distinctly older than either of the two observed at the Deep kill, which he made the subzone of *Climacograptus pungens* and *Didymograptus forcipiformis.* The zones and subzones are as follows (Ruedemann, '21, p. 121):

V Zone of *Diplograptus dentatus*
  c Subzone of *Desmogr.* and *Trigonogr. ensiformis*
  b Subzone of *Phyllogr. angustifolius, Retiogr. tentaculatus*
  a Subzone of *Climacogr. pungens, Didymogr. forcipiformis*
IV Zone of *Didymograptus bifidus*
  b Subzone of *Didymogr. similis, Phyllogr. typus*
  a Subzone of *Goniogr. geometricus, Phyllogr. anna*
III Zone of *Didymograptus*
  b Subzone of *D. extensus, Goniogr. thureaui* } *Didymograptus* beds
  a Subzone of *D. nitidus, D. patulus* }
II Zone of *Phyllograptus typus* and *Tetragr. quadribrachiatus* } *Tetragraptus* beds
I Zone of *Clonograptus flexilis* and *Tetragraptus* }

In reference to the second zone Ruedemann writes ('30, p. 89):

The second zone, that of *Phyllograptus typus* and *Tetragraptus quadribrachiatus,* has not been directly recognized in our section. It is the second zone of the Tetragraptus beds at Point Levis, but the zone is undoubtedly present in the Ordovician [Deepkill] shales of the Capital District, as is evinced by the frequent occurrence of the Tetragrapti in our first and second graptolite beds of the Deep Kill section, which we, in the earlier papers ('02, '04), called the Tetragraptus beds—or zone on account of these Tetragrapti. Since the true Tetragraptus beds at Point Levis are below this zone, we have termed the first two zones at the Deep kill the Didymograptus beds.

For lists of the Deepkill graptolites given according to zones the reader is referred to Ruedemann, 1930 (p. 88-94). A complete list from all zones follows:

Bryograptus lapworthi Rued.
B. pusillus Rued.
Callograptus cf. *diffusus* Hall
C. salteri Hall
Climacograptus? antennarius Hall
C. pungens Rued.
Dendrograptus flexuosus Hall
D. fluitans Rued.
Desmograptus cancellatus Hopkinson
D. intricatus Rued.
D. succulentus Rued.
Dichograptus octobrachiatus Hall
Dictyonema furciferum Rued.
D. rectilineatum Rued.
Didymograptus acutidens Lapworth
D. bifidus Hall
D. caduceus Salter
D. caduceus mut. *nana* Rued.
D. ellesae Rued.
D. extensus Hall
D. filiformis Tullberg
D. gracilis Törnquist
D. incertus Rued.
D. nanus Lapworth
D. nicholsoni var. *planus* Elles and Wood
D. nitidus Hall
D. patulus Hall
D. similis Hall
D. törnquisti Rued.
Diplograptus dentatus Brgt
D. inutilis Hall
D. laxus Rued.
D. longicaudatus Rued.
Glossograptus echinatus Rued.
G. hystrix Rued.
Goniograptus geometricus Rued.
G. perflexilis Rued.
G. thureaui McCoy
Loganograptus logani Hall (?)
Phyllograptus angustifolius Hall
P. anna Hall
P. ilicifolius Hall
P. typus Hall
Ptilograptus geinitzianus Hall
P. plumosus Hall
P. tenuissimus Hall
Retiograptus tentaculatus Hall
Sigmagraptus praecursor Rued.
Strophograptus trichomanes Rued.
Temnograptus noveboracensis Rued.
Tetragraptus amii Elles and Wood
T. clarkei Rued.
T. fructicosus Hall
T. lentus Rued.
T. pendens Elles
T. pygmaeus Rued.
T. quadribrachiatus Hall
T. serra Brgt
T. similis Hall
T. taraxacum Rued.
Trigonograptus ensiformis Hall

In addition to graptolites Ruedemann records two very large brachiopods *Eunoa accola* Clarke and *Lingula quebecensis* Billings (*ref. cit.*, p. 94) and a smaller form *Paterula minuta* Rued. ('34, p. 79). To these forms are added the small crustacean *Caryocaris curvilatus* Gurley, the worm tube *Serpulites interrogans* Rued. ('30, p. 90, 91), the eurypterid *Pterygotus deepkillensis* Rued. ('34a, p. 379) and *Caryocaris tridens* (Gurley) (*auth. cit.*, '34, p. 129). The small crustaceans are peculiar to the graptolite beds of eastern and western North America, and also Great Britain.

To the south of our area on the Catskill quadrangle, Ruedemann reports the Deepkill shale from four localities and states: "It is, however, undoubtedly present in more localities or along all the Cambrian-Ordovician boundaries, but fails to be recognized by being infolded with the Normanskill beds or broken up into slices by the faulting" ('42*b*, p. 81). He makes no estimates as to thickness. The only large fauna (page 98) collected is that from the *Ashhill quarry* horizon, "extending from Ashhill quarry near the south shore of South bay at Hudson along the east foot of Mt Merino to the southeast corner of the mountain, where it is separated from the Normanskill by a fault" (*ref. cit.*, p. 82). "The lithologic character of the beds at the Ashhill quarry is strikingly similar to that of the Deep Kill beds, the bands of black graptolite shales being also intercalated in thicker masses of greenish silicious shales" (*auth. cit.*, '04, p. 499).

On the Coxsackie quadrangle the Deepkill beds outcrop in five localities, only one, the Stuyvesant cut, at all fossiliferous. The other localities show mostly unfossiliferous, greenish, siliceous shales. About two miles north-northeast of Athens the point directly opposite Priming hook is formed by a mass of Deepkill contorted and slickensided and indicating shoving from southeast to northwest. Several small anticlines are shown. The beds here consist of grit and greenish shale or slate, black and green chert and thin quartzites. A four-inch breccia band consisting of greenish (mostly) and light gray chert is also seen. Even when the repetitions are taken into account, there is a great thickness of Deepkill here and much of it is the green siliceous shale or slate. Three-quarters of a mile north of Fourmile point and north-northeast of Stockport station (across the river) another point is formed by Deepkill consisting of the grit and greenish gray argillaceous shale with thin greenish quartzite bands and numerous bands of quartz. In the vicinity of Fitch's wharf to the north these same greenish and gray, much slickensided shales again outcrop.

The largest area of exposures, mainly of green shales and chert, extends from the ferry landing in Coxsackie north along the shore for two and a half miles. The beds in this whole area are contorted and crumpled. At the ferry landing the beds consist of greenish shales and chert. A quarter of a mile north (opposite lower Nutten hook, just before the road takes a northeast direction) the Deepkill outcrops between the road and the river and above the road. The beds here are largely greenish shale, in places cherty, the chert fine-grained. In the bank above the river at the north end of this outcrop is shown a two-foot belt of thin-bedded limestone and shale, broken by a NW-SE fault with a resultant fault breccia. To the south is found a two-foot bed of chert and much chert throughout the greenish shale. Chert also occurs above the thin-bedded limestone. *Didymograptus nitidus* was found here. In the hill west of the four corners, one-half mile north, are seen heavy green chert beds and thin beds with black phosphate pebbles in the greenish shale and chert. The pebble bed is one inch thick. In a gully an eighth of a mile north (east of the main road) a four-foot bed of thin limestones is seen interbedded with the green siliceous shales and cherts. To the east along the river the beds form a cliff of crumpled and slickensided siliceous shale with interbedded black beds and an abundance of thin chert bands. At the end of the lane north, limestone bands two and three inches thick are seen again. Along the river road north, in the ridge on the east side opposite the cemetery, was found Deepkill limestone with green and black chert and green and black siliceous shales, the latter quite fossiliferous and containing *Didymograptus patulus* and *D. nitidus,* characteristic of lower Deepkill beds. The chert has weathered quite white here. A piece of a pebble bed of brecciated chert was found loose in the east slope of the hill. Green chert and limestone appear in a cut at the west side of the road just north of the cemetery. Less than a quarter of a mile beyond the cemetery the road turns east toward the river. Near the foot of the hill, along the road, are green and black siliceous shales with abundant thin-bedded limestone, brecciated in places. A pebble bed also is shown.

An excellent exposure of Deepkill greenish shale and chert with some grit occurs at Stuyvesant Falls on the Kinderhook quadrangle (map 2), almost due east of Nutten hook and about three-quarters of a mile beyond the boundary of our quadrangle. These beds, exposed by erosion, form the lower falls at the State highway bridge and, together with the Schodack (page 70) constitute an inlier within the Normanskill area. Here is shown a good example of quartzite produced by crystallization of the chert (Ruedemann and Wilson, '36, p 1542).

The best section in the Deepkill on the Coxsackie quadrangle is that found in the railroad cut south of the station at Stuyvesant (figure 19). The Deepkill beds here consist of dark greenish, siliceous shale with interbedded black shale bands and intercalated thin-bedded siliceous limestones, two to three inches thick. There are also, in the northern end of the cut, seams of greenish gray siliceous shales, giving the appearance of chert, which do not, however, weather white. Three feet of this rock are shown resting on a bed of thin-bedded limestone with more cherty rock beneath. Farther south in the cut are more than seven feet composed of thin limestone beds, one inch and over thick, alternating with shale. Beneath this bed follow five feet of greenish gray shale; one and one-half feet of limestone and shale; two feet of greenish gray shale; five feet of

Figure 19 Deepkill shale at the south end of the cut along the New York Central railroad tracks, south of the Stuyvesant railroad station. View southeast. Note the characteristic calcareous bands near the figure. (Photograph by E. J. Stein)

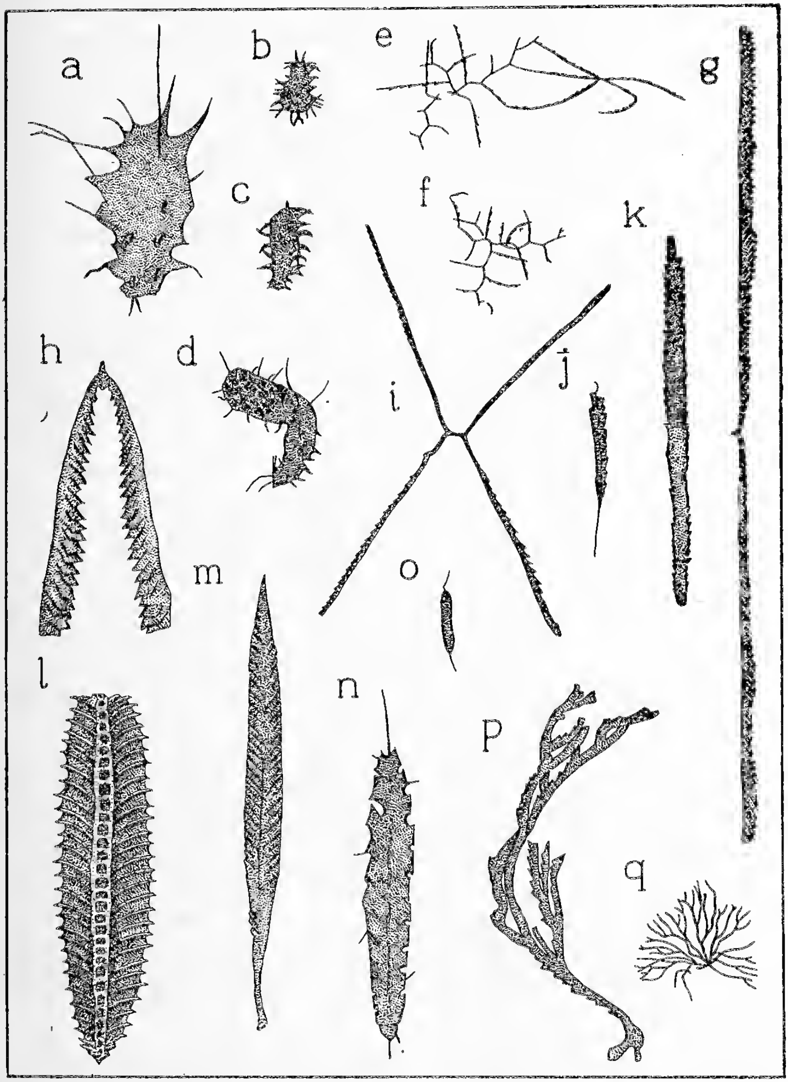

Figure 20 Deepkill shale graptolites. *a Glossograptus hystrix*, x 7. *b* the same, multispinous, x 2. *c, d Retiograptus tentaculatus*, x 2. *e, f Goniograptus geometricus*, mature and half-grown forms. *g Didymograptus nitidus*. *h D bifidus*, x 2. *i Tetragraptus quadribrachiatus*. *j, k Diplograptus dentatus*, young and mature forms. *l Phyllograptus angustifolius* x 2. *m Trigonograptus ensiformis*. *n, o Climacograptus pungens*, x 4 and average size. *p, q Dendrograptus flexuosus*, fragrant, x 2, and young form.

alternating limestone and shale, some of the beds three inches thick; two feet of shale. The limestone bands in these beds are siliceous and in one place all have weathered fibrous. The brownish beds seen are due to surface weathering of the greenish gray shale. The beds in this cut are contorted and broken; going south a crumpled anticline is seen with green shale forming the core. The beds stand nearly vertical, with a dip up to 80° or more. In one place the strike was N. 55° E., but the strike is changeable and turns with the folding. No accurate measurement can be made, but even allowing for repetition there are undoubtedly more than 200 feet represented in this section.

The Stuyvesant fauna apparently comprises all the Deepkill horizons below the Ashhill beds, so that a full series of the Deepkill shales undoubtedly is represented in this sector of the Hudson valley. The fauna (*see* figure 20) consist of:

Desmograptus cf. *succulentus* Rued.
Didymograptus bifidus (Hall)
D. nitidus (Hall)
D. patulus (Hall)
Goniograptus geometricus Rued.
G. thureaui McCoy *postremus* Rued.
Phyllograptus angustifolius Hall
P. anna Hall
Tetragraptus fructicosus (Hall)
T. pendens Elles
T. quadribrachiatus (Hall)
T. taraxacum Rued.

Besides the graptolites have been found the brachiopods *Lingula quebecensis* Billings, *L. philograptolitha* Rued. and *Orbiculoidea scutulum* Rued. and the trilobite *Shumardia pusilla* (Sars). (*See* Ruedemann, '34, p. 77, 81, 97.)

In the Ashhill quarry, along the east foot of Mt Merino, just south of our area, there are exposed 50 feet of alternating thin siliceous limestone bands and greenish gray hard siliceous slate with a few interbedded very thin, black, graptolite-bearing, shale bands. No graptolite layers are at present accessible as this road metal quarry has not been worked in years, but the New York road, south of the Ashhill quarry, has opened up various small outcrops in Deepkill shale. The Ashhill quarry has furnished the following graptolites (Ruedemann, '04, p. 499):

Climacograptus pungens Rued.
Dendrograptus sp.
Didymograptus cuspidatus Rued.
D. filiformis Tullberg
D. forcipiformis Rued.
D. gracilis Törnquist
D. spinosus Rued.
Diplograptus dentatus Brgt.
D. laxus Rued.
Glossograptus hystrix Rued.
Goniograptus perflexilis Rued. mut.
Phyllograptus angustifolius Hall
Ptilograptus plumosus Hall
Tetragraptus pygmaeus Rued.
T. quadribrachiatus Hall
T. taraxacum Rued.
Trigonograptus ensiformis Hall
Retiograptus tentaculatus Hall

In his discussion of the graptolites of the Ashhill quarry horizon Ruedemann writes (*ref. cit.*, p. 500):

A notable feature of this faunule is the considerable number of species not observed elsewhere, or in the preceding and succeeding horizons. Some of these forms, as *Didymograptus cuspidatus* and *D. spinosus,* represent, moreover, peculiar types and have no closely related congeners. Other species, as *Diplograptus laxus* and *Climacograptus pungens,* which are new and very rare in the Deep kill beds with *Diplograptus dentatus,* appear here in great profusion. These facts characterize the fauna as constituting a distinct subzone of the zone with *Diplograptus dentatus.*

In his recent report on the Catskill quadrangle ('42*b,* p. 85) he adds, "It is worth noting that since the Ashhill fauna was described *Didymograptus forcipiformis* . . . has also been found in the Deepkill fauna at the Deep kill, associated with *Didymograptus nitidus, Phyllograptus anna* mut. *ultimus* and *Climacograptus* sp. nov., thus indicating the presence of the Ashhill quarry horizon or a subhorizon, immediately preceding it, in the Deep Kill section."

From an outcrop along the New York State road, a mile southwest of the Ashhill quarry, Ruedemann reports ('42, p. 26, 27; '42*b,* p. 86), in addition to a faunule distinctly the same as that of the Ashhill quarry, two small eurypterids, *Dolichopterus antiquus* Rued. and *Pterygotus* (*?*) *priscus* Rued. Hitherto only one eurypterid, *Pterygotus deepkillensis* Rued. (page 92) was known from the Canadian system.

Ruedemann (*ref. cit.,* p. 87) notes as an interesting feature of the Deepkill beds that, southward along the foot of Mt Merino, "the hard silicious slate becomes so fine-grained and compact that it assumes the character of dark-green to gray chert." This chert was found by Ruedemann and Wilson ('36) to carry radiolarians, exactly as the Normanskill chert beds do; and from these beds they described (p. 1566-80) the following forms:

Cenosphaera antiqua R. & W.
Choenicosphaera multispinosa R. & W.
Xiphosphaera parva R. & W.
Acanthosphaera minuta R. & W.
Heliosphaera venusta R. & W.
Halioma antiquum R. & W.
Dorydictyum minutum R. & W.
Doryplegma priscum R. & W.
Spongotrochus primaevus R. & W.

The writer has noted (page 93) the presence of such green and gray-green cherts in the Deepkill beds on the Coxsackie quadrangle. Microscopic study of these cherts would undoubtedly reveal radiolarians, as have the Mt Merino cherts just to the south of this area.

Normanskill Formation

The Normanskill formation was designated the Normanskill shale by Ruedemann in 1901 for beds typically exposed at Kenwood, along the Normanskill, a tributary of the Hudson river just south of Albany. These beds, in part equivalent in age to the Upper Chazy limestones, were deposited in the Levis trough farther east and consist of chert, grit and shale, the first two predominating. Dale, under the names "Hudson shale, grit and chert" ('99, p. 185-90; '04, p. 34-39) has given an elaborate description of the petrographic character of these rocks and Ruedemann has given a full list of the fauna ('08, 13-15; '30, p. 99-101).

South of the Coxsackie quadrangle area the belt of the Normanskill beds stretches along both sides of the Hudson river on the Catskill quadrangle and southward, on the east side forming a belt several miles wide. North of the Coxsackie area the belt continues on both sides of the river to the area about Albany; northward, farther to the east and west, with an intervening belt of the Snake Hill shale (*see* Ruedemann, '30, map). On the Coxsackie quadrangle the Normanskill belt is uninterrupted on the west side of the river but largely fails to appear on the east side between the city of Hudson and a point about a mile and a half south of Schodack Landing, due to the fact that the Cambrian beds have been carried westward by the overthrust (page 281). A small exposure occurs under the overthrust Cambrian about one mile north of Stuyvesant, in a cliff along the railroad tracks. In a similiar relationship, it occurs along the tracks for a mile and a half north of Poolsburg. East of the Stottville-Columbiaville-Stuyvesant area, mainly on the Kinderhook quadrangle, is a "fenster" or window (*see* Ruedemann, '09, p. 191) of Normanskill within the overthrust belt of Cambrian. Farther east it appears again in normal succession (page 292).

In the slate belt of eastern New York and western Vermont, Dale ('99, table facing p. 178) assigns 500+ feet to the "Hudson grits," 400 or less feet to the "Hudson white beds" (chert), 50+ feet to the "Hudson shales" and 100+ feet to the "Hudson red and green shale." Ruedemann ('14, p. 91), on the west side of Willard mountain on the Schuylerville quadrangle, estimates as follows: grit, 500+ feet; white beds, 400± feet; shale, 100± feet. This estimate is probably a minimum since Ruedemann and Wilson have since estimated a total thickness of chert of about 600 feet in exposures on the southwest spur of Mt Rafinesque and about 400 feet in the chert locality east of Fly Summit, Washington county ('36, p. 1542). In his Capital District bulletin Ruedemann describes the Normanskill formation as a great mass of probably 2000 feet consisting of "mostly dark gray to black argillaceous shales, but also red and green shales and heavy beds of chert and grit" ('30, p. 97). The chert, he notes, occurs in beds two to 10 or more feet in thickness, the grit beds ranging in thickness from two to 30 feet. Dale gives an estimated thickness of

1200 to 2500 feet ('04, p. 37) for the "Hudson formation" of Rensselaer county, but this includes also the Snake Hill formation, the Tackawasick shale and limestone and the Rysedorph conglomerate (Ruedemann, '30, p. 99). Ruedemann concludes from both his and Dale's estimates that 1000 feet may be considered as a minimum for the thickness of the Normanskill formation (*ref. cit.*). Ruedemann in his Catskill bulletin ('42*b,* p. 88, 107) notes an exposure in the lower Roeliff Jansen kill of a hundred feet of black shale and concludes that this occurrence and the increased thickness noted for the chert in Washington county (see above) "suggest greater thicknesses than had been conjectured before. Considering the width of the Normanskill belt, attaining 10 miles, with a further large portion buried under the Helderberg plateau on the west and the fact that only part of the shale is exposed, as owing to its incompetent character it is usually deeply eroded and buried by drift, it is probable that more shale is connected with the formation than appears on the surface" (*ref. cit.*).

From earlier studies of the Normanskill beds Ruedemann had concluded that the grit was at the base of the formation ('14, p. 89). Dale, also, would have placed the grit at the base except that he found "that these grits do not always occur at the contact with undoubted Cambrian rocks" ('99, p. 294). More recent field work, particularly in connection with the chert problem (Ruedemann and Wilson 1936), in some of which the writer was associated with him, has led Ruedemann to revise his conclusions (*ref. cit.,* p. 1540), since the studies afforded "clear evidence of the older age of the chert and the younger age of the grit, although here again the structure [overturned syncline] of Mt Merino would suggest the opposite" ('42*b,* p. 89). The two belts are more distinct and sharply separated on the Catskill quadrangle than farther to the north, the chert belt at the east adjoining the Lower Cambrian belt, the grit belt at the west. To these two divisions Ruedemann has given the names *Mount Merino chert and shale* and *Austin Glen grit and shale* (*ref. cit.*). The divisions are justified by the evidence of their relationship, the presence of black chert pebbles in arkosic layers of the grit, as at the Broomstreet quarry at Catskill and the graptolite faunas. The Mt Merino beds contain "the older elements, as *Nemagraptus gracilis,* indicative of the lower Normanskill beds, while those of the Austin Glen beds do not carry these forms that have been recognized in the homotaxial beds of Great Britain as marking the older horizon" (*ref. cit.,* p. 90). As Ruedemann points out, the grit and chert are nowhere interbedded on a large scale and where they come together (as along the road south of Glasco) the grit in its calcareous, fine-grained character indicates transitional conditions. The two belts, due to folding and thrust-faulting, are not always sharply separated, and a belt of chert may appear in the grit belt as scattered small belts of grit are found in the chert belt.

The *Mount Merino chert* was described by Dale ('99, p. 185) as "white-weathering chert" or "white beds" of the "Hudson shales." He refers to it as "a silicious and feldspathic slate," formed probably from "a feldspathic mud, with quartz fragments and muscovite scales" (p. 186). Cushing and Ruedemann ('14, p. 85, 86) and later Ruedemann ('30, p. 97) considered that the chert is indurated shale. It is a most striking and characteristic constituent of the Normanskill and has been fully described, lithologically, structurally and faunally, by Ruedemann and Ruedemann and Wilson who have discarded the above view in favor of the primary origin of most of the chert and conclude ('36, p. 1545-48, 1563) that for the larger part it is a deep sea deposit formed in the abyssal depths of the middle of the Appalachian geosyncline. Due to their competent character erosion has left them forming the backbone of prominent hills through the Hudson valley, such as Flint Mine hill south of West Coxsackie and Mt Merino and Blue hill south of Hudson. Ruedemann calls attention to these ridges in his Capital District bulletin ('30, p. 97) and points out that, while well exposed in several localities, as south of Glenmont, they do not form "such outcrops or even ridges as they do on the Schuylerville quadrangle to the north, for instance on Willard mountain."

The color of the Normanskill chert is also discussed in detail by Ruedemann and Wilson (*ref. cit.*, p. 1543-45). They find that it is of various colors and that while the Deepkill chert is everywhere gray-green,

The Normanskill chert is found in associations with black and green, red and green, as well as black alone and green alone. The most common is green, although, in Washington county, large thicknesses of red are associated with green. Black chert is found in great quantity at Stockport and at Van Wie's Point, in both places somewhat argillaceous and carrying graptolites. Masses of red chert are found between Glasco and Kingston, between Ghent and Chatham Center, in Mt Rafinesque, and in Washington county in the slate belt. Beds of alternating black and green bands crop out at Chittenden Falls and Stuyvesant Falls. In many places, the red and green can be seen grading into each other along the strike of a single bed, so that the green chert appears as lenses in the red.

The railroad cut, along the Castleton spur, south of Schodack Landing, the finest exposure on the Coxsackie quadrangle, shows dark green and black chert (figure 21). The studies of Ruedemann and Wilson have brought out the fact that black chert is actually green chert in which there is a considerable amount of absorbed carbon; the blackest chert, as that of the Stockport (Kinderhook quadrangle) and Van Wies Point (Albany quadrangle) type, contains carbonized graptolite remains. Much of the black color of the chert is due to the presence of argillaceous material. In banded black and green chert, as that seen at Stuyvesant and Chittenden Falls (Kinderhook quadrangle) "the black is like the green except for larger amounts of opaque (carbon) material, strung out in lenses along bedding planes" (p. 1545). Ruedemann and Wilson quote Davis (1918) as authority for the derivation of green and gray cherts by decoloration of cherts originally red. "Red cherts, where iron-oxide is dissolved out by circulating water, become leached and of greenish color. Greenish cherts, therefore, often show residual cores of red chert" (*ref. cit.*). Dale thought the white weathering of the Normanskill chert might be due either to kaolinization of "a fine feldspathic cement" ('99, p. 186) or to loss of carbon on kaolinization ('04, p. 36). Thin sections do not show the presence of such a cement. From a study of the chert of more than a hundred localities, Ruedemann and Wilson found that only the surfaces of chert exposed to the light had become white and suggest (*ref. cit.*) that "it is possible that the white-weathering of the chert is, in part, a bleaching or photo-chemical effect, if it is not merely the result of selective weathering, which produced a porous condition (as proved with a touch of the tongue when the specimens are dry)."

From the type locality of the Mount Merino beds, in a road metal quarry at the north side of Mt Merino showing an alternation of indurated green slate with black graptolite-bearing shales, the following fauna has been collected (*see* Rued., '01, p. 550; fauna, '08, p. 13):

Azygograptus ? simplex Rued.
Climacograptus bicornis Hall
C. modestus Rued.
C. scharenbergi Lapworth
Corynoides gracilis mut. *perungulatus* Rued.
Cryptograptus tricornis (Carruthers)
Dicellograptus divaricatus Hall
D. gurleyi Lapworth
D. sextans (Hall)
D. sextans var. *exilis* Elles & Wood
D. sextans var. *perexilis* Rued.
Dicranograptus nicholsoni var. *diapason* Gurley
D. nicholsoni var. *parvangulus* Gurley
D. ramosus (Hall)
D. spinifer Lapworth
D. spinifer var. *geniculatus* Rued.
Didymograptus sagitticaulis (Hall) Gurley
D. serratulus Hall
D. subtenuis (Hall)
Diplograptus angustifolius Hall
D. (*Glyptograptus*) *euglyphus* Lapworth
D. (*G.*) *euglyphus* var. *pygmaeus* Rued.
D. (*Orthograptus*) *foliaceus* var. *incisus* Lapworth

D. (*O.*) *foliaceus* var. *acutus* Lapworth
Glossograptus ciliatus Emmons
G. ciliatus var. *debilis* Rued.
G. whitfieldi (Hall)
Lasiograptus bimucronatus Nicholson
L. mucronatus (Hall)
Leptograptus flaccidus mut. *trentonensis* Rued.
L. flaccidus var. *spinifer* mut. *trifidus* Rued.
Nemagraptus gracilis (Hall)
N. gracilis var. *linearis* Rued.
Thamnograptus capillaris (Emmons)

This list contains more than half of some 60 species of graptolites reported from the Normanskill of New York. Clinton Kilfoyle, of the Museum staff, has recently (1937) collected a new graptolite from these beds, *Lasiograptus pusillus* Ruedemann ('42*b*, p. 100). Ruedemann has reported altogether 13 graptolite localities from the Mount Merino beds on the Catskill quadrangle (*ref. cit.*) and three species not so far found at Mt Merino have been added to the above list: *Climacograptus caudatus* Lapworth, *C. eximinus* Rued. and *C. parvus* Hall. Ruedemann ('34, p. 79ff.) also reports from Mt Merino, in addition to the graptolites the brachiopods *Leptobolus walcotti* Ruedemann, *Paterula amii* Schuchert and *Schizotreta papilliformis* Ruedemann and the sponges *Pyritonema rigidum* Ruedemann ('25, p. 37) and *Teganium merino* Ruedemann ('42 p. 23), the latter recently added to the collection by Clinton Kilfoyle. A new species of eurypterid *Hughmilleria prisca* Ruedemann ('34*a*, p. 375) has been obtained in the Normanskill (Mount Merino) shale at Glenmont, Albany county. Ruedemann and Wilson (1936) have reported 23 radiolarians from the Normanskill cherts which they regard as undoubtedly only a fraction of the fauna. The larger faunas were reported from the radiolarite from Fly Summit, Washington county, and an outcrop a mile west of Ghent, Columbia county (Kinderhook quadrangle); but two species are listed (*ref. cit.*, p. 1567, 1570) from the Catskill quadrangle at Glasco, Greene county: *Cenosphaera pachyderma* Rüst and *Stylostaurus hindei* R. & W. (Glasco sole locality).

The *Austin Glen grit* member was named from the outcrop in Austin glen, in the Catskill valley near the village of Catskill, where there is a magnificent exposure (355 feet across the strike) of grit with thin shale intercalations. Individual beds of grit measure 12 feet in thickness (Ruedemann, '42*b*, p. 102). The petrographic character of the grit, described by Dale, agrees with the macroscopic characters discussed below and both point to an abundance of fairly fresh material carried into the sea by streams from the weathered surface of near-by land. Dale's description follows ('99, p. 187):

The Hudson grit is a rock so marked in its characteristics as to be easily identified. It is coarse, grayish, sandy looking. Fresh fracture surfaces are very dark, and show glistening glassy quartz grains and, very frequently, minute pale-greenish slaty particles. Under the microscope, it consists of angular grains of quartz, orthoclase, plagioclase and scales of muscovite, probably clastic. The cement contains not a little carbonaceous matter, secondary calcite and pyrite . . . The marked features are the heterogeneity of the fragments, their irregular size, angular outline and usually the absence of any arrangement in them. Chlorite is rarely present. . . .

A further peculiarity of the Hudson grits is that they contain particles of various fragmental rocks, showing that they were derived from the erosion not only of older granites and gneisses, but of sedimentary rocks of Ordovician or pre-Ordovician age . . . They consisted of shale, micaceous quartzite, calcareous quartzite, limestone or dolomite, slate and shale.

In the Broomstreet quarry in Catskill Ruedemann (*ref. cit.*) records over 100 feet of grit with individual beds reaching a thickness up to 35 feet. Here also are seen several arkosic conglomeratic beds which contain, besides feldspar crystals, large rounded quartz grains and mud pebbles, pebbles of black and green chert which indicate the earlier deposition of the Mount Merino beds (*see* page 102). The abundance of mud pebble layers is noted here and elsewhere, some found on the bedding planes, others intraformational. Of this feature Ruedemann writes (*ref. cit.*, p. 102):

These occurrences give the impression that the mud pebbles forming the conglomerate were piled up by small eddies or crossing waves on the sandy bottom of the sea . . . The crowded clay pebbles on the bedding plane. . . . may well be of the nature of "Ton-Gallen," as the Germans call them; clay-balls formed by the breaking up of thin clay seams on the sandy tide-flats, that are broken up by sun and wind and roll up (Häntzschel, '36, p. 341). . . . Larger mud pebbles, up to half a foot in diameter, are often seen in the grit, as in the road-metal pit along the road north of Catskill. . . . These mud pebbles appear to have been clay balls that rolled along with the current upon the sandy bottom, as one sees them do today on the bottom of rivers or bays.

Ruedemann notes the hundredfold repetition of alternating grit and shale exposed along the New York Central tracks from Hudson to the southern end of the Catskill quadrangle and beyond. He reports 100 feet of shale and grit exposed just north of Tivoli station, with grit beds up to 10 feet in thickness, individual grit beds more than 30 feet thick south of Madalin and 100 feet of solid grit at the mouth of the Roeliff Jansen kill at Linlithgo (*ref. cit.*, p. 107); and concludes that these and other exposures clearly indicate that the Austin Glen member is an exceptional mass of grits and shales that reaches 500± feet in thickness. "The infinitely alternating beds of grit and shale, the lenses of mud-pebbles, the cross-bedding, the large mud balls and the mud flow structure altogether give the impression that this formation was deposited in shallow water, probably near shore, where the velocity of the currents was frequently and rapidly changing, the slow currents depositing black and gray mud, the faster ones sandstone and grit" (*ref. cit.*, p. 108). On the Catskill quadrangle at the southern margin, owing to the great thickness of this member, it forms a broad belt eight to 10 miles wide. In this connection Ruedemann remarks, "As a glance at the southern margin of the Capital District map (1930) will show, part of the belt is buried under the Helderberg plateau" (*ref. cit.*). Owing to their hardness, massiveness and resistance to erosion the grit beds form hills, ridges and protruding ledges while the equally thick shale masses are usually buried in valleys and under drift. Also, while pure shale is merely intensely crumpled by orogenic forces, the competent thick grit beds bend in fine upstanding or overturned folds, excellent examples of which are seen both on the Coxsackie and Catskill quadrangles, in the latter area particularly well shown along the New York Central tracks south of Hudson.

In discussing the fauna of the Austin Glen beds Ruedemann writes (*ref. cit.*):

Animals are not likely to flourish on bottoms of moving sand, often overwhelmed by inflows of mud. Fossils are therefore exceedingly rare in the Austin Glen beds. They consist of seaweeds, graptolites and eurypterids. The seaweeds occur as black irregular carbonaceous patches. They were originally described as sponges (*Rhombodictyon*) by Whitfield (1886), but later recognized as plant remains (Clarke and Ruedemann, 1912, p. 412).

The *graptolites* occur only very rarely and in small faunules in the black shales of the Austin Glen member. Occasionally one sees also a few widely scattered graptolites, mostly broken rhabdosomes of *Climacograptus bicornis*, on the bedding plane of the grit beds.

From Austin glen Ruedemann reports the following graptolites, collected by G. H. Chadwick of Catskill and others (*ref. cit.*, p. 115):

Climacograptus bicornis Hall
C. bicornis var. *peltifer* Lapworth
Dicellograptus cf. *gurleyi* Lapworth
Dicellograptus sp.
Glossograptus whitfieldi (Hall)

The largest graptolite faunule, that of the Broomstreet quarry, was discovered by Chadwick in black shale, and later associated eurypterids were collected by Ruedemann. This graptolite faunule cited by Clarke and Ruedemann ('12, p. 412), lacks the characteristic elements of the lower Normanskill beds (Mount Merino fauna), especially such prevailing forms as *Nemagraptus, Dicranograptus* and *Dicellograptus*. The faunule consist of

Climacograptus bicornis Hall
C. bicornis var. *peltifer* Lapworth
Cryptograptus tricornis (Carruthers)
Dicellograptus gurleyi Lapworth

The eurypterids found associated with the graptolites in the Broom-street quarry constitute the oldest true eurypterid fauna known (Clarke and Ruedemann, '12, p. 413ff.). It consists of

Dolichopterus breviceps C. & R.
Eurypterus chadwicki C. & R.
Eusarcus linguatus C. & R.
Pterygotus ? (Eusarcus) nasutus C. & R.
P. normanskillensis C. & R.
Stylonurus modestus C. & R.

Later ('34*a*, p. 379) Ruedemann reported *Pterygotus normanskillensis* from the Austin Glen grit and shale at Kenwood, Albany county and he has recently ('42, p. 28) described a new species, *Eurypterus decipiens,* from the Normanskill grit along the Onesquethaw creek, near the base of Callanan's quarry, South Bethlehem, Albany county. Of the association of eurypterids with graptolites Ruedemann writes ('42*b,* p. 116):

> This strange and rare co-occurrence of planktonic graptolites with eurypterids has played a prominent role in discussions on the habitat of eurypterids. The fact that both the very fragmentary eurypterids and the few graptolites occur in the Austin Glen member, the grit of which points to near-shore conditions of deposition, would seem to mark the assemblage as produced by accidental washing of planktonic graptolites on littoral deposits, perhaps of deltaic nature. This would make the whole occurrence a very exceptional one.

Of the 20 graptolite zones (*see* page 90) two (8 and 9) are represented in the Normanskill formation, that of *Nemagraptus gracilis* and that of *Corynoides gracilis* which is considered of Black River age (Ruedemann). Both these zones are found in the Mount Merino member; the Austin Glen member shows only a poor representation of graptolites but apparently carries only species of the upper zone. Above this last zone in the Mohawk valley is a graptolite zone (10, *Cryptograptus tricornis insectiformis* Ruedemann) of Snake Hill (Trenton) age (*see* Ruedemann, '08, p. 29; '21, p. 122, 130; '30, p. 102, 103). "This zone is distinguished from the lower zone by the reduction in species and individuals of the genera *Dicellograptus, Dicranograptus* and *Didymograptus* and the presence of *Diplograptidae,* especially the genera *Diplograptus* and *Climacograptus*" (*auth. cit.,* '30, p. 103).

On the Coxsackie quadrangle the chert and grit members of the Normanskill formation are not so distinctly separated as on the Catskill quadrangle to the south, due to folding and overthrusting. With few exceptions the grit belt occupies the west side of the Hudson passing under the Helderberg formations to the west and extending in a roughly north-northeast to south-southwest direction. On the east side it occurs under the overthrust Cambrian beds along the railroad tracks north of Stuyvesant and north of Poolsburg, widening out northward into a broad belt from a point about a mile south of Schodack Landing. The chert belt, which lies to the east south of our area is exposed in the vicinity of Hudson, west of the thrust fault, but is largely covered elsewhere by the overthrust Cambrian. However, it reappears in its normal position, in the overthrust mass to the east of our area (map 2) on the Kinderhook quadrangle (radiolarite; Chatham Center-Ghent line). The belts would appear then to have a north-northeast to south-southwest direction. Chert is found associated with the grit and dark shales of the Austin Glen member south of Schodack Landing in the Castleton cutoff; in the fenster extending along Kinderhook creek from about two miles northeast of Stuyvesant Falls to a point about two miles southeast of Stockport (Kinderhook quadrangle); in the west bank of the river opposite the mouth of Stockport creek and opposite Stuyvesant; in Flint Mine hill south of West Coxsackie. This may in part represent the transition zone, where an alteration of grits and chert might be expected, but it is more likely largely due to folding and faulting.

In the railroad cut of the Castleton cutoff, about a mile and a quarter south of Schodack Landing, 200 feet of grits and shales occur. The grit occurs at the north end of the cut and strikes N. 84° E. with a dip of 62°. In the southern end of the cut (figure 21) are exposed 95 feet of dark green and black cherts. The chert mass strikes more nearly east and west. At the extreme south end of the cut a 20-foot grit band occurs. About a mile and half south of the Schodack Landing railroad station a lane leads east from the tracks to the state highway. On the south side of the lane near the tracks is seen an eight-foot bed of grit; in the knoll to the north (marked on the map by a group of three houses) occur 50 feet of white-weathering chert, standing almost vertical, but with a slight easterly dip, and striking roughly north and south. On the east side of the river road, one-eighth of a mile north of the junction with the road leading west to the brickyards and east to Rossman school a road metal pit in cherty shales yielded in less than an hour of collecting a fair-sized fauna of graptolites (*see* figures 22, 24):

Figure 21 Great thickness of chert beds in the Normanskill formation shown in the cut (east side) along the Castleton cutoff (New York Central railroad), one and one-half miles south of Schodack Landing. (Photograph by E. J. Stein)

Corynoides curtus Lapworth
C. gracilis Hopkinson
Climacograptus eximius Rued.
C. parvus (Hall)
C. scharenbergi Lapworth
Cryptograptus tricornis Carruthers
Didymograptus sagitticaulis Gurley
D. subtenuis (Hall)
Dicellograptus gurleyi Lapworth
D. sextans (Hall)
Dicranograptus ramosus (Hall)
Diplograptus (*Glyptogr.*) *euglyphus* Lapworth
D. (*Orthogr.*) *acutus* Lapworth
D. (*O.*) *incisus* Lapworth
Glossograptus whitfieldi (Hall)
Nemagraptus gracilis (Hall)

This cherty ridge, showing white-weathering chert in places, continues southeast along the road past the junction with the New York road, north of Columbiaville. In the cherty beds in the vicinity of the flying field specimens of *Corynoides gracilis* and *Didymograptus* were picked up in a few minutes. This chert ridge forms the western boundary of the fenster of Normanskill opened up by erosion in the overthrust Cambrian beds (map 2). Within this same fenster, on the Coxsackie quadrangle, to the north and east of the above ridge, is another fossiliferous chert ridge forming a north hill east of Nutten hook and a south hill east of Little Nutten hook. Within this fenster, just over the eastern boundary of our area, at Stuyvesant Falls (upper falls at dam) and at Chittenden Falls one to four-inch beds of black and green banded chert (sometimes up to six to eight inches thick) are intercalated with black graptolite shale. Black chert is found in great quantity at Stockport, somewhat argillaceous

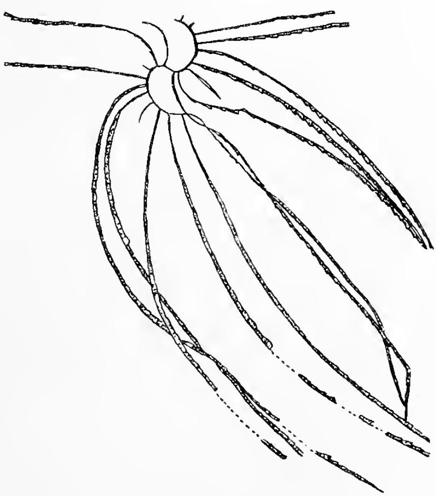

Figure 22 *Nemagraptus gracilis* (Hall). A diagnostic graptolite from the lower Normanskill formation (Mount Merino chert). A large specimen. (After Ruedemann)

and carrying graptolites. Chert with graptolites also occurs at the southern tip of the fenster, along the road about a quarter of a mile east of Stottville. From the cherty beds of the Stockport area Ruedemann ('08, p. 13-15; *see* Gurley '96, p. 67-74) reports the following graptolites (figures 22, 24):

Azygograptus walcotti Lapworth
Climacograptus bicornis Hall
C. parvus Hall
Corynoides curtus Lapworth
Dicellograptus divaricatus (Hall)
D. divaricatus var. *salopiensis* Elles and Wood
D. gurleyi Lapworth
D. intortus Lapworth
D. sextans (Hall)
D. furcatus Hall
Dicranograptus nicholsoni var. *parvangulus* Gurley
D. nicholsoni var. *diapason* Gurley
D. ramosus Hall
Didymograptus sagitticaulis (Hall) Gurley
D. serratulus (Hall)
D. subtenuis Hall
Diplograptus angustifolius Hall
D. foliaceus var. *acutus* Lapworth
D. foliaceus var. *incisus* Lapworth
Glossograptus ciliatus Emmons
G. whitfieldi (Hall)
Lasiograptus mucronatus (Hall)
Nemagraptus exilis Lapworth
N. exilis var. *linearis* Rued.
N. gracilis (Hall)
N. gracilis var. *crassicaulis* Gurley
N. gracilis var. *surcularis* Hall
cf. *Protovirgularia dichotoma* McCoy
Retiograptus geinitzianus (Hall)
Thamnograptus capillaris (Emmons)

The outcrops farther east extending roughly north and south between Ghent and Chatham Center are masses of red chert (radiolarite), containing radiolarians of which Ruedemann and Wilson report the following ('36, p. 1568-75):

Acanthosphaera robusta R. & W.
Dorydictyum magnum R. & W.
Doryplegma nux R. & W.
Heliosphaera haeckeli R. & W.
H. micropora R. & W.
H. rüsti R. & W.

In the New York Central railroad cut at the northern outskirts of the city of Hudson is a great thickness of shale and white-weathering chert. The mass here is almost entirely chert and this area may belong in the chert belt proper.

On the west side of the river opposite the mouth of Stockport creek, at Fourmile point, Normanskill dark shale and grit form the bulk of the ridge on which the lighthouse stands, but the core is white-weathering chert which forms the top of the ridge above the lighthouse. This is not the massive chert characteristic of the chert belt proper. In the ridge at the north end of the Deepkill outcrop, just south of the mouth of Coxsackie creek, black chert, white-weathering, again forms the core of the ridge.

The most striking occurrence of chert in the grit belt is found in Flint Mine hill (Minneberg or Mine mountain of the old Dutch settlers) (*see* pages 12, 291). This hill or ridge is largely composed of the black, white-weathering chert, with fine greenish chert and black and greenish shale between the chert beds. The greatest thickness of chert is not more than 10 feet. Grit occurs on the west slope and forms the ridge to the west (Berg Stuyffsink). Flint Mine hill is an anticline, the hill to the west a syncline, thus forming the two hills with a valley between (figure 2). Cross-folding is also seen here. Ruedemann and Wilson ('36, p. 1576) have reported from chert collected on the east side of Flint Mine hill the radiolarian *Druppula* (*Drupulissa*) *simplex* R. & W.

The Austin Glen grit belt shows outcrops of both grit and shale, but largely grit. Due to their massiveness, resistance to erosion and steep dip, the grit beds form the hills and ridges so conspicuous on the west side of the river, particularly south of Coxsackie. Except for the small outcrop of Deepkill just north and south of Coxsackie, they form the west bank of the Hudson river and, together with the resistant Cambrian beds of the east bank, hold the river to its course. The steeply-dipping grit beds are especially conspicuous along the river north and south of New Baltimore and between Fitchs wharf and Fourmile point, south of Coxsackie. Folding and faulting have complicated the rocks of this belt and the competent grit beds show beautiful structural features, as in the quarries south of New Baltimore (figure 23) and the Flint Mine Hill area. Some very fine exposures may be seen along the new state highway to Catskill. In the fenster to the east of the Coxsackie quadrangle there are beautiful exposures of Normanskill grit in the bed of the Kinderhook creek between Chittenden Falls and Stockport. Good exposures of grit and shale are found between Schodack Landing and Poolsburg in the Castleton cutoff and along the main New York Central tracks under the overthrust Cambrian. Here and along the road are some of the best exposures of the shale of the Austin Glen grit member. Just south of Schodack Landing, along the east side of the state road, is an exposure of dark gray and grayish green Normanskill shale with lime concretions or "niggerheads" up to a foot and more in diameter. A five-inch band of Rysedorph conglomerate, much broken up, occurs at the southern end of this outcrop. These shale beds, strongly slickensided in places, are exposed at intervals to the small ravine about one-half mile to the south where the "niggerheads" are again well shown in dark greenish gray shales. A 200-foot exposure occurs along the road to the south and here several inches of chert are found in the shale. Thin bands of siliceous shale or slate are not infrequent in these beds and these bands have furnished the largest graptolite faunas. Ruedemann ('08, p. 15) reports *Lasiograptus mucronatus* (Hall) from Schodack Landing. Ford ('84, p. 206) reported *Diplograptus foliaceus* (Murchison) from shales directly back of the railroad station and 12 species, two undescribed, from the shale along the railroad tracks a short distance south of the county line. The writer and Doctor Ruedemann recently collected 11 species from the cherty shales of the last-named locality. The combined list which follows, is not by any means complete, as many visiting scientists have been taken to this spot and made considerable collections.

Climacograptus bicornis Hall
C. parvus (Hall)
C. eximius Rued.
Corynoides curtus Lapworth
C. gracilis Hopkinson
Dicellograptus sextans (Hall)
D. sextans var. *perexilis* Elles & Wood
Dicranograptus ramosus (Hall)
Didymograptus sagitticaulis Gurley
D. subtenuis (Hall)
Diplograptus angustifolius Hall
D. foliaceus (Murchison)
D. (*Glyptogr.*) *euglyphus* Lapworth
D. (*Orthogr.*) *incisus* Lapworth
Lasiograptus mucronatus (Hall)

At Coeymans on the west side of the river there is a fall over greenish argillaceous shale and chert and, downstream from this, black shales in which Doctor Ruedemann has collected graptolites. As some graptolites can be found by searching in the black shales wherever they are exposed, no attempt has been made to collect in any of the few exposures in the western belt, especially as very full lists have been made elsewhere. Species of *Diplograptus* and a specimen of *Climacograptus* cf. *modestus* Ruedemann have been found in shale associated with the grit on the east side of the hill (Spoorenberg) west of Lampman hill.

In general the heavy grit beds strike about N. 20° E., but sometimes the strike runs nearly north and south and there are complications due to cross-folding and faulting. The beds also dip southeast to east at a steep angle, nearly vertical at times. Great thicknesses of the grit occur. Two hundred feet of grit and shale have been noted in the Castleton cutoff, south of Schodack Landing where one bed alone has a thickness of 20 feet. In the railroad cut at Poolsburg, to the south, 15 to 40 feet of grit are exposed. One mile and a half north-northeast of Coxsackie on the east side of the West Shore Railroad tracks 200 feet of grit are exposed in the bed of the Coxsackie creek from below the bridge upstream. In the ridge along the river south of the mouth of Coxsackie creek the writer measured 80 to 115 feet of grit, in the orchard west of the house, associated with gray-green shales and black, white-weathering chert. The spur or ridge extending north-northeast from the West Coxsackie-Climax highway is entirely composed of grit dipping in a southeasterly direction at an angle of 65° to 90°. The strike here is N. 22° E. There are three areas, in particular, where grit is

Figure 23 Pitching syncline in Normanskill grit (mainly) and shale in one of the quarries at Matthew point, one and one-quarter miles south of New Baltimore. View west-southwest. (Photograph by E. J. Stein)

exposed that are well worth study. Along the shore road at New Baltimore and south the grits are beautifully exposed in old quarries. Huge calcite veins are present in the grits here and in the early 1900's when the New Baltimore quarries were still being worked a series of fine calcite crystals was collected (Whitlock, '10, p. 117). A half mile south along the river, just north of the lane to Matthew point, another of these abandoned quarries shows a 100-foot wall in grit folded into an anticline and syncline. There is a series of large quarries in grit and shale north and south of Matthew point, but the most southern one is particularly notable in showing beautifully a syncline and pitching anticline (figure 23). Calcite veins with large crystals of calcite in both grit and shale are exposed along the west side of the state road at the north outskirts of Athens where they are readily accessible. Flint Mine hill and the hills immediately east (Spoorenberg) and west (Berg Stuyffsink) are of interest in studying both the chert and grit. In the east hill the grit dips steeply east and forms the whole ridge. There are at least 300 feet of grit here. The anticline forming Flint Mine hill and the probable syncline in the hill to the west are considered above (pages 112, 113) under the discussion of the chert. Both hills strike slightly east of north.

The graptolite fauna of the Normanskill formation has been cited above under the discussion of the various localities, including areas immediately east (Stockport) and south (Mt Merino) of the Coxsackie quadrangle. These, together with the graptolites cited by Ruedemann from the Capital District ('30, p. 99) constitute the complete Normanskill graptolite fauna (*see* figure 24) known at present. In the list below the graptolites cited were collected from the shales at Kenwood and from the chert at the railroad cut in Glenmont. Where not otherwise indicated the species were found in both localities (*see* Ruedemann, '08, p. 13-15):

Amphigraptus divergens (Hall)
A. multifasciatus (Hall)[2]
Azygograptus ? simplex Rued.[1]
Climacograptus bicornis Hall
C. parvus Hall
C. putillus mut. *eximius* Rued.[1]
C. scharenbergi Lapworth[1]
Corynoides curtus Lapworth[1]
C. gracilis mut. *perungulatus* Rued.[1]
Cryptograptus tricornis (Carruthers)
Desmograptus tenuiramosus Rued.[1]
Dicellograptus divaricatus (Hall)
D. divaricatus var. *bicurvatus* Rued.
D. divaricatus var. *rectus* Rued.[2]
D. divaricatus var. *salopiensis* Elles & Wood[2]
D. gurleyi Lapworth[1]
D. mensurans Rued.[2]
D. sextans (Hall)
D. sextans var. *exilis* Elles & Wood[1]
D. sextans var. *tortus* Rued.[1]
Dicranograptus contortus Rued.[2]
D. furcatus Hall
D. furcatus var. *exilis* Rued.[2]
D. nicholsoni var. *diapason* Gurley[1]
D. nicholsoni var. *parvangulus* Gurley[1]
D. ramosus Hall
D. spinifer Elles & Wood[1]
D. spinifer var. *geniculatus* Rued.[1]
Dictyonema spiniferum Rued.[1]

(For footnotes see page 119.)

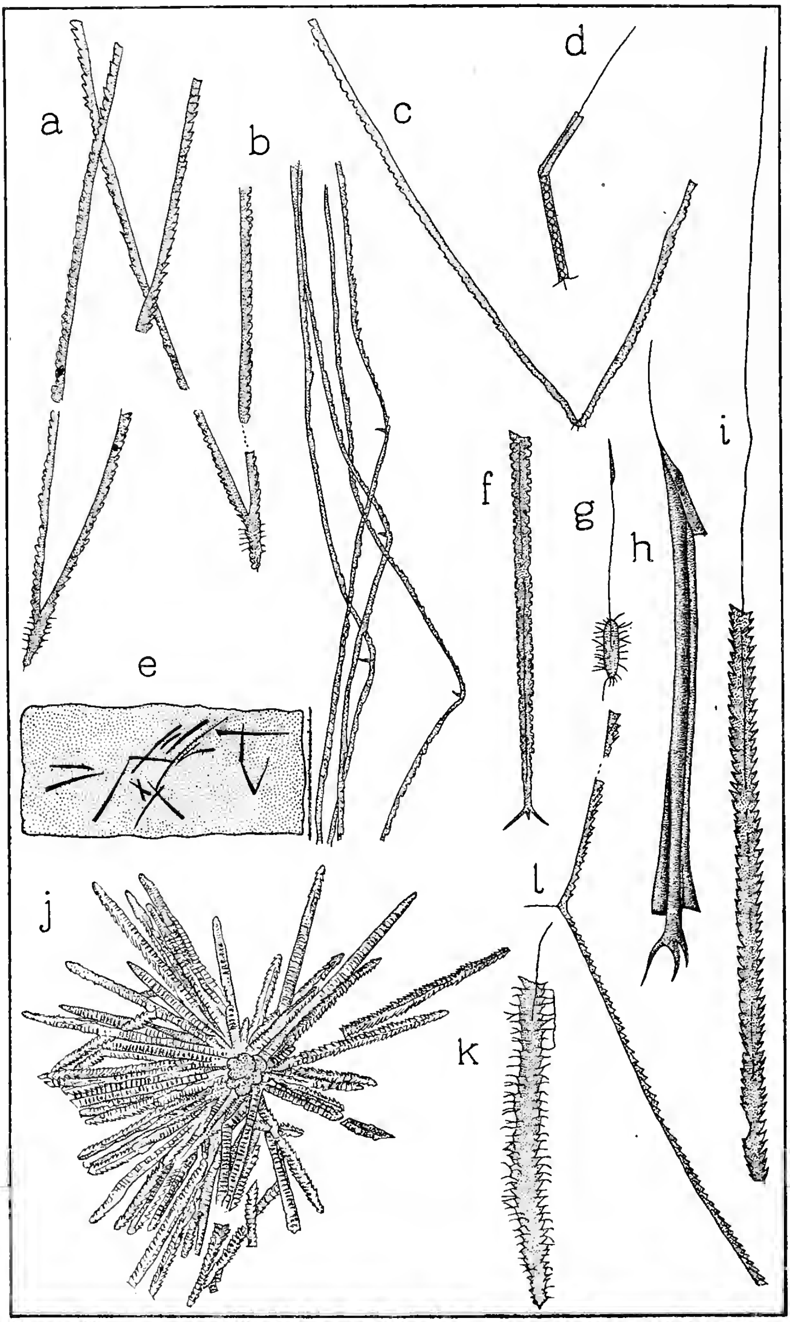

Figure 24 Normanskill shale graptolites. *a Dicranograptus nicholsoni* var *parvangulus.* *b Leptograptus flaccidus* mut. *trentonensis.* *c Dicellograptus divaricatus.* *d Cryptograptus tricornis.* *e, h Corynoides gracilis* mut. *perungulatus,* x 1 and enlarged, x 5. *f Climacograptus bicornis.* *g Glossograptus ciliatus.* *i, j Diplograptus (Orthogr.) incisus:* single rhabdosome, x 1, and colony, x ½. *k Lasiograptus bimucronatus.* *l Didymograptus serratulus.*

Didymograptus sagitticaulis (Hall) Gurley [2]
D. serratulus (Hall)[2]
D. subtenuis (Hall)[2]
Diplograptus angustifolius Hall
D. euglyphus Lapworth [1]
D. foliaceus var. *acutus* Lapworth
D. foliaceus var. *incisus* Lapworth[1]
Glossograptus ciliatus Emmons
G. whitfieldi (Hall)
Lasiograptus bimucronatus Nicholson
L. mucronatus (Hall)
Leptograptus flaccidus mut. *trentonensis* Rued.[1]
L. flaccidus var. *spinifer* mut. *trentonensis* Rued.[1]
Nemagraptus exilis Lapworth[1]
N. exilis var. *linearis* Rued.
N. gracilis (Hall)
N. gracilis var. *approximatus* Rued.
N. gracilis var. *distans* Rued.[1]
N. gracilis var. *surcularis* Hall
Odontocaulis hepaticus Rued.[1]
Ptilograptus poctai Rued.[1]
Retiograptus geinitzianus (Hall)[2]
Syndyograptus pecten Rued.[1]
Thamnograptus capillaris (Emmons)

[1] Glenmont only; [2] Kenwood only.

Rysedorph Conglomerate

The Rysedorph conglomerate was named (Ruedemann, '01) from the occurrence in Rysedorph hill (locally called Pinnacle or Sugar Loaf hill), two miles southeast of Rensselaer, and has been fully discussed in the Capital District bulletin (Ruedemann, '30, p. 104-13). It overlies the Normanskill. At the type locality the conglomerate forms a vertical ledge, the main bed two and a half feet thick, and is distinctly underlain by black and green shales on the west side. The conglomerate is of varying thicknesses in other sections, up to 12 to 50 feet in the Moordener kill near Castleton (Dale, '04, p. 34; Ruedemann, '30, p. 110), the greater thickness probably due to reduplication by folding. Of its occurrence Ruedemann writes (*ref. cit.*, p. 104):

> The Rysedorph conglomerate has a wide distribution within the Normanskill shale belt in the Capital district; but it also extends into the Schuylerville quadrangle, where the writer has described it from the base of Bald mountain ('14, p. 80); and it is found at Schodack Landing and may be identified with the Burden conglomerate described by Grabau from Becraft mountain near Hudson [*see* page 76].

The conglomerate is a fine collecting ground for fossils. Seven kinds of pebbles have been found furnishing an amazingly rich and strange fauna. Ruedemann ('01) described 84 species from the type locality, "a prodigious number for Paleozoic outcrops"; and 25 of them were new, including six new trilobites. According to Ruedemann,

> The most interesting facts obtained were that the faunas of the pebbles ranged from the Lower Cambrian to the Trenton, that the Chazy is represented in the pebbles, which is only known on the surface in northern New York and Vermont, and that the Mohawkian fauna contains Atlantic elements hitherto known only from

Europe but which since have been found at Quebec, in Pennsylvania, Virginia and Alabama in the identical forms first described from Rysedorph hill. It may be added that, with the exception of the Lower Cambrian limestone, none of the groups of pebbles with their faunas can be referred to ledges of rock in eastern New York or the neighboring parts of Vermont and Massachusetts, which means, in our view, that they came from rocks in the east and northeast which are now so metamorphosed (as the Stockbridge limestone and marble, etc.) that the faunas are unrecognizable, just as the shales of the slate belt are metamorphosed eastward into schists (the Berkshire schist). This small ledge thus presents us, like a page from a lost work, with a glance into hidden treasures that may never become more fully revealed to science (*ref. cit.*, p. 105, 106).

The seven groups of pebbles found, with their faunas, are as follows (*auth. cit.*, '14, p. 7-10; '30, p. 106-10):

1 Gray limestone of Lower Cambrian age
  Hyolithellus micans Billings
2 Gray and reddish sandstone
  No fossils
3 Black crystalline limestone (Chazy limestone)
  Bolboporites americanus Billings
  Paleocystites tenuiradiatus (Hall)
4 Lowville limestone
  Phytopsis tubulosa Hall
  Tetradium cellulosum Hall
5 Black compact limestone
  Correlated with Black River group, probably more especially the Watertown or Amsterdam limestones.
6 Reddish-gray compact limestone
  Lower Trenton fauna
7 Gray crystalline limestone
  Lower Trenton fauna

Ruedemann considers the pebbles of group 5 as the most valuable and interesting portion of the Rysedorph Hill conglomerate. The rare brachiopods, gastropods and trilobites were furnished by these pebbles. Altogether 45 species are listed:

Corals

Streptelasma corniculum Hall

Graptolites

Climacograptus scharenbergi Lapworth
Diplograptus foliaceus Murch.

Bryozoans

Callopora multitabulata Ulrich
Corynotrypa (Stromatopora) inflata (Hall)
Stictopora cf. *elegantula* Hall

Brachiopods

Christiania trentonensis Rued.
Crania trentonensis Hall
Hesperorthis [Orthis] tricenaria (Hall)
Leptaena rhomboidalis Wilckens
Platystrophia biforata (Schlotheim)
Plectambonites pisum Rued.
P. sericeus (Sowerby)
Rafinesquina alternata (Emmons)
Siphonotreta minnesotensis Hall & Clarke
Wattsella [Dalmanella] testudinaria (Dalman)

Pelecypods

Ctenodonta cf. *astartaeformis* Salter
Ctenodonta sp. undet.
Whitella ventricosa (Hall)

Gastropods

Carinaropsis carinata Hall
Conradella compressa (Conrad)
Eccyliopterus spiralis Rued.
Holopea paludiniformis Hall
Liospira americana (Billings)
Lophospira bicincta (Hall)
Senuites cancellatus (Hall)

Conularids

Conularia cf. *trentonensis* Hall

Cephalopods

Zitteloceras hallianum d'Orbigny

Trilobites

Ampyx (*Lonchodomas*) *hastatus* Rued.
Bronteus lunatus Billings
Calymene senaria Conrad
Ceraurus pleurexanthemus (Green)
Cyphaspis matutina Rued. *Cybele* sp.
Illaenus americanus Billings
Isotelus maximus Locke
Pterygometopus callicephalus (Hall)
Remopleurides linguatus Rued.
Tretaspis diademata Rued.
T. reticulata Rued.

Ostracods

Aparchites minutissimus Hall var. *robustus* Rued.
Bythocypris cylindrica Hall
Isochilina armata Walcott var. *pygmaea* Rued.
Primitia mundula Miller var. *jonesi* Rued.

In discussing this fauna Ruedemann ('30, p. 107) states:

The most important and interesting forms of this association are the brachiopods *Plectambonites pisum* and *Christiania trentonensis*, and the trilobites *Tretaspis reticulata, T. diademata, Ampyx hastatus, Bronteus lunatus* and *Sphaerocoryphe major*, because they all belong to extremely rare genera or species. Representatives of the genus *Tretaspis* were before known only from Great Britain.

The brachiopod *Plectambonites pisum,* a small, almost globular shell, is so common in these beds that it makes an excellent index fossil. It has also been found in other outcrops of the Rysedorph Hill conglomerate. . . . , and in association with *Christiana trentonensis* and *Tretaspis reticulata* has been traced into Virginia (Bassler, '09) and Alabama (Butts, '26) and Quebec (Raymond, '13). The formation in which they occur is the Chambersburg limestone, a thick formation that comprises the uppermost division of the Chazy (the Blount), and the Black River group of New York (including the Lowville, Watertown and Amsterdam limestones). It is, therefore, from the general aspect of the fauna, correct to correlate these black pebbles with the Black River group, probably more especially the upper part, the Watertown or Amsterdam limestones.

The pebbles of groups 6 and 7 belong to adjoining beds and their faunas have the principal forms in common. It is a lower Trenton fauna, the youngest fauna obtained, hence the Rysedorph conglomerate must be younger than lower Trenton in age. The pebbles of group 6 are composed of a very hard, compact, fine-grained, dark gray limestone which weathers into a reddish gray rock. Noteworthy in this fauna are the ostracods which are the most common fossils. Trilobites of the rare genera *Ampyx* and *Remopleurides* are found.

The fauna includes:

Brachiopods

Protozyga exigua Hall
Triplecia nucleus Hall
Rafinesquina alternata (Conrad)
Wattsella [*Dalmanella*] *testudinaria* (*Dalman*)

Gastropods

Carinaropsis carinata Hall

Trilobites

Ampyx hastatus Rued.
Gerasaphes ulrichana Clarke
Pterygometopus callicephalus (Green)
Remopleurides linguatus Rued.
R. tumidulus Rued.

Ostracods

Bythocypris cylindrica (Hall)
Eurychilina bulbifera Rued.
E. reticulata Ulrich
E. (?) solida Rued.
E. subradiata Ulrich var. *rensselaerica* Rued.
Isochilina armata Walcott var. *Pygmaea* Rued.
Leperditia resplendens Rued.
Schmidtella crassimarginata Ulrich var. *ventrilabiata* Rued.

The gray crystalline limestone of group 7 often changes into a veritable shell rock. By far the most common pebbles on Rysedorph hill belong to this group, and most of the pebbles are made up of shells of *Plectambonites* and *Rafinesquina alternata* or parts of the trilobite *Isotelus gigas*. The fauna follows (*ref. cit.*, p. 109):

Bryozoans

Prasopora simulatrix Ulrich var. *orientalis* Ulrich

Brachiopods

Camerella [*Parastrophia*] *hemiplicata* (Hall)
Dinorthis pectinella (Emmons)
Doleroides [*Dalmanella*] *pervetus* (Conrad)
Hesperorthis [*Orthis*] *tricenaria* (Conrad)
Leptaena rhomboidalis Wilckens
Plectambonites ruedemanni Raymond (in original list cited as *P. sericeus asper* James)
P. pisum Rued.
Plectorthis plicatella Hall
Protozyga exigua Hall
Rafinesquina alternata (Conrad)
R. deltoidea (Conrad)
Triplecia nucleus Hall
Wattsella [*Dalmanella*] *testudinaria* (Dalman)
Zygospira recurvirostris Hall

Pelecypods

Modiolopsis cf. *aviculoides* Hall

Gastropods

Carinaropsis carinata Hall
Clathrospira subconica Hall
Conradella compressa Conrad
Cyrtospira attenuata Rued.
Liospira subtilistriata (Hall)
Lophospira bicincta (Hall)
L. perangulata (Hall)
Trochonema umbilicatum (Hall)

Conularids

Hyolithus rhine Rued.

Cephalopods

Cyratoceras subannulatum Hall
Spyroceras cf. *annellus* (Conrad)
S. bilineatum (Hall)

Trilobites

Ceraurus pleurexanthemus Green
Dalmanites achates Billings
Illaenus americanus Billings
Isotelus maximus Locke
Pterygometopus callicephalus (Hall)
P. eboraceus Clarke
Remopleurides linguatus Rued.
Thaleops ovata Conrad

Ostracods

Bollia cornucopiae Rued.
Bythocypris cylindrica (Hall)
Eurychilina bulbifera Rued.
E. dianthus Rued.
E. obliqua Rued.
E. subradiata Ulrich var. *rensselaerica* Rued.
Leperditia fabulites Conrad
L. resplendens Rued.
Macronotella fragaria Rued.
M. ulrichi Rued.
Primitia mundula Miller var. *jonesi* Rued.

The Rysedorph conglomerate is reported in the area (Catskill quadrangle) to the south of the Coxsackie quadrangle along the Mt Merino road, occurring in two beds about a foot in thickness and separated by a half-foot bed of shale with some pebbles, and north of Elizaville. The second occurrence covers an amazing area 550 feet wide across the top of the hill; but it is interpreted as representing the flat top of an overturned anticline (Ruedemann, 42*b*, p. 123).

There are likewise only two occurrences on the Coxsackie quadrangle: a two-foot bed that outcrops in the hill back of the hotel at Schodack Landing and a five-inch bed interfolded with the Normanskill shale in the road cut just south of the village. The occurrence at Schodack Landing was reported by Ford in 1884 (p. 207, 208) and another in the ravine to the south along the Columbia county line, a continuation of the bed seen in the road cut. He lists from these two localities one coral, *Chaetetes* sp.; four brachiopods, *Wattsella* [*Dalmanella*] *testudinaria* (Dalman), *Plectambonites sericeus* (Sowerby), *Platystrophia lynx* (Eichwald), *Rafinesquina alternata* (Conrad); and two trilobites, *Calymene senaria* Conrad, *Isotelus* sp.

According to Ruedemann ('01, p. 8, 9), the pebbles of nonfossiliferous grayish and reddish sandstones are the strongly prevailing class of pebbles at Schodack Landing. These pebbles may represent in age the Potsdam sandstone or Beekmantown limestone beds or they may be derived from sandstone beds in the underlying Normanskill graptolite shale. Large boulders of Lowville limestone, up to a foot and a half in diameter, also occur. These boulders carry numerous "birdseyes," or worm tubes, *Phytopsis tubulosa* Hall, and the coral, *Tetradium cellulosum* (Hall), a characteristic fossil of the Lowville limestone. Pebbles of group 7, with a lower Trenton fauna are also found at Schodack Landing. This group of pebbles, by far the prevailing class in the Rysedorph Hill conglomerate and still common at the Moordener kill, has become greatly diminished here, "the relative quantity of these and the sandstone pebbles being, roughly stated, inversely proportional" (*ref. cit.*, p. 9).

Of the age of the Rysedorph conglomerate Ruedemann writes ('30, p. 113):

In the first paper ('01) dealing with this conglomerate, we placed it within the Normanskill shale, seeing in the Trenton fauna of the conglomerate evidence of the Trenton age of the Normanskill shale. With the recognition of the fact that the typical Normanskill shale is older than the Trenton, it became necessary to assume that the Rysedorph conglomerate either is intercalated in the upper division of the Normanskill (Magog shale) of the Black River and perhaps earliest Trenton age or rests entirely on the series. The relative position of the conglomerate to the shales gives no indication of its age, except that, as at the Moordener kill, it is undoubtedly interfolded with Normanskill shale, which yet must be considerably older. We are now placing the Rysedorph conglomerate at the top of the whole Normanskill shale and below the Snake Hill shale, correlating it with the lower Trenton.

In 1901 (p. 109) and again in 1930 (p. 112, 113) Ruedemann discussed fully the various views of the origin of such conglomerate: intraformational conglomerate (*see* Walcott, '94, p. 191), flood-plain deposits, glacial beds or sea-ice transportation. At the time he inclined to Walcott's view of submarine origin due to the erosion of anticlinal ridges. In his bulletin on the Catskill quadrangle ('42*b*, p. 120) he considers that these conglomerates very probably were "produced on an extensive scale on submarine slopes by periods of violent earthquakes. This would explain both the size and the variety of the boulders and pebbles." Tectonic breccia is ruled out because the components of the conglomerate are not known in the immediate neighborhood and no traces of tectonic effects are seen within the bed itself. The recent studies of Bailey, Collet and Field (1928, p. 592ff.) on the conglomerates of the Quebec District have brought forth evidence for the submarine landslip origin of breccias and conglomerates. A conglomerate (Lacolle) in southern Quebec, considered of the same nature as the Rysedorph conglomerate, has been recently described by Clark and McGerrigle (1936) who consider "that the condition which initiated the formation of the Lacolle conglomerate was a local tilting of the strata in Trenton time, after an indefinite, but small, amount of the Trenton had been deposited" (p. 674). Of the same origin is the well-known Magog conglomerate, associated with graptolite beds, which, according to Dresser (1925), is a distinct horizon marker in the "Quebec group." The Rysedorph conglomerate also is an horizon marker in the slate belt of eastern New York for, as Ruedemann points out, it "is now known to appear intermittently from Bald mountain in Washington county to Elizaville in Columbia county, a distance of 75 miles, but it is probably distributed much farther north and south" (*ref. cit.*).

SILURIAN SYSTEM

The name Silurian was given by Sir Roderick Murchison (1835) to a system of rocks, previously unknown, which were found occurring beneath the Old Red Sandstone series (Devonian) in Great Britain. These rocks were studied on the borderland between England and southern Wales where they are least disturbed, and Murchison, therefore, gave to the system a name derived from the *Silures,* a warlike tribe that occupied this territory in the days of the Romans. The Silurian System appeared in 1838. The system was divided into an upper and lower division, the latter of essentially the same age as Sedgwick's Upper Cambrian of North Wales for which Lapworth later proposed the term Ordovician system, now generally accepted. Lapworth, at the same time, also proposed the restriction of the name Silurian to the rocks comprising Murchison's Upper Silurian, an arrangement adopted by geologists of Great Britain and America. The old New York term, Ontario division, as defined 1842-43, comprised almost exactly the same range of formations now referred to the Silurian system. North America has as full a representation of the rocks of the Silurian system as is found in Great Britain, and, as with the Ordovician and Devonian, the classification used in New York is the standard of America.

At the end of the Ordovician there was a withdrawal of the sea followed by a flooding from the Arctic ocean, as well as from the Middle and South Atlantic and Pacific. It was during this flood, when a large portion of the continent was submerged, that a river delta of red sandstones was deposited in the Appalachian trough and extended from near the southern extremity of Virginia through Maryland and Pennsylvania into New York where it appears as the red sandy shales of the Queenston formation of Richmond or Lower Silurian time (considered by some authors as Upper Ordovician). These Lower Silurian (Richmond) beds cover a greater proportion of the continent than any subsequent series of Silurian deposits. There was a great, but not complete, emergence at the close of the Lower Silurian, followed by another great but oscillating submergence, that of the Middle Silurian (Niagaran) epoch. As in the preceding period (Ordovician) the highlands were along the borders of the continent and the interior basin was little above sea level. The second flooding of this interior low area was somewhat inferior in aggregate extent to the one that took place in the Lower Silurian (Richmond) and at this time approximately 20 per cent of the continent was under water. These floods were chiefly from the Arctic ocean, but smaller seaways spread northward from the Gulf of Mexico and in the west a seaway, known as the Cordilleran sea, extended from California through Idaho to Canada. Small seaways connected with the North Atlantic in the St Lawrence and Acadian areas, and there were times when there was a connection between the St Lawrence waters and the Appalachian trough. Epicontinental seas were again restricted in Upper Silurian (Salinan) time. Salinan time in northeastern North America is characterized by shifting lagoons and an arid climate. Along the northern part of the northeastern area of the interior sea salt lagoons were separated off and in these was deposited a series of red marls and shales interstratified with gypsum and rock salt. Following these came a freshening of the Salina lagoons and the deposition of a waterlime containing a remarkable assemblage of fossils, the eurypterids. The interior sea throughout Salina age had been growing more shallow and finally became land and remained so for a time. The Silurian waters persisted in the Appalachian geosyncline (and elsewhere) and there were deposited the limestones of the closing period of the Upper Silurian (Cayugan) epoch, the Cobleskill, Rondout and Manlius.

The Silurian was largely a period of limestone building except in eastern United States which is characterized, particularly in the lower part (Lower and Middle Silurian) by conglomerates, sandstones and shales derived from Appalachia to the east and carried by streams given added impetus and carrying power by the uplift at the close of the Ordovician. These sandstones increase in thickness going east until they assume the character of great sand deltas (Tuscarora of Pennsylvania; Shawangunk of New York). The thickest accumulations are found in east central Pennsylvania where a maximum thickness of several thousand (6500) feet occurs. In the interior sea, where the waters were warm and pure, pure and magnesium limestones are found almost entirely, particularly in the Middle Silurian, due to the abundant growth of corals and *Stromatoporas* which formed the reefs or reeflike accumulations, so characteristic of the Middle Silurian. Nowhere is there a thickness over 1000 feet and usually it is much less, considerably under 500 feet. Except for maritime eastern Canada, west central Tennessee has the thickest deposits of Silurian (mainly Middle) limestones; those of northeast Wisconsin and northern Michigan come next.

Near the base of the Middle Silurian (Niagaran) series is one of the most widespread iron deposits known. It was accumulated during the Clinton stage (Clinton iron ore of New York; "fossil", "pea" or "oölitic" iron ore) and outcrops occur from New York, through Pennsylvania to southern Virginia and others of corresponding age occur also in Alabama. There are several beds at different horizons in the formation, varying from a fraction of an inch to about 40 feet in thickness, though beds with a thickness of as much as ten feet are the exception. This ore is believed to be a chemical precipitate, deposited in marshes and lagoons along the shore.

The lower beds of the Upper Silurian (the Salinan) through the Appalachian region are missing south of Virginia, the uppermost Silurian beds resting upon the Middle Silurian (Niagaran) except, perhaps, in southwestern Virginia. No typically marine Salina deposits are known anywhere. In central and western New York, in northern Ohio, in Michigan and parts of Ontario the Salina beds are represented by shales and limemuds alternating with salt and gypsum, being developed to their greatest thickness in southern Michigan and adjoining areas. Concentration of water in shifting lagoons resulted in the accumulation of pure salt deposits of considerable thickness. In New York State beds of salt occur aggregating 50 to 100 feet in thickness and beds of pure salt have been found with a thickness of 40 to 80 feet.

The late Silurian seas were small and shifting. Corals showing Arctic origin occur and coral reefs form again in some areas. The Cobleskill limestone of New York marks an eastward extension of this reef fauna, although reef conditions are seldom found. This formation includes many corals of types characteristic of formations of this age in Michigan, belonging to a northern fauna. A persistent Middle or Southern Atlantic fauna of small brachiopods, *Leperditias*, pelecypods and *Tentaculites* occupied the southern part of the Appalachian trough and extended up into eastern New York (Manlius). In the northern end of the Atlantic trough (Nova Scotia) there was an Atlantic fauna, essentially that of the Upper Silurian of England.

In western North America the Silurian is not well known and is apparently poorly developed in the United States. A deep trough existed in the Cordilleran area of Canada in which between 2000 and 3000 feet of dolomites and limestones were deposited, and in the southern Cordilleran sea between 200 and 300 feet of Silurian limestones were deposited in the Great Basin area (Nevada, Utah), and a considerable thickness of Silurian graptolite shales in Idaho. A moderate thickness of Middle Silurian is represented in western Texas. An important region for the Silurian is eastern Canada, especially the Island of Anticosti in the Gulf of St Lawrence. Silurian rocks also cover large areas on the south shore of Hudson bay. In the Acadian trough of eastern Canada 4000 feet of shales and sandy limestones occur and farther south at Black Cape, Bay of Chaleur, Quebec, 7000 feet of deposits occur, here terminated by lava flows. In terms of limestone deposits, Silurian deposits of North America are the equivalent of 3000 to 4500 feet of limestone.

The Silurian was a period of quiet. Volcanic activity was rare (southern Maine) and only in a few places do igneous intrusions occur in North America. Here the close of the period is marked by no disturbance and it is generally believed that deposition continued uninterruptedly into the Lower Devonian, though in certain areas unconformities have been noted. In addition to the fossil iron ores of the Clinton and gypsum and salt of the Salina beds the Silurian (Upper) is rich in dark blue, impure, magnesium limestones of shallow-water origin, the waterlimes which are the natural cement rocks that were formerly so extensively quarried for the making of Portland cement.

New York State, at the close of the Ordovician was practically dry land and undergoing erosion. Very high lands were found only in the Taconic range along the eastern side and in the central Adirondacks. Silurian rocks are found outcropping in a narrow belt along the west side of the Hudson extending to the Helderberg mountains southwest of Albany. Here the beds turn abruptly westward, following the south side of the Mohawk valley, and south of Lake Ontario the belt becomes much wider. Silurian rocks underlie the younger rocks throughout the rest of the State, which indicates that through much of Silurian time the present area of New York south of Lake Ontario and the Mohawk valley and west of the Hudson river was submerged. The central and western parts of the State were submerged first. It was not until late in the period that the sea encroached upon the Hudson valley to the western slopes of the Taconic mountains. There is no evidence that the northern Adirondack area was submerged during this period; in fact, except for local submergence during the Pleistocene (Quaternary or Ice Age), this area has remained dry land ever since its elevation at the close of the Ordovician. To what extent Silurian and Devonian strata lapped upon the southern Adirondack area can not be determined. Thus we see that during early Silurian the sea claimed only central and western New York, but in the late Silurian practically all the State south and west of the Adirondacks was under water. A maximum of between 2600 and 3000 feet of deposits was laid down in New York State in Silurian times, the greatest thickness represented by shales and sandstones.

On the Coxsackie quadrangle only two of the Upper Silurian formations are represented, the Rondout waterlime resting upon the upturned edges of the eroded Ordovician strata (Normanskill) and the Manlius limestone above. A third Upper Silurian formation, the *Cobleskill limestone,* has been recorded in Austin glen at Catskill, but this bed, three or four feet thick, is now known to be part of the Rondout (Chadwick; letter, Nov. 1938) with a total thickness of eight feet which through repetition by thrusting occupies a wide space in the bed of the stream. In the Rondout-Kingston area a seven-inch band has been considered the attenuated eastern extension of the Cobleskill limestone but this "Middle Ledge" limestone is now known to be not the exact equivalent of the Cobleskill, but younger (R. M. Logie). To the north of the Coxsackie quadrangle in the Capital District area the Cobleskill again does not outcrop until one reaches the Helderbergs, one mile east of West Township (Berne quadrangle), Albany county (Goldring, '35, p. 78). The absence of outcrops may mean an absence of the formation or it may have been overlapped by younger deposits. The Cobleskill limestone (Clarke, '02, '03; Hartnagel, '03) was named from its exposure on the Cobleskill, Schoharie county. It is a typical coral facies and, while it does not always show the reef character, it has the reef species (Hartnagel, '03, p. 1109). Because of the great abundance of corals it was earlier known as the "Coralline limestone." The formation on the whole is thin, having its greatest thickness of seven feet in east-central New York (Schoharie county) and a thickness of five to eight feet in western New York, a dolomitic phase in Erie county of a little later faunal development (Hartnagel), named *Akron dolomite* (Sherzer and Grabau, '09) from the occurrence at the village of Akron and known locally as the "Bullhead" limestone. The Cobleskill is considered by F. M. Swartz as equivalent in age to the lower Keyser (*see* page 144). Farther south in the Hudson valley are found two older formations, the *Wilbur limestone* (Hartnagel, '05) and the *Rosendale waterlime* (Hartnagel, '05), which probably together represent the Bertie waterlime farther west, of Salina age. Still farther south, in Ulster county (Kingston-Port Jervis section), a light-colored quartzite, the *Binnewater sandstone* and the red shales beneath, the *High Falls shales* (Hartnagel, '05), constitute still older Silurian (Salina) beds. In the Capital District area and westward between the Ordovician (Indian Ladder beds or Schenectady beds) and the Upper Silurian formations occur olive or grayish clay shales often alternating with bluish beds and weathering to a lighter color, having the appearance of a solid mud bank. This is the *Brayman shale* (Grabau, '06) which reaches a thickness of 30 to 40 feet at the type locality, Braymansville in Schoharie county, but which is only a few feet thick in the Capital District and is exposed in only a few places. No fossils have been found. These beds have been considered of Upper

Silurian (Salinan) age by Hartnagel, Clarke, Alling ('28, p. 97-102) and others; as "probably the partial equivalent of the lower cement bed of Rosendale" by Grabau ('06, p. 104), and, by Ulrich and Ruedemann, as "a residual bed or soil of the Ordovician formed during an erosion interval and representing the hiatus between the Indian Ladder or Schenectady beds (Upper or Middle Ordovician) and the Cobleskill limestone or Rondout waterlime (Upper Silurian) above" (Goldring, '35, p. 78; *see* Ruedemann, '30, p. 41).

Rondout Waterlime

The Rondout waterlime is a drab-colored rock formerly known as the "Salina waterlime," which received its name (Clarke and Schuchert, '99) from the fine development in the extensive quarries and cement mines in the vicinity of Rondout. This formation extends as far west as Seneca county, where it is overlapped by the Onondaga. Eastward it lies between the Cobleskill and the Manlius to the neighborhood of West Township (Berne quadrangle) in the Helderbergs; southeastward in the Capital District (Berne and Albany quadrangles) it rests first upon the Brayman shale, then upon the Schenectady beds (Feura Bush quarry) and the Normanskill sandstone and shale (South Bethlehem). South of this area the Rondout waterlime rests upon the Normanskill formation. The bed in Austin glen (Catskill) formerly believed to be Cobleskill is now known to occur in the upper Rondout (Chadwick; letter, Nov. 1938). Southward, in the railroad cut south of Alsen, Chadwick (summer, 1938) pointed out to the writer the occurrence of reef formation below typical Rondout which may represent reef formation within the Rondout itself. In the Rosendale area and throughout southeastern New York the Rondout rests upon a reef bed (the "Middle Ledge" limestone) above the Rosendale which is not the exact equivalent of the Cobleskill, but younger (R. M. Logie).

The average maximum thickness of the Rondout is 40 feet (Howes Cave). At Manlius in Onondaga county 45 feet are reported (Hartnagel, '03, p. 1165), but in the Cobleskill region it thickens to 60 feet. The lower six feet formerly was mined at Howes Cave by the Helderberg Cement Company for the manufacture of natural or Rosendale cement. The greatest thickness in Albany county is 20 feet (Gallupville, Berne quadrangle); in the Capital District area less than three feet are found under the Helderberg cliffs at the Indian Ladder, six and a half feet south of New Salem, nine to possibly 12 feet in the Feura Bush (South Albany) quarry and 14 feet in the large quarry at South Bethlehem. At Catskill (Austin glen) only a few feet are exposed (see above) and southward the formation thickens to about 20 feet in the Rondout-Kingston area (much less if, as recent field work indicates, the upper beds are Manlius (*see* page 133). At Rondout, as at Howes Cave, the upper beds included in the formation were not used for cement, but the lower beds were quarried to a thickness of 12 to 15 feet. The Century Cement Corporation is now operating at Rosendale, just south of Rondout, in Rosendale waterlime, mainly, and some Rondout, but the quarries at Rondout are no longer operated. The caves formed here by quarrying operations are now being adapted to the cultivation of mushrooms.

The Rondout waterlime, because of its soft nature, weathers back under the Manlius limestone cliff and may be covered by talus, or may form a sort of path such as the "Lower Bear path" seen along the cliffs at the base of the Manlius in the Indian Ladder region of the Helderbergs. It is through this formation that springs at the base of the Manlius cliff issue and here natural caves or shelters are formed. At Rondout and, to a certain extent, at Schoharie (West Hill; 35 feet) the upper beds show a remarkable series of mud-crack structures (Grabau, '06, p. 111), mostly pentagonal in form, which indicate very clearly that this rock was formed from a fine lime mud that was probably exposed at low tide to the drying influence of the sun. In the Capital District area these mud cracks are well shown in the South Bethlehem quarry. Except in quarries one is not likely to find an exposure showing the surface of the rock.

The cement bed quarried is a banded lime mudrock, rather massively bedded, bluish gray in color when fresh but weathering brownish. Above the cement bed the Rondout consists mostly of lime mudrocks with frequent layers of a more sandy texture. Many of the beds are very shaly with a considerable amount of argillaceous (clayey) material which upon weathering leaves much clay behind. These upper beds are considered of no value in the manufacture of cement. The Rondout shows a transition from the Cobleskill limestone below (when present) and into the Manlius limestone above. "The transition from Cobleskill to Rondout is marked by a change from the limestone of the Cobleskill to the cement of the Rondout. The weathered surface of the upper portion of the Cobleskill varies slightly from the weathered Rondout, but fresh fracture clearly shows the distinctive character of the cement rock" (Hartnagel, '03, p. 1115).

There are few exposures of the Rondout waterlime on the Coxsackie quadrangle, though there are a number of places in which it appears abundantly in talus. The greatest thickness is shown in the vicinity of the pond one-half mile north of the Deans Mills-New Baltimore road, about four-tenths of a mile west of the state highway. The pond is located in the Rondout, in a valley which owes its origin to faulting. There is a vertical distance of 10+ feet between the pond and the base of the Manlius. How much greater is the thickness of the Rondout can not be ascertained. A more accessible exposure near the road junction at Roberts Hill shows a thickness of at least six feet. Well-developed mud-crack surfaces are seen along the northwest road in a small ridge near the road junction. Five feet of this formation are exposed in the eastern slope of the nose of the hill beneath and extending south from the highest (and most southern) summit of High Rocks, two and a half miles north of West Coxsackie. The slopes in this area are well banked with talus which on the east slope contains an abundance of Rondout. Another exposure may be found under the Manlius cliff along the Ravena-South Bethlehem road one-eighth mile south of the northern edge of the Coxsackie quadrangle (one-quarter mile north of School No. 4). A wood road leads up to the Manlius cliff and to the right in the woods at the head of a small ravine a spring issues through the Rondout, three feet of which is exposed in the cliff. Folding is shown here, developed in connection with the fault that roughly follows the ravine. The best and most accessible exposure is along the same road, on the Albany quadrangle, just one-quarter of a mile north of the Coxsackie quadrangle. Two and a half miles south of South Bethlehem along the second road west is an excellent section from the Normanskill formation into the Esopus shale. In the hill at the east, Rondout is shown resting upon the edges of the Normanskill grit and shale and followed by the Manlius. There are 18 feet between the Normanskill and the base of undoubted Manlius. At the base of the Manlius is an 11-inch bed comprising a two-inch thin-bedded waterlime band at its base which is broken up and included in the lower eight inches of the bed, indicating a slight disconformity near the base of the Manlius, if not between the Manlius and Rondout. Since 14 feet of Rondout occur in the quarry at South Bethlehem at least that much could be expected here. The Rondout here is thin-bedded, weathered buff and partly broken down into clay. The upper portion is sandy and may include the "paper shales" sometimes seen at the base of the Manlius.

Leperditias have been found in the lowest Manlius beds, but none in the Rondout formation, though Van Ingen and Clark ('03,

p. 1185) report them in the Rondout area in a bed about 25 inches thick, which "forms the roof in most of the underground cement workings." They list besides *Leperditia alta* (Conrad) Hall, another ostracod, *Beyrichia* sp.?, the pelecypod *Modiolopsis? dubia* Hall and the brachiopod *Spirifer vanuxemi* (Hall). Field work (unpublished) by R. M. Logie, recently a graduate student at Yale University, indicates that the beds in which these fossils were found are basal Manlius rather than Rondout, increasing the thickness of the Manlius in this area to over 50 feet. Hartnagel ('03, p. 1169) reports from the Rondout of Herkimer county *Eurypterus* occasionally occurring on thin sandy layers, in one case associated with *Rhynchonella ? lamellata* Hall and *Whitfieldella* sp. No fossils were found in the Rondout waterlime in the Capital District area. The Silurian coral *Halysites catenulatus* (Linn.) was found by Hall in the Rondout of Herkimer county. From the lower portion at Howes Cave Grabau and others have reported fragments and small heads of the coral *Favosites helderbergiae* var. *precedens* Schuchert which have passed up from the Cobleskill below. There is therefore no question of the Silurian age of the Rondout waterlime (*see* Swartz, '39).

Manlius Limestone

The Manlius limestone was named from exposures at Manlius, near Syracuse, N. Y. (Clarke and Schuchert, '99) and includes near the top in Onondaga county two thin beds of waterlime which are used for cement. This formation has been known as the "*Tentaculite limestone*" (Gebhard, Mather and others) from the abundant occurrence of the little straight shells of the pteropod *Tentaculites gyracanthus,* and the "waterlime group of Manlius" (Vanuxem, '39). It extends under the Coeymans limestone (Lower Devonian) as far west as Onondaga county and west of this is overlain by the Oriskany or Onondaga to the limit of its extent in Seneca county (Harris, '04).

The term "Manlius" of Vanuxem (*ref. cit.*, p. 272) clearly was used in a group sense and to the various divisions in Onondaga county Burnett Smith ('29, p. 27-32) has given the following names, in ascending order: Olney limestone, Elmwood beds (A,B,C; A and C, lower and upper waterlimes), Clark Reservation limestone, Jamesville limestone and Pools Brook limestone. These beds together have a maximum thickness of 87+ feet, according to Smith's measurements. Hartnagel ('03, p. 1165) gives a thickness of 77 feet for the formation at the type section at Manlius. Eastward, in the Schoharie area, the Helderbergs and Hudson valley, the upper beds of the

Manlius group are represented by an erosion interval; only the lower portion, probably only the *Olney limestone,* is present. In the Schoharie area (West hill) 44½ feet of the "Tentaculite limestone" have been measured, including eight feet of supposed transition beds (Grabau, '06, p. 254). The writer has measured (aneroid) 45 feet ('35, p. 84) of Manlius in the Helderberg cliff (Indian Ladder area) of the Capital District. In the Helderbergs 12½ to 14½ feet belong to the so-called transition beds below which at the top of the typical Manlius occurs a varying thickness (less than four feet at Indian Ladder; two feet ten inches in New Salem quarry to the south) of waterlime which because of its softer nature has weathered out to form the "Upper Bearpath." Measurements in the Capital District are much the same in all sections. Southward, in the Hudson valley the formation thickens to 50 or 55 feet. The only occurrences of Manlius on the east side of the Hudson river are in the Becraft mountain outlier (55 feet) south of Hudson, where it is quarried along with the Coeymans and Becraft limestones for Portland cement by the Lone Star Cement Corporation and the Universal Atlas Cement Company and in the Mount Ida outlier, north-northeast of Hudson on the Kinderhook quadrangle.

The Manlius, typically, is a thin-bedded, dark blue limestone of fairly pure composition. The layers are one to three inches or more thick and are especially thin in the lower part with alternating light and dark beds ("ribbon-limestone"). Slabs of this limestone break with a ringing sound, and the rock when weathered has a characteristic light color. The occurrence of waterlime beds has been noted above. Sometimes the basal beds are very sandy (page 136). Something over three feet of the sandy basal beds are exposed in the quarry of the Atlas Cement Corporation in Becraft mountain and two to three feet in the enlargement of the Hudson cemetery below the Hudson "Old City Quarry," in the latter case resting conformably upon Schodack beds. Due to its remarkable hardness, the Manlius tends to form a distinct vertical cliff by itself or together with the Coeymans limestone above. The Manlius limestone and the Rondout waterlime beneath tend to form caves and shelters so well shown in the Indian Ladder region (Helderbergs) of the Capital District area. Certain surfaces of the rock show immense numbers of the *Tentaculites,* while others are covered with the little brachiopod *"Spirifer" vanuxemi* and still others with numerous specimens of the fairly large ostracod *Leperditia alta.* These three fossils together with the other characteristics make this a most easily recognized formation.

Besides the thin bedding the Manlius in places shows such features as mud cracks, faint ripple marks, thin shaly films separating the limestones, mud pebbles in bottom beds, comminuted shells, parallel arrangement of *Tentaculites* shells and piled-together masses of *Leperditia* shells (Ruedemann, '30, p. 45), all of which clearly indicate tide flat conditions. In the upper part of the Manlius occur one to three of the characteristic *Stromatopora beds*. The Stromatopora beds are strikingly shown in the Helderberg cliff, particularly in the Indian Ladder area. A few miles south of this area in a road metal quarry along the state road above New Salem, three of these beds are exposed, one eight to nine feet thick at the top of the formation. At least two such beds are present in the Manlius in the Hudson valley. The Stromatoporas belong to an extinct group of hydrocorallines represented today by forms, such as the elk-horn coral (*Millepora alcicornis*), which comprise some of the most important recent reef-builders. The Manlius form was described by Girty ('95) as *Stromatopora* (*Syringostoma*) *barretti*. The Stromatopora beds represent coral reefs that can be seen in section stretching for long distances through the Helderberg cliff; in fact they characterize the top of the Manlius (Olney) limestone in its full extent from central New York eastward, southward along the Hudson valley and then southwestward to the Port Jervis region, Orange county. They consist of great subglobular masses of concentric structure and horizontally connected. In discussing these reefs in the Capital District area Ruedemann writes ('30, p. 46):

> When one sees these reefs stretching through the Helderberg cliff at various levels, one can not help connecting the peculiar thin-bedded Manlius limestones with their tentaculites, ostracods and small spirifers and lamellibranchs, mud-cracks and mud pebbles with these reefs and see in the Manlius limestone principally lagoon deposits on tide flats formed between and behind the coral reefs. The transition beds contain alternating layers with the fauna of the Manlius and with elements of the following Coeymans, thereby indicating oscillating conditions of the sea. The Coeymans elements found are especially the small brachiopods *Stropheodonta varistriata* and *Camarotoechia semiplicata*.

Chert has been reported as occurring in scattered nodules in the upper portion of the Manlius, but it is not nearly so abundant as in the higher formations (Shimer, '05, p. 179).

In the Capital District area (New Salem section) Ruedemann ('30, p. 45) draws "the boundary line with the Coeymans along a distinct somewhat wavy line with a thin seam of shale above where Manlius pebbles are seen in the Coeymans limestone." The disconformity can not everywhere be distinguished. During field work on the Berne quadrangle (Helderbergs, Capital District) in 1927 the writer's attention was directed to a disconformity between the Manlius and Coeymans in the rock cut at the top of the old Indian Ladder road, marked by an irregular, wavy contact. In the same summer Chadwick called the writer's attention in the field to the occurrence of Manlius pebbles in the base of the Coeymans in the quarry just south of the village of Catskill. In the Rondout area "there appears some evidence that the surface of the Manlius was slightly eroded before the Coeymans was deposited on it" (Van Ingen & Clark, '03, p. 1186). Since the divisions of the Manlius group above, or not far above, the top of the Olney or "Tentaculite" limestone are missing, the disconformity must represent, not a slight, but a considerable period of erosion in the east and southeast during Manlius time.

Cement companies, in recent years, have begun to use the Manlius limestone in the manufacture of Portland cement. It has long been used for this purpose by the North American Cement Company at Howes Cave where the Coeymans limestone is also used. Two cement companies are quarrying the Becraft mountain area for this purpose, the Lone Star Cement Corporation and the Universal Atlas Cement Company. Here the Coeymans and Becraft limestones are also used. There are plants south of Catskill, at Alsen (North American Cement Corporation, Acme Plant) and at Cementon just south (Alpha Portland Cement Company). The Manlius is also quarried for crushed stone, as in the Hotaling quarry south of Ravena and (with the Coeymans limestone) in the quarries of the Callanan Road Improvement Company at Feura Bush and South Bethlehem, in the Capital District and in the vicinity of Kingston.

On the Coxsackie quadrangle exposures of the Manlius limestone may be found almost any place along the Helderberg cliff (figure 27) which stretches the full length of the quadrangle, at first in a north-south direction, then north-northeast to south-southwest. The best and most accessible sections are to be looked for in quarries, working or abandoned, in road cuts or along stream courses.

Along the second east-west road south of South Bethlehem, just north of our area, where the Rondout waterlime is well shown, 38 feet of typical Manlius are exposed with perhaps three or four feet of basal sandy beds. Here are soon found the common fossils *Tentaculites gyracanthus, Leperditia alta, "Spirifer" vanuxemi* and in addition the pelecypod *Leiopteria* [*Megambonia*] *aviculoidea.* At the top of the Manlius is shown a six-foot Stromatopora bed. Farther

Figure 25 Quarry at Climax showing at the base 40 feet of the Manlius limestone. Above are 20 feet of Coeymans limestone (massive portion above jog in right wall) capped by 10 feet of the Kalkberg limestone, seen at the edge of the wood, center, and distinguishable by numerous chert seams. (Photograph by E. J. Stein)

south, along the Ravena-South Bethlehem road and five-eighths of a mile northwest of Ravena, a 12-foot Stromatopora bed is exposed in an abandoned quarry in the Manlius just south of the east-west road that climbs up over the cliff. Here 25 feet of Manlius are exposed, capped by Coeymans in the cliff. At the top of the Stromatopora bed is an irregular, wavy contact above which *Gypidulas* appear in abundance, indicating the interval of erosion in later Manlius time. Two other Stromatopora beds are shown here; a two-foot bed occurs two feet below the heavy bed, then a three-foot waterlime bed below which is a three-foot Stromatopora bed. The beds dip N. 72° W. at an angle of 17° and vertical joint surfaces are well shown covered with calcite crystals or a deposit of calcite one-quarter of an inch or more thick. The main joint surfaces strike S. 46° W. and N. 76° W.

At the top of Ravena hill along the Ravena-Aquetuck road are excellent exposures in road cuts and quarries. In the road cut at the top of the hill, 10 feet up in the section is a heavy bed, one foot thick, composed entirely of calcareous algae, a bed characteristic of the Manlius of this region. A short distance south of the junction with the road to Deans Mills a mudcrack surface is well shown in the road bed. East of this, about 250 feet from the road the bed of calcareous algae is exposed in the summit of a small knoll. North of this same road junction are abandoned quarries which give opportunity for further study. In the larger quarry a six and one-half-foot Stromatopora bed caps the Manlius, while along the road, 300 feet west of the junction, a 22-inch Stromatopora bed (lower horizon) crosses the road. In this region, in addition to the common fossils, the writer collected a cephalopod, *"Orthoceras"* sp., and a gastropod, *Holopea antiqua*.

At Deans Mills between the bridge and the base of the falls is shown a splendid section from the Manlius limestone through the lower New Scotland (Kalkberg) limestone. Forty feet of Manlius are exposed capped by a five-foot Stromatopora bed. A three-foot bed below is separated from this by seven feet of thin-bedded limestone. This is likewise a good place to study the jointing.

Two other localities are particularly worth study, the Climax quarry (figure 25) and vicinity (west of West Coxsackie) and the section along the east-west road to Bronks lake, passing north of the reservoir of the New York State Vocational School. The large quarry at Climax is located along the state road near the junction with the Urlton road. Here are exposed 40 feet of Manlius, capped by 20 feet of Coeymans and about 10 feet of Kalkberg. Four feet from the top of the Manlius are six and one-half feet of the Stromatoporas (three feet and three and one-half feet, separated by 10 inches of thin-bedded limestone). Below this are seen 12 feet of thin-bedded and massive limestone followed by a two-foot Stromatopora bed. The beds here dip from S. 1° W. to S. 28° E. at an angle of two degrees, the direction and angle of dip due to the fact that the quarry has been excavated in the southern end of a domed hill. In the ravine to the east is a good section from New Scotland (Kalkberg) into the Manlius. The Murderer kill (probably Mordaener kill or Muddy creek), a branch of the Coxsackie creek west of West Coxsackie disappears in a sink-hole at Climax in the meadow southwest of the hotel and issues again through the Manlius in this ravine. A quarter of a mile south, in the cliff, faulting has raised the Manlius which composes most of the hill, the heavy Stromatopora bed forming the summit. The Bronks Road section is about a mile south of Climax. Near the bottom of the hill and in the stream bed to the south Normanskill grit and shale is exposed. Higher up 32 feet of Manlius are exposed showing nearly vertical cleavage cutting across the westerly dipping beds. An eight-foot, two-inch Stromatopora bed is shown. In the ravine below the dam and just south of the road an anticline is well shown in the north bank, which here gives a reduplication of the Manlius, Coeymans and New Scotland (Kalkberg). Due to a fault at the east the New Scotland of the east arm is followed by Manlius with a steep easterly dip resting upon the edges of the Normanskill grit and shale.

West of Flint Mine hill a road leads west-northwest to Urlton. About three-quarters of a mile from the state road, beginning at the junction with the road south to Greens lake, a splendid section may be followed from the Normanskill into the Hamilton. At the cliffs the Manlius limestone, nearly vertical, occurs about seven feet above Normanskill, so there can be little Rondout here. The Manlius is well exposed in the cliffs north of the road. Along the south road at the Collier farm (at bench mark 162), Manlius and Coeymans are well exposed on the west side of the road where a spring issues from the Manlius. Still farther south at School No. 4, just east of Limestreet junction is a good exposure of Manlius dipping N. 67° W. at an angle of 70°. A heavy Stromatopora bed and the thin-bedded limestones beneath are shown. Less than one-quarter of a mile southwest, south of the road culvert, the Manlius in the stream bed shows the same dip and high angle. Where these beds cross the Limestreet-West Athens road, just to the south, numerous calcite veins occur, having originated during the folding and faulting that

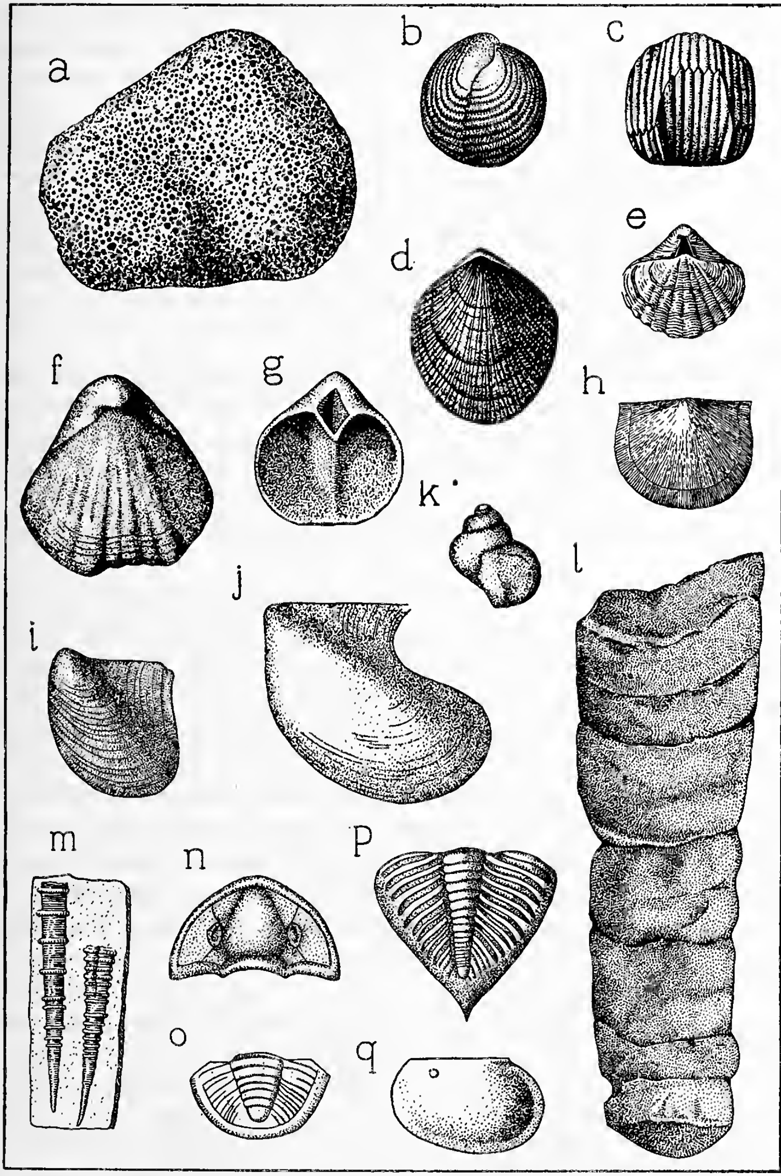

Figure 26 Manlius waterlime and Coeymans limestone fossils. (Manlius, *e, h, k, i, m, q.* Coral, *a;* brachiopods, *b-h;* pelecypods, *i, j;* gastropod, *k;* cephalopod, *l;* pteropod, *m;* trilobites, *n-p;* ostracod, *q*). *a Favosites helderbergiae,* x ½. *b, c Uncinulus mutabilis,* x ¾. *d Atrypa reticularis,* x ¾. *e "Spirifer" vanuxemi,* x 1½. *f, g Gypidula coeymanensis,* x ¾; interior of valve, x 1. *h Stropheodonta varistriata,* x ¾. *i Leiopteria aviculoidea. j Actinopteria obliquata,* x ¾. *k Holopea antiqua,* x ¾. *l "Orthoceras" (Anastomoceras) rudis,* x ½. *m Tentaculites gyracanthus,* x 2. *n, o Proetus protuberans,* head and pygidium, x 1. *p Dalmanites (Symphoria?) micrurus,* x ¾. q *Leperditia alta,* x 2.

occurred in the area. Another good road section is found at the southern end of the quadrangle where the Athens-Leeds road crosses the cliff. Here 35 feet of Manlius are exposed, including an 8-foot Stromatopora bed.

There are one or two other localities of interest. One is an old quarry in the Manlius at Roberts Hill near the road junction where there is a low broad syncline in the thin-bedded limestone. The second is less accessible, at the north end of High Rocks and east of the house at the end of the west-east lane. Here in the cliff a two-foot waterlime zone may be seen near the top of the Manlius and a nine-foot Stromatopora bed.

It is interesting to note that north of Ravena and just south, the Manlius beds have a low or moderate angle of dip, and the same is true again at the southern end of the quadrangle. In High Rocks and southward the dip of the beds steepens and from Climax south, nearly to the Athens-Leeds road, the beds, with few exceptions, stand at high angles, in places nearly vertical due to folding and faulting.

The fauna (*see* figure 26) of the Manlius is a meager one as might be expected from the nature of the formation. The three commonest fossils may be looked for in any of the Manlius limestone exposures. The writer has collected in various places a calcareous alga or seaweed, the hydrocoralline *Stromatopora* (*Syringostroma*) *barretti* Girty; the brachiopods "*Spirifer*" *vanuxemi* (Hall) and *Stropheodonta varistriata* (Con.); the pelecypod *Leiopteria* [*Megambonia?*] *aviculoidea* (Hall); the gastropod *Holopea antiqua* (Vanuxem); the pteropod *Tentaculites gyracanthus* (Eaton) Hall; the cephalopod "*Orthoceras*" sp.; and the ostracod *Leperditia alta* (Conrad) Hall. From the Capital District (Helderberg area) the following species were reported (Goldring, '35, p. 91):

Hydrocorallines

Stromatopora (Syringostroma) barretti Girty

Brachiopods

Camarotoechia semiplicata (Con.)
"*Spirifer*" *vanuxemi* (Hall)
Stropheodonta varistriata (Con.)

Pelecypods

Leiopteria [*Megambonia?*] *aviculoidea* (Hall)
Modiolopsis ? dubia Hall
Tellinomya nucleiformis Hall

Pteropods

Tentaculites gyracanthus (Eaton) Hall

Ostracods

Beyrichia (Kloedenia) notata Hall
Leperditia alta (Conrad) Hall

Chadwick reports (letter and manuscript) from the Catskill area to the south:

Hydrocorallines

Stromatopora (Syringostroma) barretti Girty

Crinoids

Lasiocrinus scoparius (Hall)
Crinoid stems

Worms

Spirorbus laxus Hall

Bryozoans

Monotrypella (?) arbuscula (Hall)

Brachiopods

"Spirifer" vanuxemi (Hall)
Stropheodonta varistriata (Con.)

Pelecypods

Leiopteria aviculoidea (Hall)

Gastropods

Holopea antiqua (Vanuxem)
H. ? elongata Hall
Tentaculites gyracanthus (Eaton) Hall

Cephalopods

"Cyrtoceras" subrectum Hall

Ostracods

Kloedenella trisulcata (Hall)
Kloedenia notata (Hall)
Leperditia alta (Conrad) Hall

(*Note*: Throughout this bulletin "Spirifer" is used in quotation marks at the suggestion of Dr G. Arthur Cooper of the U. S. National Museum. Revision of the group, already underway, will result in many changes).

In certain older regions, as at Jerusalem hill near Litchfield, in southern Herkimer county, some very remarkable crinoids and cystoids have been found (*see* Goldring, '23). From the Schoharie region Grabau has recorded ('06, p. 319) from the typical Manlius limestone (the Olney) 19 species consisting of one crinoid, one cystoid, one worm, two bryozoans, two brachiopods, five pelecypods, three gastropods, two pteropods and two ostracods. For the Manlius-Coeymans so-called transition beds 16 species are listed.

There has been considerable discussion over the demarcation of the Siluro-Devonian boundary, which may be briefly summarized, as follows: In the early days of the Survey under the leadership of James Hall, the Lower Helderberg beds (below the Oriskany sandstone) were classed with the Silurian. Later (J. M. Clarke), the Lower Helderberg limestones, with the exception of the Manlius, were placed in the Lower Devonian and known as the Helderbergian group. Because of the rather Silurian aspect of its meager fauna, the Manlius was left in the Silurian and since then has been the subject of much discussion as to its age. Some, following Clarke, class the entire Manlius as Silurian, others would place it with the Devonian and a third group places the dividing line within the Manlius (E. O. Ulrich). In his earlier studies ('29, '29*a*) of the Helderberg group from central Pennsylvania into Virginia and West Virginia, F. M. Swartz placed the Siluro-Devonian boundary at the base of the Keyser limestone [Helderbergian] chiefly because of the presence in the Keyser of members of important Devonian genera. That the species common to the faunas of the Keyser and the younger rocks are greater in number than those common to the faunas of the Keyser and the older rocks is thought to be due to the fact that the known Upper Silurian deposits of the Appalachian area do not contain an entirely representative marine fauna, rather than to any considerable time break. . . . ('29*a*, p. 52).

Those placing the dividing line within the Manlius believed that the lower portion of the Manlius exposed in the Helderberg-Schoharie area represented the lower beds and is the typical Manlius of Silurian age. The upper two to 15 feet of limestone of the Schoharie-Helderberg area, long distinguished as "transition beds," and the so-called Manlius beds exposed in the "Old Glory Hole" at Rondout were upper Manlius and Devonian (Keyser of Maryland and Virginia) in age. In accordance with this view, also, in the Rondout and Rosendale areas the lower or typical Manlius was entirely wanting or very thin and south of Rondout no Manlius (that is, the lower beds) occurs. The Upper Manlius beds of central New York were also considered as Keyser and Devonian (E. O. Ulrich, 1930, in writing). Later studies on the Manlius group by R. M. Logie, at the time a graduate student at Yale University, have shown that nothing higher than the Olney horizon of the Manlius (Silurian) is present in the Schoharie-Helderberg area and overlying horizons of the type region are wanting (in writing and conversation; work unpublished).

The latest studies of F. M. Swartz show (conversation in field, 1938: *see* '38, p. 6) that the Keyser carries the *Chonetes jerseyensis* zone through the lower half and the *Tentaculites gyracanthus* zone near the top. This and other evidence led him to conclude that the lower Keyser was the equivalent of the Manlius of New Jersey and also the Decker Ferry (carries *Chonetes jerseyensis* as also does the Cobleskill). C. A. Hartnagel (conversation) believes that the Decker Ferry is, at least in part, equivalent in age to the Cobleskill of New York. Swartz has believed for some time that all the Keyser is pre-Coeymans in age, that is, pre-Helderbergian in accordance with New York usage, and in a recent paper read before the Geological Society of America (Dec. 1938; *see* '38*a*, p. 1923) he stated definitely that the Keyser limestone was Silurian in age, that the Cobleskill was equivalent to the lower Keyser and the Manlius and Rondout to the upper Keyser. This view is fully discussed in his chapter on the Keyser and Helderberg formations in the recently published *Devonian of Pennsylvania* ('39).

DEVONIAN SYSTEM

The strata beneath the "Carboniferous" were not determined before 1833. Beneath the coal-bearing beds was a series of red sandstones and marls and above was a similar series, termed the Old and New Red Sandstone respectively. The Old Red Sandstone is typically developed in Scotland, but though widely known through the work of Hugh Miller, was not regarded as a distinct system. Sedgwick and Murchison in their work in Devon and Cornwall found distinctive fossils in rocks occurring between the Silurian and Carboniferous which made it apparent that these beds and the similarly placed Old Red Sandstone farther north belonged to a new system. To these rocks in 1837 the name Devonian was given from the exposures in Devonshire which then became the type section, though a far better section of Devonian rocks is found in western Germany and adjoining areas in Belgium. As with the preceding systems, North America furnishes the most complete record. Here, the rocks are preserved over wide areas and, unlike the type section, are for the most part little disturbed. New York State, again, has furnished the type section for the American Devonian and hence, in a way for the world. Other important exposures occur in Appalachian areas and in Michigan, the latter extending into Wisconsin and Iowa and also into Ohio, Indiana and Ontario. The transition from the Silurian to the Devonian is so gradual in certain areas, as in parts of the western half of the middle Appalachian region, that the boundary between the two systems has been long in doubt. As pointed out above, until recently the Helderbergian formations were placed in the Silurian and even the Oriskanian at one time was included in that system. Helderbergian limestones with some interruptions, occur from southwestern Virginia to Albany, N. Y., along the Appalachian line.

At the beginning of the Devonian there was an almost complete emergence of the continent of North America, and at no time during the Lower Devonian epoch was more than 10 per cent of the continent submerged. At this time the continent of Appalachia to the east was probably a broad mountainous upland with its eastern boundary extending perhaps 50 miles or more beyond the present continental shelf. That the land of Appalachia probably never reached Alpine heights, but was slowly raised as the Appalachian trough sank, is indicated by the character of the sediments. At the beginning of the Devonian (Helderbergian epoch) the seas were small and shifting; erosion occurred over the interior of North America and epicontinental waters were confined almost entirely to the Cordilleran area and the Appalachian trough, which opened to the Atlantic on the northeast (Gaspé region, Canada) and permitted the fauna from that province to enter its waters. As Lower Devonian time continued the sea was deepened and enlarged in the Appalachian trough and subsidence in the south permitted the sea to spread over western Tennessee into Missouri, southern Illinois and Oklahoma. The Lower Devonian of the Gaspé area is represented by 1500 feet of limestones (Helderbergian and Oriskanian series). The Helderbergian sea also covered northern and southern New Brunswick, northern Nova Scotia, northern Maine and parts of its coast and occupied the New England troughs. In the West Helderbergian formations have been found only in the Nevada trough and farther north on the shore of Kennedy channel (Lat. 80° N.).

At the end of Helderbergian time the sea withdrew from part of the Appalachian trough and in some areas much of the Helderberg deposits were removed in the erosion that followed. Lime sediments from this erosion, during the retreat of the sea in the late Helderbergian, accumulated locally in depressions and formed a detrital lime rock (Port Ewen beds). In the northern part of the trough, however, deposition continued forming the thick Lower Devonian seen in the Gaspé region. During the period of withdrawal of the sea, the eroded land surface was accumulating sand from various sources so that when the Lower Devonian Oriskany sea flooded the trough again and spread westward over this eroded surface these sands were reworked by the waves and deposited as the Oriskany sandstone, very fossiliferous in places and sometimes very calcareous; in other places no more than a thin layer of quartz grains, again a thick deposit of very pure quartz-sand as in Pennsylvania. At the end of Oriskany time the Cumberland area of the Appalachian trough was elevated and in eastern New York we find only the coarse sands and grits of a mud delta, the Esopus formation (Oriskanian). In late Lower Devonian (late Oriskanian) time, submergence became pronounced and continued to the maximum flooding of the continent in late Middle Devonian (Hamilton) time.

The great submergence of the Middle Devonian in North America had its counterpart in Europe, Asia, Australia and South America and was one of the greatest floodings in geologic history, exceeded later only by the great submergence of the Cretaceous. The interior sea was again established and in it was accumulated the Onondaga limestone which with its wealth of corals and brachiopods indicates a warm, clear sea surrounded by lowlands and it must have been of long duration. The warm waters, first from the North Atlantic and Gulf of Mexico and later from the Arctic sea that advanced south, brought many coral species and an abundance of corals which built extensive reefs in the limestone deposits, such as the famous occurrence at the Falls of the Ohio, Louisville, Ky. The Onondaga limestone stretches from the Hudson river across New York to Michigan and it also extends into Indiana, Illinois and Kentucky around what were perhaps islands of the Cincinnati anticline. In the West the Cordilleran sea, which probably connected on the north with the advancing Arctic sea, occupied much of the Great Basin area. As Middle Devonian time continued the land in the northeastern part of the continent was elevated, resulting in the rejuvenation of the streams which brought into the sea large quantities of mud and silt (Marcellus black shales, Hamilton shales and flags), checking the deposition of limestone. These deposits are thick in the East, and grow thinner westward. The accumulation of limestone continued in the Mississippi valley and even in New York State thin limestone beds occur at intervals in the thick mass of Hamilton shales. The Gaspé area was converted by the uplift into a coastal lagoon in which swift streams deposited masses of sand, these continental deposits containing fossils of land plants and giving indications of occasional invasions of the sea. The deposits in New Brunswick and Nova Scotia are also sandstones and shales. Part of the Middle Appalachian area (western Maryland and adjoining parts of Virginia) that was uplifted at the end of the Lower Devonian was now occupied by an extension of the interior sea. With the further rise of Appalachia and coincident further shrinking of the seas at the close of the Middle Devonian, streams were rejuvenated and continued to build great deltas in the northern part of the Appalachian trough (Ashokan bluestone delta and Kiskatom red beds of Hamilton age in New York). The *Acadian Disturbance,* which resulted in the elevation and folding of the Acadian land throughout New England and the Maritime Provinces of Canada, started in the Middle Devonian but continued even to the end of Devonian time, and forever destroyed the seaways from the North Atlantic through Acadia connecting the interior sea with the St Lawrence trough. Meanwhile through the later Middle Devonian the Cordilleran sea was spreading eastward bringing in its waters immigrants from Asia by way of Alaska. The Middle and Upper Devonian beds are separated by an erosion interval indicating the withdrawal of the sea at the end of Hamilton time.

During the Upper Devonian the continental seas were gradually withdrawn, first from the southern Mississippi Valley area and then from the interior and the Cordilleran areas, until at the end of the Devonian there was a practically complete emergence of North America. Here and there in the Mississippi valley the Upper Devonian overlaps older rocks where the Lower and Middle Devonian are absent. At the beginning of the Upper Devonian, parts of Tennessee, Alabama, Kentucky, northeastern Arkansas, Indiana and western Michigan were submerged and received deposits of black fissile shale that contains a typical Genesee shale fauna and that, in all the areas mentioned, is followed by the Ohio or Chattanooga shale now generally conceded to be of early Mississippian age (early Carboniferous). In the East the Genesee is another mass of bituminous black shale with few fossils which increases in thickness from Lake Erie to Pennsylvania and is followed by shales largely arenaceous and constituting the "Portage" (Naples) beds which in western New York and Virginia carry a characteristic fauna (Naples fauna) of goniatites and pelecypods which has little in common with the Hamilton but is well marked in many parts of the world, having been traced by way of our northwest through Manitoba into Siberia and thence through Russia into Westphalia (Germany). In New York it was an alien fauna, replaced eastward by the Ithaca fauna of Hamilton aspect. Above the "Portage" (Naples) beds in western New York occur the marine Chemung and post-Chemung beds (Chautauquan, Bradfordian) which reach their maximum thickness in Pennsylvania (3500 feet in central part) and thin greatly westward. Going eastward these beds are successively replaced by nonmarine beds of red and gray and gray or greenish shales and sandstones carrying plant remains at intervals and at some horizons, at least to the top of the Chemung equivalent ("Catskill" red beds), fresh or brackish water clams. In New York State the Upper Devonian beds of the east are mainly continental, becoming increasingly red toward the top, while in the west they are marine with no red beds and in between intermediate conditions are seen. The red "Catskill" beds spread west and progressively replace the marine Genesee, "Portage" (Naples) and Chemung beds (see Chadwick '35, '35*a*, '36). They represent a facies that began in the East in upper Hamilton (Middle Devonian) time (Kiskatom red beds) and continued through the Upper Devonian even into early Mississippian in Pennsylvania, and are believed to have been deposited in a long and narrow estuary running from eastern New York into Pennsylvania.

As we have seen, besides in New York State rocks of Devonian age outcrop in the Michigan area and extend into Wisconsin and

Iowa, Ohio, Indiana and Ontario, Canada. Occurrences are also found in Oklahoma, Missouri and western Tennessee and Kentucky. Along the line of the Appalachians Devonian rocks have been traced with interruptions from southwestern Virginia to Albany, N. Y. In the St Lawrence region deep deposits occur in the Gaspé area. Northern Nova Scotia and northern Maine also have these rocks. In the West Devonian strata, often in considerable thickness, occur in the Rocky mountains and in the Canadian northwest; even far north on the shore of Kennedy channel, 80° N. latitude. In the northern Appalachians the deposits are mostly shales and fine-grained sandstones and here are found the thickest series of Devonian beds in the country, representing the longest sequence. Pennsylvanian deposits show the greatest thickness, 13,000 feet of shales and sandstones which become less marine, coarser and redder toward the top. Here the Lower Devonian has a thickness of about 1400 to 2750 feet, the Upper Devonian of about 5800 to 9700 feet (mostly red shales, coarse sandstones and conglomerates). In Maryland the Lower Devonian has a greater thickness, the Middle and Upper Devonian less. Devonian deposits in the interior are very thin compared to those in the East. About 50 feet of Middle Devonian limestone and shales are represented at Louisville, Ky. In the southern Mississippian valley and Oklahoma the deposits represent, for the most part, Lower and early Middle Devonian and here also the deposits are thin (less than 250 feet thick). In western Ontario, Canada, there is a thickness of something over 500 feet of deposits, mostly shales, but the thickest accumulations in the median part of North America, thicker than in Ontario, are the Middle and Upper Devonian beds found in Michigan, particularly about Alpena. In the Cordilleran area the Devonian deposits are mostly limestones and in Nevada reach a thickness of 4000 to 8000 feet (limestones and calcareous shales), though in the United States most sections in this area are comparatively thin. About 1000 feet (nearly one-half limestone) were deposited in the MacKenzie valley and exposures show about 600 feet of limestone in southeastern Alaska.

The Devonian period had a little more than half the duration of Ordovician time. Throughout the period, and especially in the Upper Devonian, igneous activity occurred in the New England states and the Maritime Provinces of Canada in connection with the Acadian Disturbance which was perhaps a forerunner of the later revolution that formed the Appalachian mountains. The volcanic cones are eroded away and only the deeper-seated volcanic rocks remain. Mount Royal at Montreal is one of these. Besides the volcanic extrusions, there were igneous intrusions (granitic), such as those found in many places throughout New Brunswick, in Nova Scotia and southern Quebec. Igneous intrusions of Devonian age also occur in Maine and possibly Vermont and New Hampshire. Thin coal beds of very local distribution occasionally occur in the Upper Devonian but are not of commercial value. They are an indication of the presence of swampy areas abounding in plants. Petroleum is found quite extensively in the Upper Devonian of southwestern New York and northwestern Pennsylvania. It occurs rarely in the Onondaga of New York, but in Canada the production is entirely from the Onondaga.

In the area covered by the present state of New York Devonian history is comparatively simple. Rocks of this age are more widespread here than those of any other age, covering nearly one-third the area of the State, and they have a combined thickness of between 8000 and 9000 feet, the Catskill mountains along the Hudson representing the most impressive single accumulation of Devonian deposits in the United States. The Devonian strata along the Hudson valley, as indicated by the outliers (Becraft mountain and Mt Ida) on the east side of the river, formerly extended some distance to the east into Massachusetts and perhaps the Connecticut valley. These beds, standing out now as a bold escarpment facing the Mohawk valley, must also have extended northward across this valley to the southern Adirondacks. The great limestone deposits of the New York Devonian occur in the Lower and early Middle Devonian. The great bulk of the Devonian rock lies above the limestones and consists of huge deposits of sandstones and shales. Except for the nonmarine deposits of the East, the Devonian rocks throughout abound in fossils of marine organisms. The Upper Devonian beds have furnished a wonderful flora of land plants including tree ferns (*Archaeopteris*) and giant club mosses (*Protolepidodendron*). The discovery of the "Gilboa" tree (seed fern, *Eospermatopteris*) in the Middle Devonian (Hamilton; Moscow) beds in the Catskills (Gilboa, N. Y.) has made that area famous and the Upper Devonian "Naples" tree (club moss) has done the same for western New York.

Devonian deposits present in the area covered by the Coxsackie quadrangle are represented by all formations from the Helderbergian Coeymans limestone into the Middle Devonian red Hamilton (Kiskatom) beds.

Coeymans Limestone

The Coeymans limestone received its name from the town of Coeymans, Albany county (Clarke and Schuchert, '99), but in the earlier reports it was known as the "Lower Pentamerus" limestone because of the abundant occurrence of the brachiopod *Pentamerus* (*Gypidula*) *galeatus* (later *Sieberella coeymanensis*). This limestone extends farthest west of any of the members of the Helderberg group, reaching the town of Manlius in Onondaga county (*see* Hopkins, '14, p. 20) where it is overlain by a thin representation of reworked Oriskany (basal quartz sands of the Onondaga).

In east central New York, from Schoharie through the Helderberg area of the Capital District, the Coeymans has a thickness of about 50 feet. Because of its massive character, hardness and thickness it is the most striking Helderberg formation and also the principal cause of the Helderberg cliff which continues south and southeastward along the west side of the Hudson valley. Two outliers occur on the east side of the Hudson, in Mt Ida (Mt Bob of Grabau, '03) northeast of the city of Hudson and Becraft mountain to the south. Grabau ('03, p. 1034) reports a thickness of 45 feet in the Becraft mountain outlier south of Hudson, but in general south of the Capital District the formation gradually thins to a thickness of about 15 feet (11 feet in Turtle Pond quarry just south of the village) in the Catskill region (Chadwick, in field, 1938). Van Ingen and Clark ('03, p. 1187) report 49 or 50 feet in the Rondout area and Shimer ('05, p. 181) 40 feet of "Coeymans proper" in southeastern New York (Trilobite mountain, Orange county). Layers of chert have been observed in some of the outcrops in the Becraft Mountain section and many New Scotland species (*see* Grabau, '03, p. 1055) occur in the upper layers of the "Coeymans", associated with *Gypidula coeymanensis,* characters which together would indicate the inclusion of the Kalkberg member of the New Scotland in the measurement given for the Coeymans here. The Rondout measurement includes at least 28 feet of cherty and argillaceous beds which, taking the fauna into consideration, might well represent the lower New Scotland beds. Shimer also, describes the upper part of his "Coeymans proper" as characterized by thin chert bands, so characteristic of the Kalkberg.

The base of the Coeymans is generally accepted to be above the heavy Stromatopora bed where the first specimens of *Gypidula coeymanensis* come in and where a disconformity has in places been noted, as in the New Salem and Indian Ladder sections in the Helderbergs, in the Turtle Pond quarry south of the village of

Catskill and in the Rondout area (*see* page 135). The characteristic vertical jointing of the Coeymans and the presence of the softer, so-called "transition beds" beneath cause this limestone to stand up as a vertical cliff which usually projects beyond the underlying Manlius and Rondout in whose softer beds caves and shelters tend to develop.

The Coeymans limestone may be readily distinguished from the Manlius by its massiveness, the bluish gray color which weathers light gray, and the rather coarse, semicrystalline structure. It is composed of fragments of shells, crinoids and corals and at intervals is a nearly typical shell limestone or coquina, with the brachiopod shells in large part in a very perfect state of preservation. These weather out in relief on the surface and along exposed edges, where, with care, they may be collected. This rock in general is fairly regularly bedded, but there is an irregular subbedding into flat, interlocking lenses which is brought out by weathering. The most massive beds occur in the lower part of the formation, several feet thick, while toward the top the formation becomes more thin-bedded. There are also occasional shale partings, nodules and thin lenses of chert, though chert in abundance is characteristic of the succeeding lower New Scotland (Kalkberg) beds. The Coeymans is more siliceous than the Manlius and the fossil remains which it carries tend to become silicified. In some sections this limestone was quarried and burned for lime.

Wherever the Coeymans limestone occurs the vertical jointing is very characteristic. There are usually two distinct groups of intersecting joints, one running west of north, the other east of north. Minor joint fissures, also, are present, crossing the main groups. While there is more of a tendency for caves to develop in the underlying Manlius and Rondout formations, they may also be found in the Coeymans, as exemplified in the cave northeast of Shutter corners in the Helderbergs (Goldring, '35, p. 97, 98), where the course of the cave (simply an underground stream channel) is governed by the two main directions of jointing, alternately following one or another of these joints.

The fauna of the Coeymans limestone, in general, seems to be a small one, though extensive lists have been published for the Schoharie region, Becraft mountain, Ulster county (Rondout region) and Orange county (Trilobite mountain). Fossils are difficult to collect because of the hardness of the rock, but three common brachiopods may be found in most sections. The most common and characteristic fossil is the brachiopod *Gypidula coeymanensis* with the helmetlike shape of the shell, from which the original specific name (*galeatus*) was derived. The next common forms are the long range brachiopod with many fine ribs and prominent concentric lines on the shell, *Atrypa reticularis,* and the subglobular form with many ribs, *Uncinulus mutabilis.*

For the Schoharie region Grabau ('06, p. 320) lists a fauna of 41 species, including two corals, one cystoid, three crinoids, one bryozoan, eleven brachiopods, six pelecypods, three gastropods, seven cephalopods, one pteropod, five trilobites and one ostracod. In the Schoharie region and Herkimer county the Coeymans limestone has furnished a number of beautiful crinoids, as *Lasiocrinus scoparius* (Hall), *Melocrinus pachydactylus* (Con.) and *M. paucidactylus* (Hall), and strange cystoids as the very characteristic *Lepadocrinus* (*Lepocrinites*) *gebhardi* (Con.). The small crinoid *Lasiocrinus scoparius* (Hall) was found (Clarke and Ruedemann) occurring in great numbers at Jerusalem hill, near Litchfield, Herkimer county, in both the Manlius and Coeymans limestones, associated with the peculiar starfish *Hallaster forbesi* (Hall). According to Ruedemann ('30, p. 49), this would indicate that crinoid plantations grew in this region during these times in water apparently more quiet than prevalent farther east.

North of our area in the Capital District (including the Helderbergs) the following fossils have been collected (Goldring '35, p. 101, 103; Prosser and Rowe, '99, p. 349):

Corals

Favosites helderbergiae Hall

Cystoids

Lepadocrinus gebhardi (Con.)

Bryozoans

Bryozoan sp.

Brachiopods

Anastrophia verneuili (Hall)
Atrypa reticularis (Linn.) Dalman
Camarotoechia semiplicata (Con.)
Gypidula coeymanensis Schuchert
Leptaena rhomboidalis (Wilckens)
Meristella laevis (Vanuxem)
Orthostrophia strophomenoides Hall ?
O. sp.
"Spirifer" perlamellosus Hall
"S." vanuxemi Hall
Stropheodonta [*Brachyprion*] *varistriata* (Con.)
Uncinulus mutabilis (Hall)

Cephalopods

"Orthoceras" (*Anastomoceras*) *rudis* Hall

Trilobites

Dalmanites pleuroptyx (Green)

From the Catskill area to the south Chadwick reports (letter, April 1938):

Corals

Favosites helderbergiae Hall

Crinoids

Melocrinus (etc. ?) stems

Brachiopods

Atrypa reticularis (Linn.) Dalman
Gypidula coeymanensis Schuchert
Uncinulus mutabilis (Hall)

Pelecypods

Actinopteria obliquata (Hall)

Trilobites

Dalmanites (*Synphoria ?*) *micrurus* (Green)
Proetus protuberans Hall

Of *Stropheodonta* [*Brachyprion*] *varistriata* Chadwick writes:

While it is reasonable to suppose that *Brachyprion varistriatum* may have a representative mutation in the Coeymans, all the specimens I have found of the species in the Coeymans have been in the basal foot or so and are clearly imbedded in reworked slabs of Manlius, hence it is necessarily present in these fragments within the Coeymans.

Grabau ('03, p. 1055, 1056) reports from the upper beds of the Coeymans limestone of Becraft mountain a list of 33 species, including two corals, two bryozoans, 21 brachiopods, one pelecypod, four gastropods and three trilobites. Since this fauna has a decidedly lower New Scotland (Kalkberg) aspect (*see* page 161) it has not been listed here for the Catskill area. Farther to the southwest, from Ulster county (Rondout area), Van Ingen and Clark ('03, p. 1188) have reported from the lower, chert-free beds a fauna consisting of 38 species: two corals, two bryozoans, 25 brachiopods, two pelecypods, one cephalopod, unidentified ostracods and five trilobites. In the Coeymans of this area the brachiopods are considerably more abundant than in the Schoharie area. Farther south, from the Trilobite Mountain section in Orange county, a fauna similar in size and composition to that of Becraft mountain, consisting of two corals, one bryozoan, 21 brachiopods, one pelecypod, one gastropod, one pteropod, one cephalopod and three trilobites, has been listed (Shimer, '05, p. 207ff.) from the beds fairly free of chert.

The Coeymans limestone is quarried in places for road materials, as at Feura Bush and South Bethlehem in the Capital District (Callanan Road Improvement Company). It has been used for this purpose in several abandoned quarries in the Coxsackie area. Together with the Manlius (page 136) it is used for the manufacture of cement at Howe's Cave by the North American Cement Company; with the Manlius and Becraft at Becraft mountain by the Lone Star Cement Corporation and the Universal Atlas Cement Company.

In the area of the Coxsackie quadrangle the Coeymans limestone, like the Manlius, may be found exposed almost anywhere along the Helderberg cliff and also, as is the case with the Manlius, is largely confined to this cliff (figure 27). Only between Deans Mills and the area just north of the Ravena-Coeymans Hollow road do these formations spread out to any extent. The best sections are to be looked for in road cuts, stream beds and quarries, and a few of these deserve especial mention.

Just over the northern boundary of the Coxsackie quadrangle, along the second east-west road south of South Bethlehem about

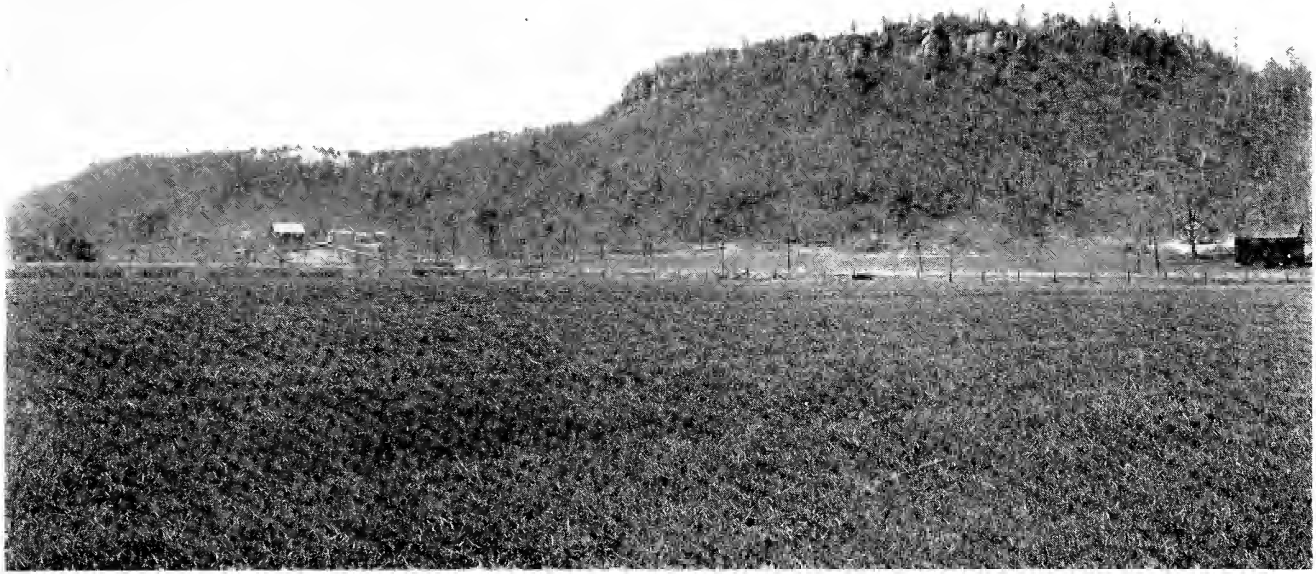

Figure 27 Coeymans-Manlius cliff north-northeast of Ravena, above School No. 4. A few feet of Kalkberg limestone caps this cliff. View south from the state highwav. (Photograph by E. J. Stein)

Figure 28 Coeymans limestone at Deans Mills, showing the characteristic weathering into joint blocks. The top of the Manlius limestone is shown at the base of the falls; upstream is seen the Kalkberg limestone with numerous chert seams. See figure 29 for close-up view of the Kalkberg.

26 feet of typical Coeymans are exposed. In the first ravine about one-quarter of a mile south of the northern boundary of our area, along a wood road and in the cliff to the south in the vicinity of School No. 4, over 30 feet are exposed. Beautiful jointing occurs in these localities and in the last-named locality is shown vertical cleavage, due to the proximity of a minor fault. The dip in this area is to the southwest at a low angle, at the schoolhouse S. 58° W. at an angle of six degrees. About five-eighths of a mile north-northwest of Ravena, in an abandoned quarry in the cliff 33 feet of Coeymans are exposed of which 22 feet are free of chert and 11 feet show some chert but still carry numerous Gypidulas. *Gypidula coeymanensis* is very abundant here and unusually large specimens, up to two inches in length, are found. Joints are well displayed, the major groups running N. 76° W. and N. 22° E. The angle of dip has steepened here to 17° and the direction is N. 72° W.

The section in the stream at Deans Mills (figure 28) is easily accessible and splendid for study, not only of the Coeymans but of the Manlius and lower New Scotland (Kalkberg) beds as well. There is a low angle of dip here (3°), S. 38° W. Three sets of joint cracks may be distinguished, the major joints directed N. 50° E. and N. 40° W., the third set running N. 14° E. The formation here has a thickness of about 15 feet. Huge heads of *Favosites helderbergiae* are present and *Gypidula coeymanensis* occurs abundantly. Occasional chert nodules are present in the upper beds. The joint seams are so widely opened by solution that the Coeymans is divided into a mass of huge blocks with rounded edges. Normally it would form the top of the falls, but the wide joint fissures allow the water to sink through to the base of the formation and ordinarily there is only a small falls over the Manlius beneath, obscured by huge fallen blocks of Coeymans. Fifteen to 20 feet of Coeymans are exposed in the cliff south of Deans Mills.

The abandoned quarry at Climax (figure 25) provides another study section easy to reach. Twenty feet of Coeymans limestone are exposed here, with variable dips from S. 1° W. to S. 28° E. at a very low angle of 2°. The variable dips and low angle are due to the fact that the quarry was excavated in the southern end of a domed hill. Good exposures of the formation, with the same or a slightly increased thickness, are seen in the ravine to the east (south of the highway) and in the cliff immediately to the south (23 feet).

The section along the east-west road past the reservoir of the New York State Vocational Institution (east of Bronks lake) has been discussed under the Manlius limestone (page 139). Eighteen to 20 feet of Coeymans are exposed here dipping N. 77° W. at an angle of 74° and showing cleavage. The exposure along the road represents the left (west) arm of an anticline; in the bank of the ravine just below, the east arm is exposed. The structure here is complicated by a small fault. Another good cut is made by the next east-west road to the south (west of Flint Mine hill). Here the beds stand nearly vertical (angle of 80°) and dip N. 48° W. Fifteen feet of Coeymans are exposed along the stream northeast of the junction of the Greens Lake and Limestreet-West Athens roads. In several places between this locality and the one last-mentioned the dip has flattened to a low angle, but here again folding and faulting have steepened the angle of dip to 60° and the direction is S. 43° W. The Coeymans continues with approximately the same thickness to the southern end of the Coxsackie area. In the cut made by the Leeds-Athens road, within half a mile of the southern edge of the quadrangle at least 13 feet of this formation are exposed. Above are cherty beds full of Gypidulas, crinoid stems and corals, the basal layers possibly representing the Coeymans as 20 feet are exposed in the cliff a short distance to the south. In the road cut the dip is S. 10° W. at an angle 8° which steepens to 24° in the cliff farther south where the direction of dip has changed to S. 68°-78° W.

Except for the coral *Favosites helderbergiae* and the characteristic brachiopod, *Gypidula coeymanensis* fossils have not been found in any abundance in the area of the Coxsackie quadrangle. The complete list for this area follows:

Crinoids

Melocrinus sp., stems

Bryozoans

Bryozoan sp.

Brachiopods

Atrypa reticularis (Linn.) Dalman
Gypidula coeymanensis Schuchert
"Spirifer" cyclopterus Hall
Uncinulus mutabilis Hall

Pelecypods

Actinopteria obliquata Hall

Gastropods

Loxonema cf. *planogyratum* Hall
cf. *Diaphorostoma* sp.

Cephalopods

"Orthoceras" (Anastomoceras) cf. *rudis* Hall

Trilobites

Dalmanites micrurus (Green)

The transition from the Coeymans to the lower New Scotland (Kalkberg) beds is gradual. In places the upper Coeymans beds carry chert nodules or thin lenses of chert and these beds merge gradually into the conspicuously cherty Kalkberg. The Coeymans fossils also continue into the basal, cherty New Scotland beds.

New Scotland Beds

The earliest name for the New Scotland limestone was "Catskill shaly" limestone, so-called from exposures along the Catskill in Austin glen, near the village of Catskill. Also known to the geologists of the first Survey as the "Delthyris shaly" or "Lower shaly" limestone, this limestone received its present name (Clarke and Schuchert, '99) from the town of New Scotland, Albany county (the village of New Scotland being located on Schenectady beds). It continues westward into Herkimer county without interruption and there it disappears, due to uplift and erosion which has allowed the Onondaga to rest upon the Coeymans. Farther west in Madison county there is evidence that it reappears; but except for this occurrence the Oriskany is the only intervening formation and west of the central part of the State is the basal Devonian formation. East of the Hudson river the only occurrence of the New Scotland is found in the Becraft Mountain outlier south of the city of Hudson (Catskill quadrangle).

In 1908 the beds between the Coeymans limestone and the typical shaly New Scotland limestone, long known as transition beds, were separated by Chadwick as a distinct formation, the *Kalkberg limestone,* which was so designated from the local Dutch name for the Helderberg ridge (Kalkberg, meaning limestone mountain). The name was applied to these beds, variously included in the Coeymans limestone and New Scotland beds previously, because they have a wide distribution, carry a mixed fauna and are characterized by parallel seams of chert which form heavy beds in the type section, at and below the so-called "Coffin Rocks" in Austin glen where these beds cross the Catskill. In a recent letter to the writer (April 1938), in connection with his manuscript for the bulletin on the Catskill quadrangle, Chadwick writes: "In my revise I am using New Scotland as the inclusive term with Kalkberg as the lower member and reviving the term Catskill shaly limestone for the higher member, as this term still had standing as late as Handbook 15" (Clarke, '99). This name for the upper member of the New Scotland beds was used by Chadwick in mimeographed outlines for the Catskill meeting of the New York Geological Association, April 1940.

In the type section the Kalkberg limestone has a thickness of about 40 feet, but the thickness varies in that area (Catskill quadrangle) from 25 to 40 feet. In the Capital District (Helderberg area) only about 20 feet are represented. In Becraft mountain the measurement for the Kalkberg apparently is included, at least in part, with the measurement for the Coeymans and this seems to be true also for sections studied in Ulster (Van Ingen and Clark, '03) and Orange (Shimer, '05) counties. These beds are darker in color, of denser grain than the Coeymans and more impure, with clayey matter, silica and iron. The conspicuous seams of black chert begin close to the contact of the Coeymans with the Kalkberg, in which also the fossils are more numerous and more silicified. Typically the Kalkberg is more siliceous and less shaly than the upper New Scotland beds and weathers a buff color; but, in certain areas, as the Helderbergs, there are thin, highly fossiliferous limestones interbedded with shales like those of the overlying beds. Only about 20 feet of Kalkberg are represented in the Helderberg area and the upper and lower New Scotland beds here more nearly approach each other in character since the lower beds are less siliceous and the upper beds more so than in the type area. Where the chert beds are heavy and the limestone more pure, as in the type area, the Kalkberg forms a cliff in connection with or behind the Coeymans; in the Helderberg area, and, indeed, the Capital District in general, it forms a low terrace below the shaly beds which is often conspicuous in the topography. The upper beds of the Kalkberg are more impure and grade up into the shaly limestone above. In all the layers, but especially the upper ones, nodules of purer, more fossiliferous limestone are imbedded in the more argillaceous and siliceous material, in this respect bearing a strong resemblance to the Alsen which weathers a similar buff color and with which the Kalkberg may easily be confused at first glance in the field. Strong jointing occurs in these beds as in the Coeymans below. This character and ready solubility have developed such blocks as the "Coffin Rocks" of the type section in Austin glen and entrances to caves which may extend down even into the Manlius.

The Kalkberg limestone as a whole contains a fairly profuse fauna. The uppermost beds are characterized by an abundance of bryozoans, represented by many genera (*Hallopora, Fistulipora, Monotrypa, Trematopora* etc.). Fossils here are more abundant, especially the smaller ones. Thick stems of crinoids, as *Mariacrinus stoloniferus,* characterize this member. The lower beds carry the characteristic little brachiopod *Bilobites varicus* which does not appear in the beds above. As shown by the lists, the fauna is, in general, a mixture of Coeymans and New Scotland types. The only list of Kalkberg species, as such, for the Capital District is that published for the Indian Ladder area (Goldring, '35, p. 108):

Sponges

Hindia sphaeroidalis [*inornata, fibrosa*] Duncan

Hydrocorallines

Stromatoporoid

Corals

Streptelasma (Enterolasma) strictum Hall

Crinoids

Mariacrinus stoloniferus Hall
Myelodactylus [*Brachiocrinus*] *nodosarius* (Hall), stems

Bryozoans

Callopora (*Callotrypa*) sp.
Fenestella sp.
Fistulipora sp.
Monotrypella sp.
Paleschara incrustans Hall
Ptilodictya sp.
Stictopora sp.
Thamniscus sp.

Brachiopods

Atrypa reticularis (Linnaeus)
Bilobites varicus (Conrad)
Eatonia medialis (Vanuxem)
Gypidula coeymanensis Schuchert
Isorthis [*Dalmanella*] *perelegans* (Hall)
Leptaena rhomboidalis (Wilckens)
Levenea [*Dalmanella*] *subcarinata* (Hall)
Meristella laevis (Vanuxem)
Rhipidomella oblata Hall
Schuchertella [*Orthothetes*] *woolworthana* (Hall)
"*Spirifer*" *cyclopterus* Hall
"*S.*" [*Delthyris*] *perlamellosus* (Hall)
"*S.*" (*Eospirifer*) *macropleura* (Conrad)
Stropheodonta cf. *varistriata* (Conrad)
Strophonella leavenworthana Hall

Trilobites

Phacops logani Hall

For the Schoharie area (Grabau, '06, p. 321), Becraft mountain (Grabau, '03, p. 1058), Ulster (Van Ingen and Clark, '03, p. 1190) and Orange (Shimer, '05, p. 207ff.) counties the lists of fossils were published before the separation of the New Scotland beds into members. It is possible that part of the Kalkberg fauna is included in the list of fossils for the Coeymans of Becraft mountain and that the fauna listed for the upper cherty Coeymans beds and lower New Scotland beds of Ulster and Orange counties belongs in part to the Kalkberg. For the area to the south of the Coxsackie quadrangle Chadwick (letter 1938) has brought together a considerable fauna for the Kalkberg limestone, as follows:

Sponges

Hindia sphaeroidalis [*inornata, fibrosa*] Duncan

Corals

Caninia roemeri Hall
Favosites conicus Hall
F. helderbergiae Hall
Streptelasma (*Enterolasma*) *strictum* Hall

Crinoids

Cordylocrinus plumosus Hall, stems
Melocrinus sp., stems
Myelodactylus [*Brachiocrinus*] *nodosarius* (Hall), stems

Bryozoans
(numerous)

Callotrypa sp.
Chilotrypa sp.
Fistulipora sp.
Hallopora sp.
Monotrypa sp.
Polypora sp.
Trematopora sp. etc.

Brachiopods

Anastrophia verneuili (Hall)
Anoplotheca (*Coelospira*) *concava* (Hall)
Atrypa reticularis (Linnaeus)
Atrypina imbricata Hall
Bilobites varicus (Conrad)
Camarotoechia transversa (Hall)
Cyrtina dalmani (Hall)
Eatonia medialis (Vanuxem)
E. singularis (Vanuxem)
Gypidula coeymanensis Schuchert
Isorthis [*Dalmanella*] *perelegans* (Hall)
Leptaena rhomboidalis (Wilckens)
Levenea [*Dalmanella*] *concinna* (Hall)

L. [*D.*] *quadrans* (Hall)
L. [*D.*] *subcarinata* (Hall)
Meristella laevis (Vanuxem)
M. arcuata Hall
Nucleospira ventricosa Hall
Platyorthis [*Dalmanella*] *planoconvexa* (Hall)
Rhipidomella oblata Hall
Rhynchospira formosa Hall
R. globosa Hall
"Spirifer" cyclopterus Hall
"S." [*Delthyris*] *perlamellosus* (Hall)
"S." (*Eospirifer*) *macropleura* (Conrad)
Stropheodonta (*Brachyprion*) *arata* Hall
Strophonella leavenworthana Hall
Trematospira perforata Hall
Uncinulus abruptus Hall
U. nucleolatus Hall
U. pyramidatus Hall

Trilobites

Goldius [*Bronteus*] *pompilius*
Odontochile sp.
Phacops logani Hall

The upper member of the New Scotland (*Catskill shaly limestone* member of Chadwick), the typical shaly limestone, has a thickness of 75 to 100 feet and over. In the Capital District area (Goldring, '35) the thickness is 100 to 105 feet; for the Schoharie region Grabau ('06) cites a thickness of 115 feet for the New Scotland beds, a measurement which also includes the Kalkberg member which apparently thins in that direction. The thickness of the New Scotland shaly limestone in Becraft mountain is 70-75 feet (Grabau, '03); in the Catskill Quadrangle area 100 feet (Chadwick). In Ulster county (Kingston region) the 100+ feet measured (Van Ingen and Clark, '03) may include some Kalkberg. In the Port Jervis area Shimer ('05, p. 182) divides the 170 feet of New Scotlands beds into an upper and lower horizon, the upper 125 feet characterized by a great abundance of *"Spirifer" cyclopterus* which in exceedingly rare in the lower 45 feet, the latter characterized by an abundance of bryozoans. Of New Scotland here Shimer writes (*ref. cit.*) that it "is at times very full of chert bands which in places make up almost half of the rock mass. These chert bands, like many of those in the upper Coeymans are, when weathered, one mass of fossils." The indications are that the Shimer's upper Coeymans and his "lower horizon" of the New Scotland beds, in part or entirely represent the Kalkberg member.

The shaly New Scotland limestone is in general the least conspicuous and the most fossiliferous member of the Helderbergian series. It consists of thin-bedded, very impure, shaly sandstones and calcareous shales which tend to be heavier and less fossiliferous in the lower portion, at least in certain areas, as the Indian Ladder region (Helderbergs) of the Capital District area, where in the lowest 20 feet or more only the brachiopods *Lingula* and *Orbiculoidea* were found. Locally seams of black chert appear in the uppermost 20 feet or so. The occurrence of an abundance of chert in the New Scotland beds of the Port Jervis area probably has a different significance, as suggested above. The transition from the New Scotland to the Becraft is not sharp, since the lower Becraft has partings of shale and the uppermost New Scotland carries limestone bands that are packed with crinoidal fragments.

When weathered the New Scotland shaly beds have a gray or gray-brown color, but in fresh exposures the rock has a dark bluish gray color and the massive appearance of a true limestone. Because it consists of thin-bedded shaly limestones and calcareous shales this shaly limestone weathers readily and forms the gentle slopes above the Coeymans limestone. While the latter tends mostly to wooded back slopes, the soil-covered, gentle slopes of the New Scotland frequently constitute the farm lands and often are used for grazing. Numerous good outcrops, therefore, are not to be expected. The best ones are to be found in road cuts and stream beds and because they afford such fine collecting have always been much sought after by collectors.

The name "Delthyris shaly limestone" used in the old days for this upper member was based upon the common occurrence of the two characteristic brachiopods *Delthyris perlamellosus* and *D. macropleura* (now *"Spirifer"*). In general the fossils of the shaly beds occur only as impressions or natural molds, but in certain areas where the limestone is more siliceous the fossils have become silicified. The middle beds are, on the whole, the most fossiliferous. To the north of our area, the Helderberg area of the Capital District was the source of much of the early collections of the New York State Survey, more particularly the Countryman Hill section near New Salem and around the village of Clarksville. Ruedemann in his Capital District bulletin ('30, p. 49) draws attention to the fact that the Clarksville region was the "stamping ground" of Hall and his assistants (Beecher, Clarke, Schuchert, Simpson, the Van Deloos, father and son, Walcott and Whitfield). He has estimated for this region, from the various reports, a fauna of 184 species for the entire New Scotland beds (two calcareous algae, one sponge, 10 corals, 71 bryozoans, 62 brachiopods, nine pelecypods, 21 gastropods, one conularid, seven trilobites). The two outstanding classes in the fauna are the bryozoans and brachiopods, with the mollusks only well represented by the gastropods. This is true of the fauna of these beds in the Coxsackie area as well as elsewhere. For the New Scotland beds of the Schoharie area Grabau ('06, p. 321-23) lists 115 species, with a decided increase in the number of mollusks (15 pelecypods, 28 gastropods, four cephalopods) and fewer bryozoans (six) and brachiopods (38) though the latter still predominate in number. Eight crinoid species form an interesting constituent of this fauna, indicating quieter waters. From the upper shaly member of the New Scotland in the Helderberg region Goldring ('35, p. 110, 111) lists the following:

Sponges

Hindia sphaeroidalis [*inornata, fibrosa*] Duncan

Corals

F. conicus Hall
Favosites helderbergiae Hall
F. sphaericus Hall
Michelinia (*Pleurodictyum*) *lenticularis* Hall
Streptelasma (*Enterolasma*) *strictum* Hall

Crinoids

Aspidocrinus scutelliformis Hall
Edriocrinus pocilliformis Hall
Stems and joints

Bryozoans

Ceramopora maculata Hall
Fenestella cf. *compressa* Hall
F. crebipora Hall
F. sp.
Fistulipora [*Lichenalia*] *maculosa* Hall
Paleschara incrustans Hall
Trematopora sp.

Brachiopods

Atrypa reticularis (Linnaeus)
Atrypina imbricata Hall
Eatonia medialis (Vanuxem)
E. peculiaris (Conrad)
Isorthis [*Dalmanella*] *perelegans* (Hall)
Leptaena rhomboidalis (Wilckens)
Levenea [*Dalmanella*] *subcarinata* (Hall)
Lingula rectilatera Hall
L. perlata Hall
L. spathata Hall
Meristella arcuata Hall
M. laevis (Vanuxem)
M. princeps Hall
Nucleospira ventricosa Hall
Orbiculoidea cf. *conradi* (Hall)
O. discus (Hall)
O. sp.
Parazyga deweyi (Hall)
Platyorthis [*Dalmanella*] *planoconvexa* (Hall)
Rhipidomella oblata Hall
Rhynchonella bialveata Hall
Schuchertella [*Orthothetes*] *woolworthana* (Hall)
"*Spirifer*" *cyclopterus* Hall
"*S.*" [*Delthyris*] *perlamellosus* (Hall)
"*S.*" (*Eospirifer*) *macropleura* (Conrad)
Stenoschisma formosum (Hall)
Stropheodonta (*Leptostrophia*) *becki* (Hall)
Strophonella headleyana Hall
S. leavenworthana Hall
S. punctulifera (Conrad) Hall
Trematospira globosa Hall
T. multistriata Hall
Uncinulus abruptus Hall
U. nucleolatus Hall
U. vellicatus Hall

Pelecypods

Actinopteria textilis Hall
Aviculopecten tenuilamellata (Hall)

Gastropods

Platyceras gebhardi Hall
P. platystomum var. *alveatum* Hall
P. spirale Hall
P. unguiforme Hall
P. ventricosum Conrad
P. (*Igoceras?*) *elongatum* Hall

Conularids

Hyolithes centennialis Barrett

Pteropods

Tentaculites elongatus Hall

Cephalopods

"*Orthoceras*" (*Michelinoceras?*) cf. *helderbergiae* Hall
"*O.*" (*Anastomoceras*) *rudis* Hall
"*O.*" sp.

Trilobites

Dalmanites pleuroptyx (Green)
Lichas pustulosus Hall

For Becraft mountain Grabau ('03, p. 1058, 1059) lists 31 species from the New Scotland shales of which 23 are brachiopods. For the Kingston area, Ulster county (Van Ingen and Clark, '03, p. 1190, 1191), 51 species are listed from all the New Scotland beds, with the brachiopods predominating (35); for the Port Jervis region, Orange county, Shimer ('05, p. 205-34) reports 41 species (26 brachiopods) for his lower New Scotland and 37 species (29 brachiopods) for his upper New Scotland. From the Catskill area south of our region Chadwick has submitted (letter 1938) the following list from the upper shaly limestone, his Catskill shaly limestone member.

Seaweeds

"Receptaculites" infundibuliformis (Eaton) Hall

Sponges

Aulocopium sp. (?)
Hindia sphaeroidalis [*inornata, fibrosa*] Duncan

Crinoids

Aspidocrinus callosus Hall
Edriocrinus pocilliformis Hall
Stems and joints

Bryozoans
(various species)

Callotrypa macropora (Hall)
C. stricta Hall & Simpson
C. unispina Hall
Fistulipora maculosa (Hall)
Monotrypella ? (Eridotrypa?) densa Hall
Polypora obliqua Hall & Simpson
Stictopora ? granatula Hall & Simpson
(Also, but possibly Kalkberg):
Polypora arta Hall
Ptilodictya nebulosa Hall
Unitrypa praecursor Hall

Brachiopods

Delthyris perlamellosus (Hall)
Eatonia medialis (Vanuxem)
Leptostrophia becki Hall
Lingula rectilatera Hall
Meristella arcuata Hall
Orthostrophia strophomenoides Hall
Pholidops ovata Hall
Rhipidomella tubulostriata Hall
Schuchertella woolworthana (Hall)
"Spirifer" [Delthyris] perlamellosus (Hall)
"S." (Eospirifer) macropleura (Conrad)
Strophonella headleyana Hall

Pelecypods

Actinopteria communis (Hall)
A. textilis (Hall)
Aviculopecten tenuilamellata (Hall)

Gastropods

Diaphorostoma ventricosum Conrad
Platyceras calantica Hall
P. gebhardi Conrad
P. intermedium (?) Hall
P. platystomum alveatum Hall
P. retrorsum Hall
P. trilobatum Hall
P. ventricosum Conrad
P. (Orthonychia) lamellosum Hall
P. (Orthonychia) spirale Hall

Pteropods

Tentaculites elongatus Hall

Cephalopods

"Orthoceras" (Anastomoceras) rudis Hall

Trilobites

Ceratocephala tuberculata (Conrad)
Dalmanites pleuroptyx (Green)
Phacops logani Hall

On the Coxsackie quadrangle the New Scotland beds form a belt in back of the cliff (west), usually narrow but in places spreading out, as in the northern third of the area, to a width of about three-quarters of a mile. In these belts the beds dip at lower angles (in places as low as 3°), increasing in the more folded and faulted areas to dips even as high as 80°.

The incorporation of the lower New Scotland (Kalkberg) in the Helderberg cliff varies from a few feet to 35 feet (north of Ravena, vicinity of School No. 4) and 40 feet and over (one-half mile north-northeast of Albrights). The maximum thickness of this member apparently is not over 50 feet. The best sections are to be looked for in road cuts, stream beds and quarries. A few of the better and more accessible exposures will be discussed here.

In the northern part of the quadrangle the Kalkberg in places tends to form a low terrace back of the Coeymans cliff, as it does so conspicuously in the Capital District area. Such a terrace may be seen west of the Coeymans cliff along the second southwesterly trending road south of South Bethlehem just over the northern boundary of the Coxsackie quadrangle. A fair collection has been made in road cuts in both the lower and upper members of the New Scotland along this road. A good road cut with fair collecting may also be studied three-quarters of a mile west of Ravena along the road to Aquetuck, just where the road dips down the first steep hill. About a mile and a half north of Ravena, in the cliff above School No. 4 where at least 35 feet of Kalkberg are displayed, beautiful jointing and nearly vertical cleavage, developed in connection with local faulting, may be studied. This is an interesting locality, but involves a steep climb. At Deans Mills, where the Coeymans and Manlius are so well shown, 10 feet of Kalkberg limestone are exposed in the stream bed and banks below the dam with a dip of 3°, S. 38° W. (figure 29). The characteristic chert bands are numerous, with the upper foot and a half of the exposure more shaly in character like the upper member, the Catskill shaly limestone. The Kalkberg here, as in many other places, is broken up by a series of joint cracks and they are emphasized by widening through solution. The direction of the main joints is N. 50° E., N. 40° W. and N. 14° E. The surfaces are marked by solution pitting and potholes have been developed in the stream bed. South of the valley of the Hannacrois creek at Deans Mills the Kalkberg is well displayed in the fields and here, a quarter of a mile south of the sharp bend in the ravine, a very minor fault on the west side of an anticlinal hill has exposed a small fenster or window of Coeymans limestone. Eight to 12 feet of Kalkberg limestone are exposed in the cliff to the east. The road from Roberts Hill to Medway crosses the Kalkberg less than a quarter of a mile west of the junction with the north-south road at Roberts Hill and continues through the entire section of the New Scotland beds with good fossil collecting in both members. Bryozoans are abundant in the Kalkberg, and the characteristic yellowish buff weathering may be seen. Five-eighths of a mile south-southwest of Roberts Hill, below the dam of the lower Coxsackie reservoir, the Kalkberg may again be studied and north of this along the east side of the main reservoir are good exposures of the upper New Scotland beds.

The abandoned quarry at Climax (figure 25) provides a good place to study the Kalkberg and its relation to the Coeymans be-

Figure 29 Kalkberg limestone at Deans Mills downstream from the road bridge and dam. The numerous chert seams are well shown and also, in the foreground, numerous small potholes. (Photograph by E. J. Stein)

neath. Ten feet are exposed in the quarry face and 20 feet to the north in the summit of the domed anticline into which the quarry has been cut. Here a coarse cleavage has been developed. South and east of the quarry, on the south side of the highway a branch of the Coxsackie creek, the Murderer kill, disappears in a sink hole through the Kalkberg. From this point east along the stream course are exposures showing good jointing. To the south, just west of the cliff, strong cleavage has been developed in connection with the faulting and the beds stand at a high angle (43°-60°). With few exceptions the beds dip at a high angle from this point to the southern end of the quadrangle where they again assume a flatter altitude (8°), as exposed in the cut made for the Athens-Leeds road as it passes over the cliff.

The section along the east-west road past the reservoir of the New York State Vocational Institution (east of Bronks lake) has been discussed in connection with the Coeymans and Manlius limestones (pages 139, 157). Forty to 45 feet of Kalkberg are exposed in this area. Here the Kalkberg is well exposed along the road and at the falls on the south side of the road below the reservoir dam. West of Flint Mine hill an east-west road past School No. 4 mounts the cliff exposing a fair section of New Scotland beds dipping N. 72° W. at an angle of about 80°. Forty feet of Kalkberg are exposed here, and a number of fossils were collected in the upper New Scotland beds. New Scotland beds dipping N. 87° W. at an angle of 68° form the bed of the Hans Vosen kill downstream from the culvert near the junction of the Greens Lake road with the West Athens-Limestreet road. The falls in the stream are over the Kalkberg limestone. About a quarter of a mile south of the road junction the greatest thickness (50 feet) has been measured in the hill on the east side of the road where the beds also dip at a high angle (56°). An easily accessible and very good section through the New Scotland beds, complicated by some minor folding and faulting may be seen about half a mile east of Leeds along the Catskill-Leeds road. Some collecting is possible here.

Collections can be made in most of the Kalkberg exposures, but except in road cuts the collecting is difficult. For the whole Coxsackie quadrangle the following fauna (*see* figures 30, 31) has been listed:

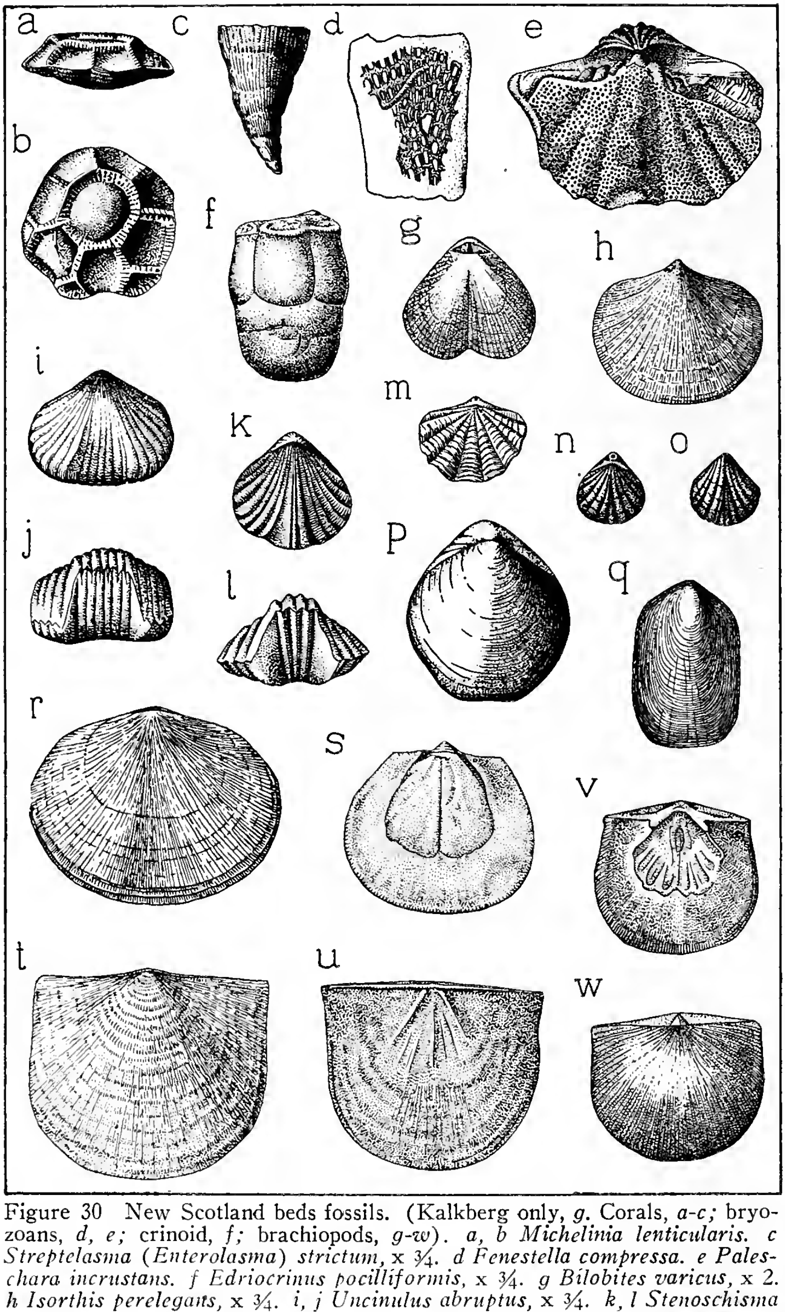

Figure 30 New Scotland beds fossils. (Kalkberg only, *g*. Corals, *a-c;* bryozoans, *d, e;* crinoid, *f;* brachiopods, *g-w*). *a, b Michelinia lenticularis.* *c Streptelasma (Enterolasma) strictum,* x ¾. *d Fenestella compressa.* *e Paleschara incrustans.* *f Edriocrinus pocilliformis,* x ¾. *g Bilobites varicus,* x 2. *h Isorthis perelegans,* x ¾. *i, j Uncinulus abruptus,* x ¾. *k, l Stenoschisma formosum,* x ¾. *m Atrypina imbricata,* x ¾. *n, o Rhynchospira globosa.* *p Meristella laevis,* x ¾. *q Lingula rectilatera,* x ¾. *r, s Rhipidomella oblata,* x ¾, x 1. *t, u Leptostrophia becki,* x ¾, x ½. *v, w Schuchertella woolworthana,* x ¾.

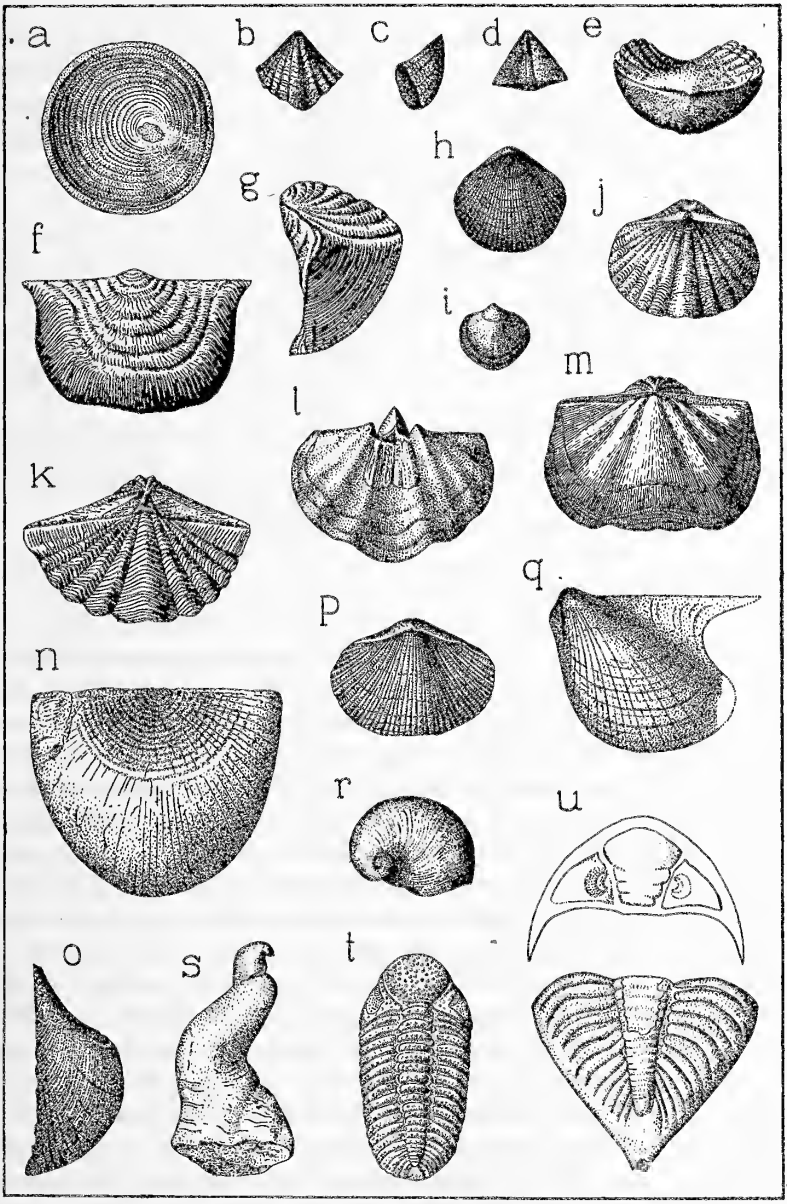

Figure 31 New Scotland beds fossils. (Brachiopods, *a-p*; pelecypod, *q*; gastropods, *r, s*; trilobites, *t, u*). *a Orbiculoidea discus*, x ¾. *b-d Cyrtina dalmani. e Eatonia medialis*, x ½. *f, g Leptaena rhomboidalis*, x ½. *h Parazyga deweyi*, x ¾. *i Nucleospira ventricosa*, x ½. *j "Spirifer" cyclopterus*, x ¾. *k "S." perlamellosus*, x ¾. *l, m "S." (Eospirifer) macropleura*, x ½. *n, o Strophonella leavenworthana*, x ¾. *p Trematospira multistriata*, x ¾. *q Actinopteria communis*, x ¾. *r Platyceras ventricosum. s P. spirale*, x ½. *t Phacops logani*, x ¾. *u Dalmanites pleuroptyx*, x ½.

Sponges

Hindia sphaeroidalis [*inornata, fibrosa*] Duncan

Corals

Favosites helderbergiae Hall
Michelinia (*Pleurodictyum*) *lenticularis* Hall
Streptelasma (*Enterolasma*) *strictum* Hall

Crinoids

Mariacrinus stoloniferus Hall, stems

Bryozoans (numerous)

Callopora (*Callotrypa*) sp.
Fenestella sp.
Hallopora sp.
Monotrypella sp.
Paleschara incrustans Hall
Stictopora sp.
Thamniscus sp.
Trematopora sp. etc.

Brachiopods

Anastrophia verneuili (Hall)
Atrypa reticularis (Linnaeus)
Atrypina imbricata (Hall)
Bilobites varicus (Conrad)
Cyrtina dalmani (Hall)
Eatonia medialis (Vanuxem)
Gypidula coeymanensis Schuchert
Isorthis [*Dalmanella*] *perelegans* (Hall)
Leptaena rhomboidalis (Wilckens)
Levenea [*Dalmanella*] *subcarinata* (Hall)
Meristella laevis (Vanuxem)
Meristella sp.
Nucleospira ventricosa Hall
Orbiculoidea discus (Hall)
Parazyga deweyi (Hall)
Platyorthis [*Dalmanella*] *planoconvexa* (Hall)
Rhipidomella oblata Hall
"*Spirifer*" *cyclopterus* Hall
"*S.*" [*Delthyris*] *perlamellosus* (Hall)
"*S.*" (*Eospirifer*) *macropleura* (Conrad)
Stropheodonta (*Leptostrophia*) *becki* Hall
Strophonella leavenworthana Hall
S. punctulifera (Conrad)
Uncinulus abruptus Hall
U. nucleolatus Hall

Trilobites

Phacops logani Hall

The Catskill shaly limestone member has an estimated thickness of between 100 and 120 feet on the Coxsackie quadrangle and this thickness is better displayed in the lower half of the area where the beds, through folding and faulting, stand at a higher angle and also show the development of excellent cleavage. Some good exposures of this member have been mentioned in connection with the discussion of the Kalkberg limestone member, as along the second southwesterly trending road south of South Bethlehem, which in the New Scotland belt of the Coxsackie area appears as the first north-south road west of the cliff at the northern boundary. A fair collection of fossils was made here and also in the sections exposed along the road west of Roberts Hill and west of Flint Mine hill in the cliffs. About three-eighths of a mile north of Roberts Hill, at the first road junction, the uppermost New Scotland, just beneath the Becraft, is exposed. It is dark drab in color, full of crinoid stems and quite crystalline. Three-quarters of a mile north-northeast of this in the hill west of the cliffs the New Scotland beds form a well-developed anticline. Three-eighths of a mile south-southwest of Roberts Hill in the vicinity of the upper Coxsackie reservoir it is involved in the anticline to the east. There are good exposures along the shore and chert is shown in the upper five feet above the dam. The contact of the Catskill shaly limestone with the Becraft is shown one mile north of Climax along the first east-west road and again one-half mile directly south of the junction of the Urlton and Medway roads at Climax. While the upper New Scotland may be well studied in the domed anticlinal hill to the north of Climax, good exposures are more accessible in the area to the south and there are splendid sections for study along a southerly trending wood road just in back (west) of the cliffs. Here the beds dip at a high angle (up to 60° and over) and show good cleavage. They may be studied again just to the south along the road east of Bronks lake, where the lower formations are well exposed, but particularly in the stream bed and banks below the dam of the New York State Vocational School reservoir. The new dam crosses the stream just above the fault through the upper New Scotland and the reservoir now occupies the flat downstream from the location given on the map, which is now a swamp. The exposures in the ridge extending southward on the east side of the reservoir are less accessible. In the section along the east-west road west of Flint Mine hill over 100 feet are exposed, very fossiliferous and standing at an angle of 78° to 80°. Cleavage is well shown in the woods to the north and to the south in easily accessible exposures. North of the road to Greens lake, at School No. 4 east of Limestreet, the estimated thickness of the upper New Scotland beds is between 100 and 120 feet and the angle of dip is still steep (70°), a condition which in general holds southward through the Black Lake region until the southern end of the quadrangle is reached. At the junction of the Greens Lake road with the West Athens-Limestreet road a road cut has made good collecting possible. In the bed of the Hans Vosen kill just north of the junction these beds are well exposed (*see* page 169). The exposures in the anticlinal ridge continuing southward back of the cliffs to the Greens Lake area show interesting structures and dips as high as 80° but are not easily reached. The section along the Athens-Leeds road east of the junction with the road from Greens lake (past Black lake) is accessible and worth study as the beds are involved in folding and some collecting may be done here.

In the area east and north of Leeds there are three interesting occurrences of the Catskill shaly member. These are inliers developed by erosion of the younger Becraft beds in a northward pitching anticline. One may be seen north of the Leeds-Catskill state road in the eastern outskirts of the village of Leeds in the domed southern end of the anticline. To the north and east a smaller one crosses the Leeds-West Athens road east of the first road junction. One-quarter of a mile north of this road, along the west and steeply dipping arm of the anticline, a third but less accessible one has been developed.

The upper New Scotland beds (Catskill shaly limestone) are very fossiliferous, but even so, good collections can only be made where there are road cuts or quarries for road metal. Below is given a complete list of fossils (figures 30, 31) collected or noted on the Coxsackie quadrangle:

Sponges

Hindia sphaeroidalis [*inornata, fibrosa*] Duncan

Corals

Favosites helderbergiae Hall
Favosites sp.
Streptelasma (*Enterolasma*) *strictum* Hall

Crinoids

Aspidocrinus scutelliformis Hall
Edriocrinus pocilliformis Hall
Stems and joints

Bryozoans
(various species)

Callotrypa stricta Hall & Simpson
Fenestella sp.
Fistulipora (*Lichenalia*) *maculosa* (Hall)
Monotrypella sp.
Paleschara incrustans Hall
Stictopora sp.
Trematopora sp.

Brachiopods

Atrypa reticularis (Linnaeus)
Atrypina imbricata (Hall)
Cyrtina dalmani (Hall)
Eatonia medialis Vanuxem
E. peculiaris (Conrad)
Isorthis [*Dalmanella*] *perelegans* (Hall)
Leptaena rhomboidalis (Wilckens)
Levenea [*Dalmanella*] *subcarinata* (Hall)
Lingula rectilatera Hall
Meristella laevis (Vanuxem)
M. arcuata Hall
Nucleospira ventricosa Hall
Parazyga deweyi Hall
Platyorthis [*Dalmanella*] *planoconvexa* (Hall)
Rhipidomella oblata Hall
Rhipidomella sp.
R. tubulostriata Hall
Schuchertella [*Orthothetes*] *woolworthana* (Hall)
"*Spirifer*" *cyclopterus* Hall
"*S.*" [*Delthyris*] *perlamellosus* (Hall)
"*S.*" (*Eospirifer*) *macropleura* (Conrad)
Stenoschisma formosum (Hall)
Stropheodonta cf. *varistriata* (Conrad)
S. (*Leptostrophia*) *becki* Hall
Strophonella headleyana Hall
S. leavenworthana Hall
S. punctulifera (Conrad) Hall
Trematospira multistriata Hall
Uncinulus abruptus Hall
U. nucleolatus Hall
U. sp.

Pelecypods

Actinopteria communis (Hall)
A. textilis (Hall)
Aviculopecten tenuilamellata (Hall)

Gastropods

Diaphorostoma ventricosum Conrad
Platyceras calantica Hall
P. gebhardi Hall
P. spirale Hall
P. platystomum var. *alveatum* Hall
P. unguiforme Hall
P. ventricosum Conrad

Pteropods

Tentaculites elongatus Hall

Cephalopods

"*Orthoceras*" (*Anastomoceras*) *rudis* Hall
"*Orthoceras*" sp.

Trilobites

Dalmanites pleuroptyx (Green)
Phacops logani Hall

Becraft Limestone

In the earlier reports this limestone received the names of "Scutella" or "Encrinal" limestone, due to the presence of numerous crinoid bases or Scutellas (*Aspidocrinus scutelliformis*), and it was also known as the "Upper Pentamerus" limestone because of the occurrence of the characteristic brachiopod *Gypidula* [*Pentamerus*] *pseudogaleata*. In 1894 N. H. Darton, at the suggestion of James Hall, gave to this formation the name Becraft limestone (*ref. cit.*, p. 406), derived from the exposure in the Devonian outlier, known as Becraft mountain, near Hudson (Columbia county), where it is extensively quarried for Portland cement. This formation was placed at the top of the Silurian in earlier correlations; later it became the uppermost member of the Helderbergian (Lower Helderberg) limestones; finally, the overlying Alsen and Port Ewen limestones were included in the Helderbergian group.

On the whole, the Becraft is a very pure limestone and massive, forming conspicuous ledges. The rock is semicrystalline and very coarse-grained, the coarsest grained of any of our limestones, and not infrequently has the character of a shell rock or consolidated coquina. Crinoidal fragments are abundant and are found mingled with brachiopods, usually rather small and not very numerous in species; the flatly bowl-shaped bases of *Aspidocrinus scutelliformis* in places are very abundant. Weathered surfaces are usually somewhat darkened, but the rock, typically, is light-colored with pinkish and light gray, sometimes yellowish tints. Chert is sometimes found but is not usual. Van Ingen and Clark ('03, p. 1192) in their discussion of the Rondout area give the composition of the middle massive portion of the Becraft as 94 to 97 per cent lime carbonate.

The lower part of the formation is thinner bedded with seams of siliceous shale, sometimes of a greenish color and one to several inches thick. These seams have an abundance of silicified fossils among which *Atrypa reticularis* is common. Van Ingen and Clark note that the lower 10+ feet of Becraft in the Rondout (Ulster county) area "graduate nicely into the thinner layers of limestone forming the subjacent New Scotland beds. There is, however, a well-marked division plane between the two formations" (*ref. cit.*). The writer has found no sharp separation from the upper New Scotland beds in the mapping of either the Berne or Coxsackie quadrangles. A few places in the latter area where the New Scotland-Becraft contact may be studied have been pointed out in the discussion of the upper New Scotland outcrops. In the Indian Ladder region (Helderbergs) of the Capital District area this is well shown in a cut (nine feet) at the four corners on Rock road (going west), where partings of shale in the lower Becraft and limestone bands with crinoidal fragments in the upper New Scotland are clearly seen (Goldring, '35, p. 115).

For the Port Jervis region (Orange county) Shimer ('05, p. 183) describes the Becraft limestone as "a very dark gray, heavy bedded limestone. The lower portion is coarsely crystalline, a coarse calcarenite. Most of the formation, however, is finely crystalline, even at times rather shaly." Of the 16 feet included in the formation here, "the lower two and one-half feet are characterized by a great abundance of *Gypidula pseudogaleata,* the typical Becraft fossil." In the following 14 feet, although *Gypidula pseudogaleata* was not found, the characteristic *"Spirifer" concinnus* is very abundant, at times practically making up the entire rock mass. Shimer concludes (*ref. cit.*) that "the entire Becraft here represents a temporary invasion of a few typical Becraft species into the very slightly changing New Scotland seas, so that the mass of the New Scotland fauna continues through the Becraft into the Port Ewen. Only a few forms, such as *"Spirifer" macropleura,* unable apparently to live in the slightly purer waters, disappeared."

As in typical development, so in thickness the Becraft limestone varies eastward and southward. Grabau ('06, p. 154, 254) measured 15 to 21 feet in the Schoharie region (West hill, Dann's hill) and an even smaller thickness has been noted at Cherry Valley (Otsego county; *fide* C. A. Hartnagel). In Onondaga county it may be represented by the six feet of Bishop Brook limestone separated from the Manlius group below and the Onondaga above by unconformities. Burnett Smith ('29, p. 32) cites the fauna (unstudied) as apparently Helderbergian and describes the formation as gray in color, the lower portion in places a mass of crinoid fragments, the upper layers evenly bedded with cross-bedding in the basal portions. Chadwick ('30, p. 82) believes it "to be essentially the topmost Becraft or Alsen, high in the Helderbergian." In the Helderberg region (Capital District area) the beds vary from nine to 27 feet, only the lowest beds (nine feet) with shale seams appearing in the Indian Ladder area. From Clarksville southward the formation thickens until in the type section at Becraft mountain near Hudson it has a thickness of 40 to 45 feet (Grabau, '03, p. 1034; *see* Davis, '83). Chadwick has cited 60 feet for the maximum thickness found in the Catskill quadrangle area (Greene county). Farther south in the Rondout region (Ulster county; *see also* Darton, 94*a*), Van Ingen and Clark measured 40 feet of this limestone, and for Orange county (Port Jervis region) Shimer ('05, p. 183) gives a measurement of 16 feet (*see* above).

Like the Coeymans below and the Onondaga above the Becraft limestone is traversed by a system of joints which may be observed more or less well-developed on any of the Becraft flats. The joint fissures are widened by solution and sometimes deep circular holes are formed. "Karst" features, due to solution in limestone areas, may be well shown on a small scale in places. Caverns and sink-holes, other characteristic features of a karst topography, are not commonly found in the Becraft (Goldring, '35, p. 116).

This limestone is sometimes used for building stone because of its purity, massiveness and the fact that it takes a good polish. It has been extensively quarried for lime in the past, particularly in the Rondout area (Van Ingen and Clark, '03, p. 1192), and is still being quarried for Portland cement in places, as in Becraft mountain along with the Manlius and Coeymans limestones.

The fossils in the Becraft limestone are rarely silicified except in the siliceous shale seams in the lower portion. In spite of the abundance of crinoid parts, shells and shell fragments, the formation has not furnished a very large fauna. Some of the fossils are very characteristic, striking among them the shieldlike crinoid base or anchor *Aspidocrinus scutelliformis* which, though it also occurs in the upper New Scotland, is found throughout the Becraft, sometimes in great abundance. These fossils give a very characteristic appearance to the rock, especially where seen in cross section, since the Scutellas are rendered crystalline by secondary infiltration and are often of a pinkish, yellowish or a glistening white color. In addition to the brachiopod *Gypidula* [*Pentamerus*] *pseudogaleata* another form, *"Spirifer" concinnus,* may likewise occur in abundance. For the Schoharie region Grabau ('06, p. 323) has listed 24 species, including two crinoids, one pteropod, 11 brachiopods, one pelecypod and nine gastropods; for Ulster and Orange counties combined lists (Van Ingen and Clark, '03, p. 1206-08; Shimer, '05, p. 262-68) show one crinoid, one bryozoan, 24 brachiopods, one trilobite. For the Capital District area to the north of our region the following fauna has been listed (Prosser & Rowe, '99, p. 341, 351; Ruedemann, '30, p. 55, 56; Goldring, '35, p. 120, 121):

Corals

Favosites sphaericus Hall
Streptelasma (*Enterolasma*) *strictum* Hall

Crinoids

Aspidocrinus scutelliformis Hall
Stems and joints

Bryozoans

Bryozoan sp.
Fenestella sp.
Lichenalia (*Fistulipora*) *tora* (Hall)
Paleschara cf. *incrustans* Hall

Brachiopods

Atrypa reticularis (Linnaeus)
Gypidula pseudogaleata (Hall)
Isorthis [*Dalmanella*] *perelegans* (Hall)
Leptaena rhomboidalis (Wilckens)
Levenea [*Dalmanella*] *subcarinata* (Hall)
Meristella arcuata Hall
M. laevis (Vanuxem)
M. princeps Hall
Parazyga deweyi (Hall)
Platyorthis [*Dalmanella*] *planoconvexa* (Hall)

Rhipidomella discus Hall?
R. oblata Hall
Rhynchonella sp.
Schuchertella [*Orthothetes*] *woolworthana* (Hall)
Schizophoria multistriata Hall
"*Spirifer*" *concinnus* Hall
"*S.*" *cyclopterus* Hall
"*S.*" [*Delthyris*] *perlamellosus* (Hall)
Stenoschisma formosum (Hall)
Strophcodonta (*Leptostrophia*) *becki* Hall
Strophonella punctulifera (Conrad)
S. sp.
Trematospira multistriata Hall
Uncinulus campbellanus Hall
U. nobilis Hall
Wilsonia ventricosa (Hall)

Pteropod

Tentaculites elongatus Hall

In the Becraft Mountain section to the south Grabau collected ('03, p. 1060-62):

Crinoids

Aspidocrinus scutelliformis Hall

Bryozoans

Fenestella sp.
Monotrypa sphaerica (Hall)

Brachiopods

Atrypa reticularis (Linnaeus)
Eatonia medialis (Vanuxem)
Gypidula pseudogaleata (Hall)
Leptaena rhomboidalis (Wilckens)
Meristella arcuata Hall
M. princeps Hall
Rensselaeria mutabilis Hall
Rhynchospira formosa Hall
Schizophoria multistriata Hall
"*Spirifer*" *concinnus* Hall
"*S.*" *cyclopterus* Hall
"*S.*" *perlamellosus* (Hall)
Trematospira perforata Hall
Uncinulus campbellanus Hall
U. nobilis Hall

Chadwick reports (letter, 1938) for the Catskill quadrangle only five brachiopods, including *Orbiculoidea discus* Hall not listed from Becraft mountain. He also adds the bryozoan *Fistulipora torta* (Hall); the gastropods *Phanerothema labrosum* (Hall), *Salpingostoma profundum* (Conrad), *Straparollus decollatus* and *Strophostylus fitchi* Hall (the last three all rare), and an orthoceratoid cephalopod.

On the Coxsackie quadrangle the combined Becraft and Alsen limestones form a usually narrow, ribbonlike belt stretching from north to southwest of the broader area covered by the New Scotland limestones. In certain places it broadens out, as just south of the northern border of the quadrangle, west of Albrights, south of Climax, west of Flint Mine hill, south of Black lake and north and south of the Leeds-Athens road. Thicknesses of 45 to 65 feet have been estimated for the Becraft in this area, but there are only a few places where measurements for total thickness can be obtained. A few places offer some interesting features and are worth particular study.

One-half mile south of the northern boundary is a good study exposure showing relations of the Becraft and Oriskany. The Becraft is well exposed in a small hill, showing a steep fold, on the west of the north-south road and in the fenster just west of the road junction, due to the opening up by erosion of a small dome or

Figure 32 Becraft limestone showing at the top layers of chert pebbles which indicate at least local erosion. In edge of woods on west side of road one-half mile north of the road junction at Roberts Hill. (Photograph by E. J. Stein)

swell. A number of species of fossils may be collected here both in the outcrops and in the stone fences. A cut very accessible for study occurs along the road to Ravena one-half mile north-northeast of Aquetuck. Fifteen inches at the top of the exposure, showing a six to eight-inch chert band, has been referred to the Alsen. Shaly partings and occasional chert nodules occur about three feet below this. Across the road (south), in back of the house, are exposed 10 feet of typical Becraft. Between Deans Mills and Albrights, on both sides of the road south, the Becraft outcrops in a broader belt, in places nearly one-half mile wide. To the east it forms the western arm of an anticline. The Scutellas are abundant in this area.

Two exposures about one-half mile north of the three corners at Roberts Hill are of considerable interest as they mark a period of erosion within the Becraft, at least locally. In the field to the west near the first road junction the Becraft outcrops along the hollow. At the top of the exposure is shown a zone of chert pebbles (figure 32) six to ten inches thick, below which occur one and one-half feet of limestone, a three-inch chert band, then two inches of limestone and a three-inch chert band, with pebbles of chert in the limestone. The pebbles in the pebble zone are so numerous as to give the effect of a conglomerate and they range in size up to three inches in diameter, the average specimen half that size or less. On the left (northwest) side of the road east, at the summit of a knoll three-sixteenths of a mile from the junction, chert bands of a blue-gray color and a layer of well-rounded chert pebbles may be seen. The estimated thickness of the Becraft in this area is 40 to 45 feet.

At the Coxsackie village reservoir in the vicinity of the dam, three-eighths of a mile south-southwest of Roberts Hill junction, eight feet of the basal shaly portion of the Becraft is exposed showing strong cleavage. The contact with the New Scotland beds is well shown. Along the Climax-Urlton road, three-eighths of a mile out of Climax a road cut exposes the Becraft from its contact with the New Scotland upward. The good exposures continue to the south and east in the fields and woods and are found again west of Coxsackie in the vicinity of the New York State Vocational Institution reservoir in a cut along the road to Bronks lake and at the reservoir dam. The Alsen is also exposed here. The new and enlarged reservoir lies in a fault valley farther to the north and east than the one shown on the map, with the dam just west of the fault. The Becraft borders this valley going south-southwest on the west arm of a broken anticline. The beds here stand at a high angle of

68° to 71° and higher with an estimated thickness in various places of 45 to 62 feet, the last perhaps including some Alsen.

The road leading west-northwest from Flint Mine hill to Urlton, just after it climbs the steep slope formed by the Helderberg cliff, passes on the north a cut in Becraft and Alsen abutting at a steep angle (68°) against Oriskany dipping at a nearly flat angle, indicating a break. To the north in the woods these steep beds bear the same relation to Becraft beds forming the hollow to the west. Here about one-quarter of a mile north of the road, there is exposed an estimated thickness of 42 feet of Becraft and Alsen, 20 feet belonging to the latter. South of the junction of the Limestreet-West Athens road with the Greens Lake road a thickness of 52 feet is exposed, with beds standing at an angle of 82°, along the east side of the north-south valley (Esopus) and forming part of the west arm of a fractured anticline. These beds may be followed southward with good exposures into the high hill bordering the cliff east-northeast of Greens lake. The high angle of dip of 80° (S. 82° E.) is still maintained here. Minor, roughly north-south, faults have in the south end of this hill cut off a splinter of Becraft which dips in a northwesterly direction at the low angle of 20°. A minor east-west fault here has developed in the Becraft strong slickensides and large calcite crystals. The Becraft here also shows an abundance of gray chert.

Two outcrops especially worth study and quite accessible are the one along the east side of Black lake (figure 34) extending northward and along the east side of the "Canoe," the synclinal canoe-shaped valley (figure 53) one-half to one mile south-southeast of Black lake. Sixty-two and a half feet of Becraft (including about 15 of lower shaly beds) have been paced in the former area and 25 feet of Alsen (to the water's edge). There is good fossil collecting here. These steeply dipping beds (angle 72°; N. 82° W.) continue southward to the Leeds-Athens road. In the "Canoe" area, on the east, the Becraft limestone occurs in the eastern arm of the broken syncline forming the "Canoe" (western arm of anticline to the east). The beds dip from almost due west to northwest and southwest at an angle of about 60° and the thickness of the combined exposure of Alsen and Becraft is estimated as about 80 feet. There is a thickness of 62½ feet of Becraft in the vicinity of the junction of the Leeds-Athens road with the Greens Lake road. The Becraft, still with a high angle of dip, continues south-southeast, bordering the synclinal hollow which extends north from the Leeds-Catskill state road, one-quarter of a mile east of the village of Leeds.

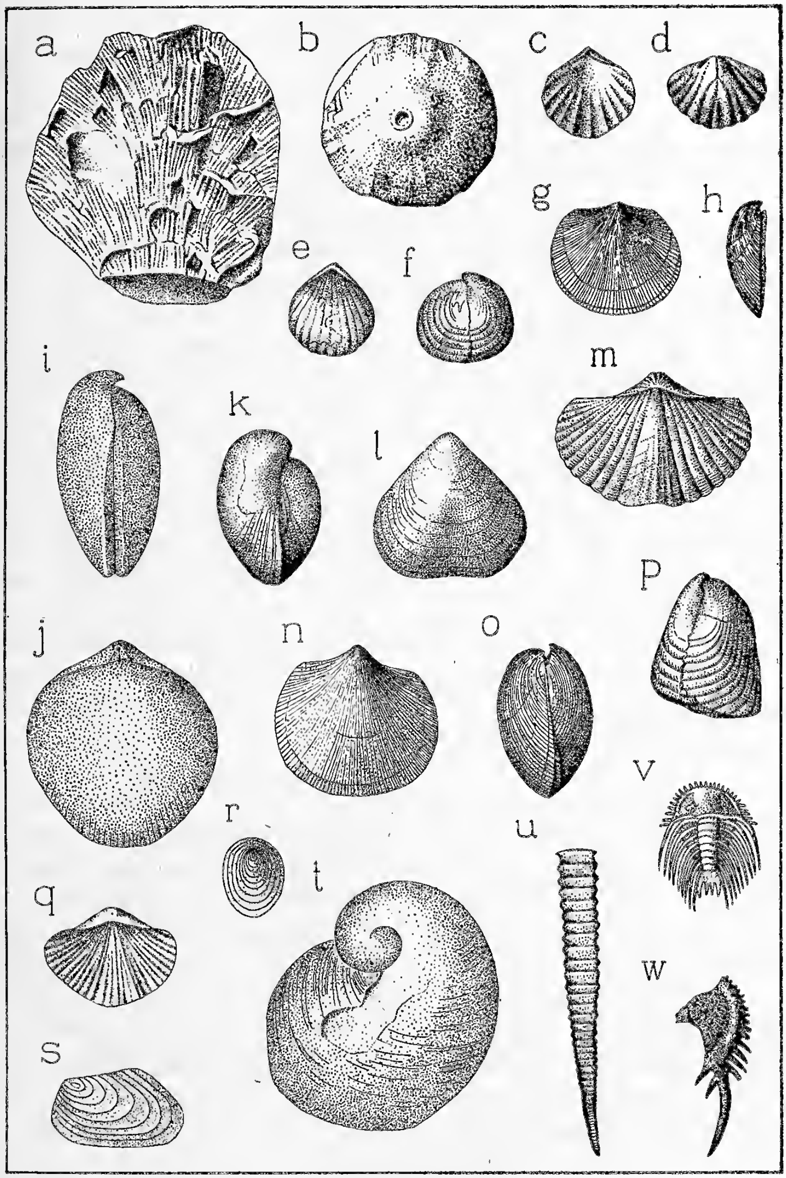

Figure 33 Becraft, Alsen and Port Ewen limestone fossils. (Becraft only, *b, k, t;* Alsen, Port Ewen only, *a;* Port Ewen only, *c, d, r, s, v, w.* Bryozoan, *a;* crinoid, *b;* brachiopods, *c-r;* pelecypod, *s;* gastropod, *t;* pteropod, *u;* trilobite, *v, w*). *a Monotrypa tabulata. b Aspidocrinus scutelliformis. c, d Anoplotheca concava. e, f Wilsonia ventricosa. g, h Platyorthis planoconvexa. i, j Rensselaeria [Beachia] suessana. k Gypidula pseudogaleata,* x ¾. *l Meristella arcuata,* x ¾. *m "Spirifer" concinnus,* x ¾. *n, o Schizophoria multistriata. p Uncinulus campbellanus,* x ¾. *q Trematospira perforata. r Pholidops ovata. s Cypricardinia lamellosa. t Strophostylus fitchi,* x ½. *u Tentaculites elongatus. v, w Acidaspis tuberculata;* right cheek enlarged. (*See* New Scotland plates)

East of the cliff thus formed a thickness of 58 feet has been measured with a dip N. 37° W. at an angle of 68° to 72°. Where the state highway cuts the limestones the angle of dip is as high as 84° and there is an exposure of 72½ feet of combined Alsen and Becraft. Fossils are abundant and good slickenside surfaces, due to a minor break, are shown. The hill to the west, is the southern end of an anticlinal ridge which extends northward nearly to Greens lake. In this ridge both Alsen and Becraft may be studied to advantage particularly along both sides of the Athens-Leeds road west of the Leeds lumberyard and in the open fields in the northern end of the pitching anticline, three-quarters of a mile south of Greens lake, where Alsen forms the east side of this "nose" and Alsen with a thin veneer of Port Ewen the west side, with the Becraft exposed in a deep depression. One-quarter of a mile north of the lumberyard, in the woods (in the vicinity of the depression contour shown on the map), a cavern has been developed in the steeply dipping limestone beds. It is a dangerous spot because one could easily slip down the steep slope of the limestone into the cavern which apparently continues to great depth.

Fossils may be collected at almost any of the Becraft outcrops, but collecting is not easy except in road cuts and where there has been some quarrying. From the area as a whole the writer has collected the following fossils (figure 33):

Corals

Streptelasma (*Enterolasma*) *strictum* Hall

Crinoids

Aspidocrinus scutelliformis Hall
Stem joints

Bryozoans

Fistulipora [*Lichenalia*] *torta* (Hall)

Brachiopods

Atrypa reticularis (Linnaeus)
Gypidula pseudogaleata (Hall)
Isorthis [*Dalmanella*] *perelegans* (Hall)
Leptaena rhomboidalis (Wilckens)
Meristella laevis (Vanuxem)
Meristella princeps Hall
M. sp.
Parazygga deweyi (Hall)
Rhipidomella oblata Hall
Schuchertella woolworthana (Hall)
Schizophoria multistriata Hall
"Spirifer" concinnus Hall
"S." cyclopterus Hall
"S." [*Delthyris*] *perlamellosus* (Hall)
Stropheodonta cf. *varistriata* (Conrad)
Strophonella punctulifera (Conrad)
Trematospira multistriata Hall
Uncinulus campbellanus Hall
U. nobilis Hall
Wilsonia ventricosa (Hall)

Alsen Limestone

The Alsen limestone is the name "proposed for the cherty limestones which overlie the Becraft and contain a modified Becraft fauna" (Grabau, '19, p. 470). They bear the same relation to the Becraft as the Kalkberg does to the Coeymans and are "everywhere stratigraphically continuous with the Becraft" (*ref. cit.*). Originally these beds were included in the Port Ewen as a basal phase. The formation was named from the section at Alsen, N. Y., where it is well shown in the hills. It is also well displayed in Becraft mountain and at Schoharie where it is disconformably followed by the Oriskany. At Alsen the Port Ewen is likewise absent, but at Kingston and in the West Shore Railroad cut near Port Ewen station the Port Ewen beds rest disconformably on the Alsen.

As with the Kalkberg, with the incoming of the black chert seams there is a general reduction in the purity of the limestone as compared with the beds below. The basal Alsen is light-colored though finer-grained than the Becraft, but it quickly becomes a dark blue-gray in color, often weathering into buff colors. Another characteristic feature is the development of a subargillaceous meshwork such as is seen in the Kalkberg, but more conspicuous.

Grabau (*ref. cit.*) gives the thickness of the Alsen limestone as 20 to 50 feet. In the quarry at Alsen 25 feet have been measured, though about 20 feet is considered the average for the Catskill quadrangle as a whole (Chadwick, in field 1938). In Becraft mountain the thickness is 25 feet (Grabau, *ref. cit.*; cited as Port Ewen '03, p. 1034) and at Port Ewen (Ulster county) 30 feet. The studies of the Rondout (Van Ingen and Clark, '03) and the Port Jervis (Shimer, '05) areas were made previous to the separation of the Alsen limestone from the Port Ewen beds and therefore the measurements for the latter include also any representation of Alsen there may be. The Alsen limestone is missing in the Helderberg sections of the Capital District until one approaches the Schoharie region. In the Fox Kill valley west of West Berne there are five feet of dark, fine-grained limestone with chert, carrying some Becraft fossils, which interfinger with 27½ inches of distinct Port Ewen and may be only transitional beds or may be considered as interfingering Alsen (Goldring, '35, p. 122-23). In the Schoharie region Grabau ('06, p. 154, 254) measured 30 feet of rock between the top of the New Scotland and the base of the Oriskany of which nine to nine and one-half feet were assigned to the Port Ewen, later regarded by him as Alsen, with a possibility of an additional five and one-half feet above the 15½ feet of typical Becraft. I have found no reference to this formation west of the Schoharie area except the statement by Chadwick ('30, p. 82) that he regards the Bishop Cap formation of Onondaga county "to be essentially the topmost Becraft or Alsen" (*see* page 176).

The Alsen seldom is conspicuous in the landscape. It may cap the Becraft ledges in natural outcrops or appear inconspicuously behind them. Sometimes alone or with the Port Ewen it covers broad stretches. The fossils are mostly silicified and two of them the brachiopod *"Spirifer" concinnus* and the bryozoan *Monotrypa tabulata* distinguish the formation from the Kalkberg limestone with which it might be confused in the field, at first glance. Grabau gives no list of fossils for the Schoharie region. In the section in the Helderbergs, west of West Berne, the writer (*ref. cit.*) lists from the possible Alsen limestone the following forms:

Corals

Favosites sp.
Streptelasma (*Enterolasma*) *strictum* Hall

Crinoids

Joints and stems

Brachiopods

Atrypa reticularis (Linnaeus)
"Dalmanella" cf. *perelegans* Hall
Meristella arcuata Hall
M. laevis (Vanuxem)
M. sp.
Parazya deweyi (Hall)
Rhipidomella sp.
"Spirifer" concinnus Hall
Stropheodonta sp.
Wilsonia ventricosa (Hall)

Grabau lists the following fauna, largely of brachiopods, from the Alsen of Becraft mountain (first described by him as Port Ewen; '03, p. 1066, 1067):

Bryozoans

Cladopora cf. *styphelia* (Clarke)
Monotrypa tabulata (Hall)

Brachiopods

Eatonia peculiaris Conrad, rare
Leptaena rhomboidalis (Wilckens)
Meristella cf. *princeps* Hall
Meristella typus Hall
M. sp.
Schuchertella becraftensis Clarke
Rensselaeria sp.
Rhynchospira formosa Hall, rare
"Spirifer" concinnus Hall
"S." cyclopterus Hall
"S." perlamellosus Hall, rare
"S." sp.
Stropheodonta sp.
S. (*Leptostrophia*) *magnifica* Hall

Gastropods

Platyceras cf. *trilobatum* Hall

The largest and most varied fauna collected from the Alsen, as such, is that listed by Chadwick for the Catskill quadrangle (letter, 1938).

Sponges

Hindia sphaeroidalis (*inornata, fibrosa*) Duncan

Corals

Caninia roemeri (E. & H.)
Enterolasma strictum (Hall)
Favosites conicus Hall
F. helderbergiae Hall
Pleurodictyum [*Michelinia*] *lenticulare* (Hall)
Vermipora serpuloides Hall

Crinoids

Stems, esp. *Clonocrinus? macropetalus* Hall

Bryozoans

Fistulipora maculosa (Hall)
Monotrypa tabulata (Hall)
Many other forms

Brachiopods

Atrypa reticularis (Linnaeus): a thickened gerontic form is usual
Brachyprion schuchertanum Clarke
Cyrtina varia Clarke
Eatonia peculiaris Conrad
Leptaena rhomboidalis (Wilckens)
Lingula rectilatera Hall
Meristella princeps Hall
Nucleospira ventricosa Hall
Rhipidomella oblata Hall
Rhynchospirina globosa (Hall)?
"Spirifer" concinnus Hall
"S." cyclopterus Hall
"S." [*Delthyris*] *perlamellosus* (Hall)
"S" (*Eospirifer*) *macropleura* (*Conrad*), rare
Trematospira perforata Hall

Gastropods

Platyceras obesum Hall

Figure 34 Black lake bordered on the east by a wall of the steeply dipping Alsen and Becraft limestones. The New Scotland beds are seen higher in the hill in the woods. (Photograph by E. J. Stein)

On the Coxsackie quadrangle 20 to 30 feet of Alsen have been measured. This limestone may be studied in most of the areas where the Becraft outcrops and certain of these exposures have been mentioned under the discussion of the Becraft limestone. There are a few fairly accessible places worth noting. Good exposures are found north and south of the east-west road to Bronks lake in the vicinity of the reservoir of the New York State Vocational Institution at Coxsackie. The road cut exposes 40 feet of Becraft and Alsen, the latter dark, fine-grained with black chert seams. Fifteen feet of Alsen are exposed just west of the cliff edge in a road cut on the north side of the road leading northwest from Flint Mine hill to Urlton. About an eighth of a mile north of the road, in the woods, 20 feet of Alsen are exposed. The beds here have a high dip of 68°, more or less. About a tenth of a mile south of the junction of the Limestreet-West Athens and Greens Lake roads Alsen with black chert seams is exposed. It continues south in the hill to the east bordering the north-south hollow formed on the Esopus and acquires a nearly vertical dip (82°), a little south of east. In the ridge east of Black lake (figure 34), in the vicinity of the dock, 25 feet of cherty beds have been allotted to the Alsen and this is apparently not the full thickness. About the same thickness was estimated in the ridge to the east of the "Canoe" valley, one-half mile south and east of Black lake. A good exposure showing an estimated thickness of 30+ feet is very accessible in the road cut at the junction of the Greens Lake and Leeds-Athens roads a mile and a half south of Black lake, and in the field just north. At least 28 feet are exposed in a cut along the state highway on the eastern outskirts of the village of Leeds. Here in the gorge, in the north bank, the Alsen limestone is well exposed, quite characteristic and very accessible. The cut along the state road one-quarter of a mile east of Leeds, as well as the continuation of these beds south along the Catskill creek, has been mentioned under the discussion of the Becraft limestone; also the cavern in the steeply dipping Alsen beds forming the east arm of the anticline, north of the Leeds Lumber Yard (Saxe Bros.). About 20 feet of Alsen are exposed about five-eighths of a mile south of the west end of Greens lake in a depression on the west side of the anticlinal ridge pitching north.

As with the Becraft limestone fossils are difficult to collect, even more so where chert is abundant and the beds are more siliceous. The following fauna (*see* figure 33) has been collected from the area as a whole:

Sponges

Hindia sphaeroidalis [*inornata, fibrosa*] Duncan

Corals

Favosites helderbergiae Hall
Pleurodictyum [*Michelinia*] *lenticulare* (Hall)
Streptelasma (*Enterolasma*) *strictum* Hall

Crinoids

Stem joints

Bryozoans

Fenestella sp.
Fistulipora torta (Hall)
Monotrypa tabulata (Hall)
Ptilodictya sp.

Brachiopods

Atrypa reticularis Linnaeus
Eatonia peculiaris (Conrad)
Leptaena rhomboidalis (Wilckens)
Lingula rectilatera Hall
Meristella laevis (Vanuxem)
M. princeps Hall
M. sp.
Nucleospira ventricosa Hall
Rhipidomella oblata Hall
Schuchertella woolworthana (Hall)
Schizophoria multistriata Hall
"Spirifer" concinnus Hall
"S." cyclopterus Hall
"S." [*Delthyris*] *perlamellosus* (Hall)
Stropheodonta sp.
Uncinulus nobilis Hall
U. sp.

Port Ewen Beds

The Port Ewen beds consist of a series of shaly limestones, above the Alsen limestone, similar in character and fossil content to the shaly limestones (New Scotland) underlying the Becraft. When first recognized as a unit by Davis they were described as the "Upper Shaly beds" ('83, p. 390), in recognition of the resemblance to the New Scotland or "Lower Shaly beds." This name, changed to Kingston beds by Clarke and Schuchert ('99), was later found preoccupied, and the formation was then termed the Port Ewen beds (Clarke, '03) from the town of that name, opposite Rondout where the beds are best exposed. At the end of the Helderbergian epoch the sea withdrew from part of the Appalachian trough and through the erosion that followed much of the Helderberg deposits were removed in some areas. The lime sediments from this erosion, during the retreat of the sea in later Helderbergian time, locally accumulated in depressions and formed a detrital lime rock, the Port Ewen beds.

The best development of this formation is found in southeastern New York (Port Jervis area) where the maximum thickness is about 200 feet (Shimer, '05, p. 179, 184). In the vicinity of Rondout, Van Ingen and Clark ('03, p. 1194) found the minimum thickness varying from 110 to 160 feet, but stated that "the formation probably attains, in places, a maximum thickness of about 200 feet." The Port Ewen thins rapidly northward entering the area of the Catskill quadrangle with a thickness of a few feet. Fifteen feet occur at Alsen and seven or eight feet in Austin glen, Catskill; in places it is missing entirely (Chadwick; field, 1938). The 25 feet of Port Ewen cited by Grabau ('03, p. 1034) for Becraft mountain has since been shown by him to be Alsen ('19, p. 470). These beds are missing to the north in the Capital District and in the Helderberg sections as far west as the vicinity of West Berne (*see* page 185) where a few feet of drab, shaly limestone (Port Ewen), resembling the New Scotland and carrying New Scotland fossils, interfingers with dark fine-grained limestone above the typical Becraft. West of this no Port Ewen has been recorded, since the Port Ewen cited by Grabau for this region ('06, p. 154) was later regarded by him as Alsen ('19, p. 470).

The Port Ewen beds, darker and more argillaceous than the Alsen, are lithologically very similar to the New Scotland. When fresh the rock is dark drab in color, usually turning grayish to buff in weathering. Shimer ('05, p. 184) describes these beds in the Port Jervis region as "varying from a dark blue limestone to a siliceous shale," and Van Ingen and Clark state, for the Rondout area, that "they consist of massive beds of impure siliceo-argillaceous limestones which slightly resemble the New Scotland limestone." ('06, p. 1194). "Toward the top of the Port Ewen beds the rock changes from the even grained dark limestone, which persists through a thickness of about 100 feet, and seams of black chert become intercalated in the layers of limestone. These chert layers increase in thickness, the limestone diminishes in thickness and finally layers of pebbles appear to indicate the proximity of the overlying Oriskany sandstone. The chert layers. . . .seem to mark the upper part of the Port Ewen beds at all points where this formation has been observed" (*ref cit.*, p. 1196). Chadwick, in his field studies connected with the mapping of the Catskill quadrangle, has found phosphate nodules at the top of the Port Ewen or the Alsen when the former is absent, marking the base of the Oriskany (Glenerie) and indicative of a break (in field, 1938).

The Port Ewen is less fossiliferous than the Alsen and though there is a similarity of the fauna to that of the New Scotland it is less fossiliferous than those beds also. The fauna is a mixture of New Scotland and prenuncial Oriskany forms. Van Ingen and Clark believed that "the fauna of the Port Ewen beds is strictly Helderbergian in its expression, no true Oriskany species have yet been found in it, though many of its members are also found in the Oriskany" (*ref. cit.*, p. 1197). Shimer notes the similarity of the Port Ewen fauna to that of the New Scotland but points out that the transitional character of the beds is indicated by two forms (*Meristella lata* and *"Spirifer" murchisoni*). He continues the discussion ('05, p. 184):

From the close of the Becraft to the uppermost *Dalmanites dentatus* beds the fauna is transitional from the typical Helderbergian to the Oriskanian. The fauna acquires more and more an Oriskanian aspect as the beds are ascended. Yet the lower beds contain so many very typical Helderbergian species that there is no hesitancy in placing these beds in the lower Helderberg. From the upper 30 feet of these transition beds, however, the above mentioned Helderbergian species (*Stropheodonta becki, Strophonella punctulifera, Streptelasma strictum, Lichenalia torta, Coelospira concava* and *Eatonia singularis*) are absent and there is a great increase of the Oriskanian element. It was thought well, therefore, on account of the very decided faunal change, to place these upper (*D. dentatus*) beds in the Oriskany.

From the Helderbergs (Berne quadrangle, Capital District area) the writer collected in a short time from the Port Ewen ('35, p. 122) three corals, three bryozoans, 18 brachiopods (including *"Spirifer" murchisoni*) and three pelecypods (*Actinopteria communis* Hall, *A. textilis* Hall, and *Pterinea* cf. *schohariae* Hall). For the Catskill quadrangle area, immediately to the south of our region the writer has compiled a faunal list from specimens in the collection of the State Museum and a list made by Chadwick for his Catskill bulletin (letter, 1938):

Sponges

Hindia sphaeroidalis [*inornata, fibrosa*] Duncan

Corals

Ducanella rudis Girty
Pleurodictyum [*Michelinia*] *lenticulare* (Hall)
Streptelasma (*Enterolasma*) *strictum* (Hall)

Worms

"Fucoidal markings" or tubular worm burrows

Bryozoans

Fistulipora ponderosa Hall
Monotrypa tabulata (Hall)

Brachiopods

Camarotoechia ventricosa Hall
Coelospira concava Hall
Eatonia medialis (Vanuxem)
E. peculiaris (Conrad)
Leptaena rhomboidalis (Wilckens)
Leptocoelia (*Anoplotheca*) *flabellites* (Conrad)
Leptostrophia [*Stropheodonta*] *becki* (Hall)
Orthothetes becraftensis (Conrad)
Pholidops ovata Hall
Platyorthis [*Dalmanella*] *planoconvexa* (Hall)
Reticularia ? modesta (Hall)
Rhipidomella discus Hall var.?
R. oblata Hall
Schizophoria multistriata Hall
"Spirifer" concinnus Hall
"S." cyclopterus Hall
"S." [*Delthyris*] *perlamellosus* Hall
"S." (*Eospirifer*) *macropleura* (Conrad)
Uncinulus nobilis Hall

Pelecypods

Cypricardinia lamellosa Hall

Pteropods

Tentaculites elongatus Hall

Trilobites

Ceratocephala (*Acidaspis*) *tuberculata* (Hall)
Dalmanites pleuroptyx (Green)
Homalonotus vanuxemi Hall
Phacops logani Hall

Shimer ('05, p. 262-68) lists for Orange county (Port Jervis region) one coral, one bryozoan, 10 brachiopods (including the

Oriskanian types, *Meristella lata* Hall and *"Spirifer" murchisoni* Castelnau). The following faunal list for Ulster county (Rondout-Kingston region), compiled from the State Museum collection and the lists given by Clarke ('00, p. 73) and Van Ingen and Clark ('03, p. 1197), is the most complete we have:

Sponges

Hindia sphaeroidalis [*inornata, fibrosa*] Duncan

Corals

Chaetetes sp.
Ducanella rudis Girty
Favosites helderbergiae Hall
F. proximus Hall
Pleurodictyum [*Michelinia*] cf. *lenticulare* Hall
Streptelasma (*Enterolasma*) *strictum* (?) Hall
Zaphrentis roemeri E. & H.

Brachiopods

Anastrophia verneuili (Hall)
Atrypa reticularis (Linnaeus) (Some very old individuals with thickened anterior margins of shell)
Coelospira concava Hall
Crania sp.
Eatonia medialis (Vanuxem)
E. peculiaris (Conrad)
Isorthis [*Dalmanella*] *perelegans* (Hall)
Leptaena rhomboidalis (Wilckens)
Leptaenisca concava Hall
Leptocoelia (*Anoplotheca*) *flabellites* (Conrad)
Leptostrophia [*Stropheodonta*] *becki* (Hall)
Levenea [*Dalmanella*] *subcarinata* (Hall)
Meristella bella (Hall)
M. laevis (Vanuxem)
M. princeps Hall
Nucleospira elegans Hall
N. ventricosa Hall
Pholidops ovata Hall
Platyorthis [*Dalmanella*] *planoconvexa* (Hall)
Rensselaeria sp.
Reticularia modesta (Hall)
Rhipidomella oblata Hall
R. oblata var. *emarginata* (Hall)
Rhynchonella acutiplicata Hall
Rhynchospira sp.
Schuchertella [*Orthothetes*] *woolworthana* Hall
"Spirifer" concinnus Hall
"S." cyclopterus Hall
"S." cyclopterus var. *rotundatus* Chadwick
"S." [*Delthyris*] *perlamellosus* Hall
Stenoschisma formosum Hall
Strophonella leavenworthana Hall
Trematospira perforata Hall
Uncinulus campbellanus (Hall)
U. mutabilis Hall
U. nobilis Hall
U. nucleolatus Hall

Pelecypods

Cypricardinia lamellosa Hall

Gastropods

Platyceras sp.

Pteropods

Tentaculites elongatus Hall

Trilobites

Ceratocephala (*Acidaspis*) *tuberculata* (Hall)
Dalmanites pleuroptyx (Green)
Homalonotus vanuxemi Hall
Phacops logani Hall

The maximum thickness of the Port Ewen limestone on the Coxsackie quadrangle is six to eight feet. There are not many exposures and except where this limestone spreads out in broader areas, as in the Leeds gorge (figure 54), north-northeast of this between the Leeds-Catskill and Leeds-Athens roads and in the northern end of the dissected anticline south of Greens lake and west of Black lake, it has been mapped with the Becraft and Alsen limestones. Road cuts or excavations may expose new outcrops, but at present the northernmost outcrop occurs on the east side of the Greens Lake road, about one-tenth of a mile south of the junction with the Limestreet-West Athens road. Here a thickness of two feet is exposed, standing nearly vertical. With the Alsen and Becraft it continues southward in the anticlinal hill bordering on the east the north-south Esopus hollow. In the woods on the south side of the lane to Black lake, three-sixteenths of a mile east of the main highway about six feet of fossiliferous Port Ewen is exposed capped by three and a half feet of Oriskany. In the dissected anticline to the west of Black lake (south of the west end of Greens lake) a thickness of four to six feet is exposed in the vicinity of the deep depression on the west side of the hill and two feet cap the summit. The area on the west side of the ridge marked on the geologic map as Port Ewen includes some Alsen exposures. In many places the Port Ewen is only a veneer.

Six to eight feet of Port Ewen, with fossils, are exposed along the east side of the "Canoe" valley (figure 53) south and west of Black lake near the middle of the deepest part of the valley, also at the road junction one-half mile southeast of this and to the northwest, in the vicinity of the cavern about one-quarter of a mile north of the Leeds Lumber Yard along the Leeds-Athens road. The Port Ewen covers the flat to the north of the lumberyard and extends southward across the Leeds-Athens road through the synclinal valley. South of the Leeds-Catskill road on the east side of the valley, one-quarter of a mile east of Leeds only a thin veneer on the Alsen limestone, sometimes two feet thick, follows a short distance along the steeply dipping beds of Becraft and Alsen bordering the fault on the east. In the northern end of this area, a small ridge or swell of Alsen is located across the road from the lumberyard, cut off on the north by a small fault. In the Leeds gorge, in the vicinity of the right-angled (south) bend in the Catskill creek the Port Ewen spreads over a considerable area and then extends south and west along the creek in a narrower outcrop. It is shown in the bed of the creek east of the Oriskany outcrop and in the west side of the hill (domed southern end of anticline) on the north side of the stream across from the Esopus arch, with about eight feet exposed in both places (*see* figure 54). Lime-loving plants were found on the Port Ewen in the Leeds gorge.

Most of the Port Ewen outcrops are fairly fossiliferous, though collecting is sometimes difficult. From the various exposures the writer has collected the following fauna (*see* figure 33):

Sponge

Hindia sphaeroidalis [*inornata, fibrosa*] Duncan

Corals

Favosites helderbergiae Hall
F. sp.
F. sphaericus Hall
Pleurodictyum [*Michelinia*] cf. *lenticulare* Hall
Streptelasma (*Enterolasma*) *strictum* Hall

Crinoids

Stem joints

Bryozoans

Fenestella sp.
Fistulipora torta Hall
Unidentified forms

Brachiopods

Anoplotheca concava (Hall)
Eatonia medialis (Vanuxem)
E. peculiaris (Conrad)
Isorthis [*Dalmanella*] *perelegans* (Hall)
Leptaena rhomboidalis (Wilckens)
Leptostrophia [*Stropheodonta*] *becki* (Hall)
Meristella sp.
Pholidops ovata Hall
Platyorthis [*Dalmanella*] *planoconvexa* (Hall)
Rhipidomella oblata Hall
"*Spirifer*" *arenosus* (Conrad)
"*S.*" *concinnus* Hall
"*S.*" *cyclopterus* Hall
"*S.*" [*Delthyris*] *perlamellosus* Hall
"*S.*" (*Eospirifer*) *macropleura* (Conrad)
Strophonella punctulifera (Conrad)

Pelecypods

Actinopteria textilis Hall

Gastropods

Platyceras cf. *gibbosum* Hall
P. trilobatum Hall

Pteropods

Tentaculites elongatus Hall

Trilobites

Dalmanites pleuroptyx (Green)
Phacops logani Hall

Oriskany Sandstone (including Glenerie Limestone)

The Oriskany formation has been one of those best known to paleontologists and geologists, partly because of the fine collections of remarkable fossils that have been obtained from it and partly from its geological position at the base of the series of formations known as the upper Helderberg group (now Oriskanian and Ulsterian series). The name Oriskany sandstone was applied by Vanuxem ('37) to a nearly pure, white or yellowish fossiliferous quartz-sand rock, often friable and crumbling, exposed at the type locality, Oriskany Falls, Oneida county, where it has a thickness of 20 feet. In the early days of the Survey, under the leadership of James Hall, this sandstone was regarded as the base of the Devonian in America. At present the Oriskany and the Esopus grit together comprise the Oriskanian, which with the Helderbergian series below constitutes the Lower Devonian, but the question of the base of the Devonian is again arousing interest and study.

The Oriskany sandstone represents shore deposits of a transgressing sea. Variation in thickness in different meridional sections and apparent actual absence of the formation from the rock series in certain places indicate an exposed and broken coast line in the western part of the State (Clarke, '00, p. 79). The early Oriskany sea was restricted to the eastern part of the present Helderberg area. Where the westward transgression of this sea occurred the subsiding land surface was more or less irregular due to elevation and erosion at the end of Helderbergian time. Therefore, in the east the lower Oriskany beds overlie the Port Ewen, the uppermost member of the Helderbergian series. In the northern Helderbergs the Oriskany rests upon the Becraft, in the Schoharie area on the Alsen, at Litchfield in Herkimer county on the Coeymans, in central New York on the Manlius and in western New York and Canada on the Cobleskill (Akron). From Manlius (Onondaga county) westward the so-called Oriskany sandstone occurs as a series of thin lentils, sometimes does not appear at all or is represented only by scattered sand grains or sand filling in crevices in the rock below as in the Buffalo area (*see* Clarke, '00, p. 78). Some (E. O. Ulrich) consider this the clastic initial deposit of the Onondaga.

Clarke, in his treatise on the Oriskany fauna of Becraft mountain, writes in connection with the discussion of the character of the Oriskany sandstone at Oriskany falls (*ref. cit.*) :

This quality of rock does not occur in any of the eastward exposures of the Oriskany from Albany county to the New Jersey line except as an occasional thin streak without fossils. From Oriskany Falls westward no calcareous beds [*see* below] appear except toward the top of the deposit as the sedimentation grades into that of the Onondaga limestone above. Through Onondaga county into Cayuga, the white, often granular, sandstone is frequently exposed, perhaps nowhere better than at its extreme western appearance at Yawger's woods just north of Union Springs. Vanuxem observed that at no other outcrop of this sandstone are fossils so finely preserved.

Both arenaceous and calcareous sediments represent the Oriskany formation in the east. In the Cobleskill-Schoharie area the rock is a mixture of quartz and lime grains and, where long exposed, the lime is commonly dissolved out leaving a brown, porous sandrock in which the fossils are beautifully preserved as both internal and external molds. Grabau ('06, p. 158) cites a maximum thickness of five or six feet (West hill) for the formation in this area, though in some places it is only one or two feet thick and in others perhaps missing. In the northern Helderberg region the rock is similar. It is represented by a very dark, bluish gray to blackish, hard quartzose sandstone with a strong admixture of calcareous matter that increases southward but is variable in the Helderbergs. The maximum thickness is about four feet with an average of one or two feet (Goldring, '35, p. 124). Darton ('94, p. 439) gives the thickness in Albany county as varying from one to four feet with an average of three feet for the greater part of the area (*see* Prosser, '00, p. 56, 59, 61;

Prosser and Rowe, '99, p. 336, and Ruedemann, '30, p. 57), and also notes the absence of the formation for several miles south of Callanans Corners (near South Bethlehem).

Because of its flinty nature the Oriskany sandstone is very hard and resistant and, even though of little thickness, forms a distinct broad platform or terrace wherever the beds are more or less horizontal, the softer Esopus above having been eroded away. These terraces are very characteristic in the Helderberg area and, indeed, are well displayed in the Capital District in general and continue less conspicuously into the northern part of the Coxsackie quadrangle. Such Oriskany surfaces, in most exposures, are seen to be covered with the worm burrows, *Taonurus cauda-galli,* which also so characteristically mark the bedding planes of the Esopus shale and were termed "Cock-tails" because of their appearance. Another well-marked feature of the Oriskany sandstone is the system of intersecting joint fissures which break it up into blocks and have made this sandstone in the past so satisfactory for use in the old stone fences.

Going southward from the Capital District area the rock soon changes in character and becomes a chert or cherty limestone. On the Catskill quadrangle (Greene county) immediately south of our area the Oriskany no longer has its typical appearance, although characterized, as the typical beds, by the brachiopod *"Spirifer" arenosus.* The sandstone character of the formation disappeared farther north on the Coxsackie quadrangle and here it has become a highly fossiliferous cherty limestone, sometimes with interbedded shaly phases, showing buff brown colors upon weathering. It enters the area with a thickness of nine or 10 feet which increases to about 20 feet in the vicinity of West Camp (Chadwick, in field) and Glenerie (Van Ingen and Clark, '13, p. 1199). Farther southward (south of Saugerties) it thickens more and more and highly fossiliferous limestone beds, the *Glenerie limestone* (Chadwick, '08, p. 348) come in at the top. Still farther south, in the Rondout region (Ulster county) the limestones are underlain by a basal pebble conglomerate, 18 to 20 feet thick, the *Connelly conglomerate* (*ref. cit.*). Van Ingen and Clark ('03, p. 1198) for that region cite a lower portion of six to 18 feet of conglomerate and an upper portion, 20 to 50 feet thick, consisting of "layers of sandy limestones intercalated with bands of cherty limestone, both of which are replete with fossils." This total of about 70 feet (maximum thickness) Clarke ('00, 74) divides into 11 feet, three inches of chert followed by 18 feet, seven inches of fine quartz pebble conglomerate; five feet, six inches of siliceous and quite fossiliferous limestone; 36 feet of chert bands containing a few fossils. In the southern extension (Orange county) of these beds "true silicious sandstones are absent but the pebble beds and cherts are well defined" (Clarke, *ref. cit.*, p. 75). Ries in his report on the geology of Orange county gives the thickness of the Oriskany in the Neversink valley north of Port Jervis as 125 feet ('98, p. 402). Two belts are recognized: a western belt, forming the western part of the Helderberg ridge and consisting of fine-grained, shaly sandstones and impure limestones; a second area along the western side of Bellvale and Skunnemunk (Schunemunk) mountains where a fine-grained red or gray quartzite changes locally into a conglomerate. For the Trilobite Mountain section, three miles southeast of Port Jervis, Shimer ('05, p. 185) gives a thickness of 180 feet and Weller ('03, p. 93) found 170 feet in the Wallpack ridge a few miles south of Port Jervis. Shimer (*ref. cit.*), on faunal grounds entirely, divides the beds representing the Oriskany into Lower Oriskany (30 feet; *Port Jervis limestone,* Chadwick, '08, p. 348) or *Dalmanites dentatus zone* with Helderbergian (largely) and Oriskany species; and the Upper Oriskany (150 feet), or *"Spirifer" murchisoni zone* with a preponderance of Oriskanian forms. The deposits of Oriskany age in southeastern New York are considered as representing a deep-water or calcareous phase of the shallow-water, typical Oriskany sandstone. Certain of the large typical Oriskany fossils, such as *Rensselaeria ovoides* and *Hipparionyx proximus,* are absent from the Port Jervis region, which might be accounted for by depth of water (Shimer, '05), and there is a persistence of Helderbergian species in this region even to the beginning of the Esopus (*see* discussion of Oriskany fauna of Pennsylvania by Cleaves, '39).

The fossils of the Oriskany sandstone are difficult to distinguish in fresh rock, but they may be seen beautifully preserved as internal and external molds in the decayed rock and in the old days splendid collections were obtained largely in the old stone fences around Schoharie and in the Helderbergs. Among the common and characteristic fossils found in the Capital District area (Helderbergs) are the brachiopods *"Spirifer" arenosus* and *"S." murchisoni, Hipparionyx proximus, Rensselaeria ovoides, Leptocoelia* (*Anoplotheca*) *flabellites* and the gastropod *Platyceras nodosum.* Grabau ('06, p. 324) cites for the Schoharie region 10 brachiopods, five pelecypods, six gastropods, one conularid, one cephalopod. For the Helderberg area the following fauna has been listed (Prosser & Rowe, '99

p. 341; Prosser '00, p. 59; Ruedemann, '30, p. 58; Goldring, '35, p. 128):

Brachiopods

Eatonia peculiaris (Conrad)
Hipparionyx proximus (Vanuxem)
Leptocoelia (Anoplotheca) flabellites (Conrad)
Leptostrophia cf. *magnifica* (Hall)
Meristella lata Hall
Metaplasia pyxidata (Hall)
Orbiculoidea ampla (Hall)
Rensselaeria ovoides (Eaton)
Rhipidomella musculosa Hall
"Spirifer" arenosus (Conrad)
"S." murchisoni Castelnau
Stropheodonta (Leptostrophia) cf. *magniventra* Hall

Pelecypods

Actinopteria textilis var. *arenaria* Hall

Gastropods

Diaphorostoma ventricosum Conrad
Platyceras nodosum Conrad
P. sp.

The State Museum has obtained a fine collection of fossils from weathered joint cracks in the Glenerie limestone at Glenerie in Ulster county. Of the species collected here Clarke writes: "This association has some peculiarities, *e.g.*, the presence of some of the Cumberland, Md., species which have not before been observed in the Oriskany of New York (*Platyceras gebhardi* and *P. reflexum*) and several forms of novel aspect" ('00, p. 75). With the incoming of the limestone beds into the Oriskany formation southward the species of fossils have increased in number. For detailed lists and analyses the reader may consult Barrett ('76, p. 386; '93, p. 72), Clarke ('00, p. 74ff.), Van Ingen and Clark ('03, p. 1203) and Shimer ('05, p. 185ff.). For the vicinity of Port Jervis (Orange county) Shimer (*ref. cit.*) lists 33 species from the Lower Oriskany or *Dalmanites dentatus zone* (two bryozoans, 19 brachiopods, two pelecypods, six gastropods, two pteropods, two trilobites) and 24 species from the Upper Oriskany or *"Spirifer" murchisoni zone* (14 brachiopods, two pelecypods, five gastropods, two pteropods, one trilobite). Van Ingen and Clark (*ref. cit.*) cite for the Rondout area (Ulster county) a Glenerie-Oriskany fauna of 96 species (one sponge, three corals, one crinoid, two worms, one bryozoan, 63 brachiopods, four pelecypods, 12 gastropods, one pteropod, one cephalopod, one ostracod, one cirripede ?, four trilobites, one fish), and point out that in this fauna are included 26 New Scotland species, 29 species typical of the Oriskany of the central New York province, two Onondaga limestone types, and eight Cumberland, Md., species. The most extensive list of Oriskany (Glenerie) fossils is given by Clarke ('00, p. 65-67) for Becraft mountain (Greene county), on the Catskill quadrangle immediately south of our area. This fauna is as follows:

Hydrozoans

Dictyonema cf *splendens* Billings
Plumulites sp.

Corals

Aulopora cf. *schoharie* Hall
Cladopora smicra Clarke
C. styphelia Clarke

Vermipora serpuloides Hall var.
V. streptocoelia Clarke
Zaphrentis sp.

Crinoids

Edriocrinus becraftensis Clarke

Worms

Annelid teeth
Autodetus beecheri Clarke
Cornulites cingulatus Hall
Spirorbis assimilis Clarke

Bryozoans

Fenestella biseriata (Hall)?
Hederella arachnoidea Clarke
H. graciliora Clarke
H. magna Hall & Simpson
H. ramea Clarke
Hemitrypa columellata Hall
Isotrypa sp.
Lichenalia cf. *crassa* Hall
Monotrypa helderbergiae (Hall)?
Monotrypella arbuscula H. & S.
Polypora separata Hall?
P. sp.
Polyporella cf. *compressa* Hall
Reteporina sp.
Rhombipora rhombifera Hall
Stictopora sp.
Unitrypa acclivis Hall
U. lata Hall

Brachiopods

Anastrophia sp.
Anoplia nucleata Hall
Anoplotheca concava (Hall)
A. dichotoma (Hall)
Brachyprion majus Clarke
B. schuchertanum Clarke
Camarotoechia dryope Billings
C. oblata Hall
C. sp.?
Centronella [*Oriskania*] *sinuata* Clarke
Chonetes hudsonicus Clarke
Chonostrophia complanata Hall
Crania cf. *bella* Billings
C. pulchella Hall & Clarke
Cryptonella (?) *fausta* Clarke
C. sp.
Cyrtina varia Clarke
"*Dalmanella*" (*Isorthis*) *perelegans* Hall
Eatonia medialis Vanuxem
E. peculiaris Conrad
Hipparionyx proximus Vanuxem
Leptaena rhomboidalis Wilckens
Leptocoelia (*Anoplotheca*) *flabellites* Conrad
Leptostrophia magnifica Hall
L. oriskania Clarke
Lingula cf. *rectilatera* Hall
"*Megalanteris*" (*Rensselaeria*) *ovalis* Hall
Meristella lata Hall
M. lentiformis Clarke
M. (?) *vascularia* Conrad
Metaplasia pyxidata Hall
Pholidops terminalis Hall
P. sp.
"*Plethorhyncha*" (*Straelenia*) *barrandii* Hall
"*P.*" (*S.*) *fitchana* Hall (?)
Rensselaeria ovoides Eaton
"*Reticularia*" (*Elytha*) *saffordi* (Hall)
Rhipidomella oblata Hall
Schuchertella becraftensis Clarke
"*Spirifer*" *arenosus* Conrad
"*S.*" *murchisoni* Castelnau
Stropheodonta lincklaeni Hall
Trematospira multistriata Hall

Pelecypods

Actinopteria communis Hall
A. insignis Clarke
Aviculopecten sp.
Conocardium inceptum Hall (?)
Cypricardinia lamellosa Conrad
Goniophora sp.
Lyriopecten sp.
Megambonia crenistriata Clarke
Pterinea sp.?
Pterinopecten pumilus Clarke
P. proteus Clarke
P. signatus Clarke
P. subequilatera Hall

Gastropods

Bellerophon sp.
Cyrtolites expansus Hall
Diaphorostoma desmatum Clarke
D. ventricosum Conrad
Orthonychia tortuosum Hall
Platyceras cf. *gebhardi* Hall
P. nodosum Conrad
Pleurotomaria sp.
Strophostylus expansus Conrad

Conularids

Conularia sp.

Pteropods

Tentaculites (?) *acus* Clarke
T. elongatus Hall

Ostracods

Beyrichia sp.?

Trilobites

Acidaspis tuberculata (Conrad)
Cordania becraftensis Clarke
C. hudsonica Clarke
Cyphaspis minuscula Hall
Dalmanites bisignatus Clarke
D. phacoptyx Hall & Clarke
"*D.*" (*Synphoria*) *stemmatus* Clarke
"*D.*" (*S.*) *stemmatus* var. *convergens* Clarke
Homalonotus sp.
Lichas cf. *pustulosus* Hall
Phacops correlator Clarke
P. logani Hall
Proetus conradi Hall

Of the 113 recognizable, distinct specific forms listed by Clarke 94 were identifiable with species already known or were clearly new forms peculiar to the fauna. He points out that of the 94 species, 25 are Helderbergian, 24 occur in the arenaceous beds of the Oriskany and 10 range upward into the Upper Helderberg (Ulsterian), part of these restricted to the sandy, lower beds (Schoharie grit) and others noted only in the chert beds of Ontario, Canada, where the intermixture of Oriskany and Onondaga species is well marked (*ref. cit.*).

For the entire Catskill quadrangle Chadwick has listed about 40 species, adding to the list above the coral *Enterolasma strictum* ? (Hall); the crinoids *Ancyrocrinus quinquepartitus* Goldring and *Edriocrinus sacculus* Hall; the worm *Taonurus cauda-galli* (Vanuxem); the brachiopods *Eatonia sinuata* Hall, *Leptaena rhomboidalis ventricosa* Hall, *Rhipidomella musculosa* Hall; *"Plethorhyncha"* (*Straelenia*) *pleiopleura* (Conrad), and the trilobite *Homalonotus vanuxemi* Hall.

There are few places on the Coxsackie quadrangle where the Oriskany formation spreads out to any extent and is accessible for study. As the Oriskany sandstone it outcrops one-half mile south of the northern boundary of the area, surrounding the fenster of Becraft referred to in the chapter on that formation. Twenty-two inches are represented in the vicinity of this small swell or domed anticline and the commoner fossils may be collected in the fences and, with more difficulty, from the outcrop itself. The road going north shows a cut on the west side about one-eighth of a mile north of the junction. To the west, north of the right-angled bend in the road, the Oriskany belt soon narrows down and along the old woods road which passes over the Becraft limestone a thin cherty representation of Oriskany covers the limestone in patches.

North of the Flint Mine Hill-Urlton road, one-quarter of a mile east of the junction with the road past Bronks lake, the Oriskany is well displayed in the southern end of the fault-valley extending south-southwest of the reservoir of the New York State Vocational Institution at Coxsackie. Six feet of Oriskany are found on the west side of the anticlinal hill dipping N. 57° W. at an angle of 45°. The rock is very black in appearance and quite cherty, weathering to buff colors on the surface. On the southeast slope of this ridge just north of the road the Oriskany outcrops with only a foot and a half of weathered rock, buff-colored and spongy looking. One-quarter of a mile east along the same road the Oriskany spreads out north and south of the road in a shallow synclinal basin. A fresh cut made in widening the road shows about four feet of drab-colored, very cherty rock, resembling an impure siliceous limestone, which dips N. 76° W. at an angle of 10° and abuts against steeply dipping Alsen and Becraft on the east side of the fault. The Oriskany here has already taken on something of the character of the Glenerie limestone.

Along the lane to Black lake, three-sixteenths of a mile from the highway at the west, three and a half feet of Oriskany cap the Port Ewen in the woods south of the lane and in the vicinity of the lane over the summit of the hill and down to Black lake the Oriskany outcrop broadens out somewhat. The typical Oriskany sandstone has disappeared, as is well shown in the synclinal valley to the south and west (figure 53), the "Canoe," and in the vicinity of the junction of the north-south road past Black lake with the Leeds-Athens road. Seven to nine feet of Oriskany cherty limestone (Glenerie) weathering spongy and buff to reddish in color, are exposed in this area. The exposure in the "Canoe" is quite accessible from the Leeds-Athens road, but in the spring or during a season of heavy rains the bottom of the "Canoe" is occupied by water. West of the junction much weathered, buff and reddish, rather calcareous rock is exposed in the hill to the east of the Leeds Lumber Yard, forming a low terrace in the hill. South of Greens lake in the northern part of the anticlinal ridge, south of the swamp, a broad expanse of Glenerie chert and limestone is exposed. The rock here is very cherty in the upper beds, quite calcareous and weathers buff or reddish with a spongy appearance.

Nine to 10 feet of Glenerie chert and limestone are exposed in the Leeds gorge in the vicinity of the arch in the Esopus (figure 54). It extends eastward to the elbow in the creek and then follows the creek southward. It weathers buff and rather reddish and displays a great abundance of chert. At low water the Glenerie may be seen crossing the stream to the Esopus arch where five feet are exposed in the bank at the center. The Glenerie here has become involved in a minor thrust and on both sides of the stream, but particularly on the south side at low water, may be seen thrust over the Esopus. In the bed of the stream at low water, at the base of the formation, may be seen a conglomerate bed up to eight inches in thickness containing pebbles at Port Ewen with a maximum size of at least three inches.

A fair representation of fossils (figures 35, 36) may be collected from the outcrops described, though collecting is more or less difficult. The writer has collected from the Oriskany sandstone and the cherty limestone (Glenerie) the following fauna:

Corals

Streptelasma (*Enterolasma*) *strictum* Hall

Worms

Taonurus cauda-galli (Vanuxem)

Bryozoans

Fenestella sp.
Unidentified species

Brachiopods

Chonetes hudsonicus Clarke
Chonostrophia complanata Hall
Eatonia peculiaris Conrad
Hipparionyx proximus Vanuxem
Leptaena rhomboidalis Wilckens
Leptocoelia (*Anoplotheca*) *flabellites* Conrad
Leptostrophia oriskania Clarke
"*Megalanteris*" (*Rensselaeria*) *ovalis* Hall
Meristella sp.
"*Plethorhyncha*" (*Straelenia*) *barrandii* Hall
Rensselaeria ovoides Eaton
Rhipidomella musculosa Hall
Rhipidomella sp.
Schuchertella becraftensis Clarke
"*Spirifer*" *arenosus* Conrad
"*S.*" *murchisoni* Castelnau
Trematospira multistriata Hall

Gastropods

Diaphorostoma ventricosum Conrad
Platyceras gebhardi Hall

Pteropods

Tentaculites elongatus Hall

Trilobites

Homalonotus vanuxemi Hall
Phacops logani Hall
Synphoria stemmata Clarke

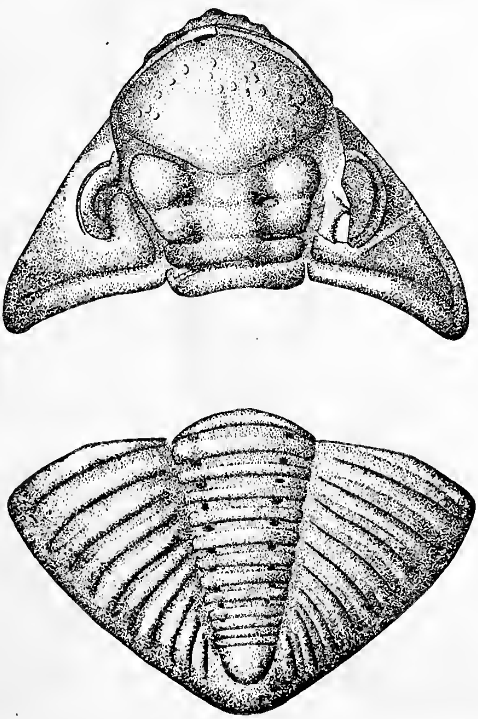

Figure 35 *Synphoria stemmata* Clarke, x ¾. Head and pygidium of trilobite from the Glenerie limestone. (After Clarke)

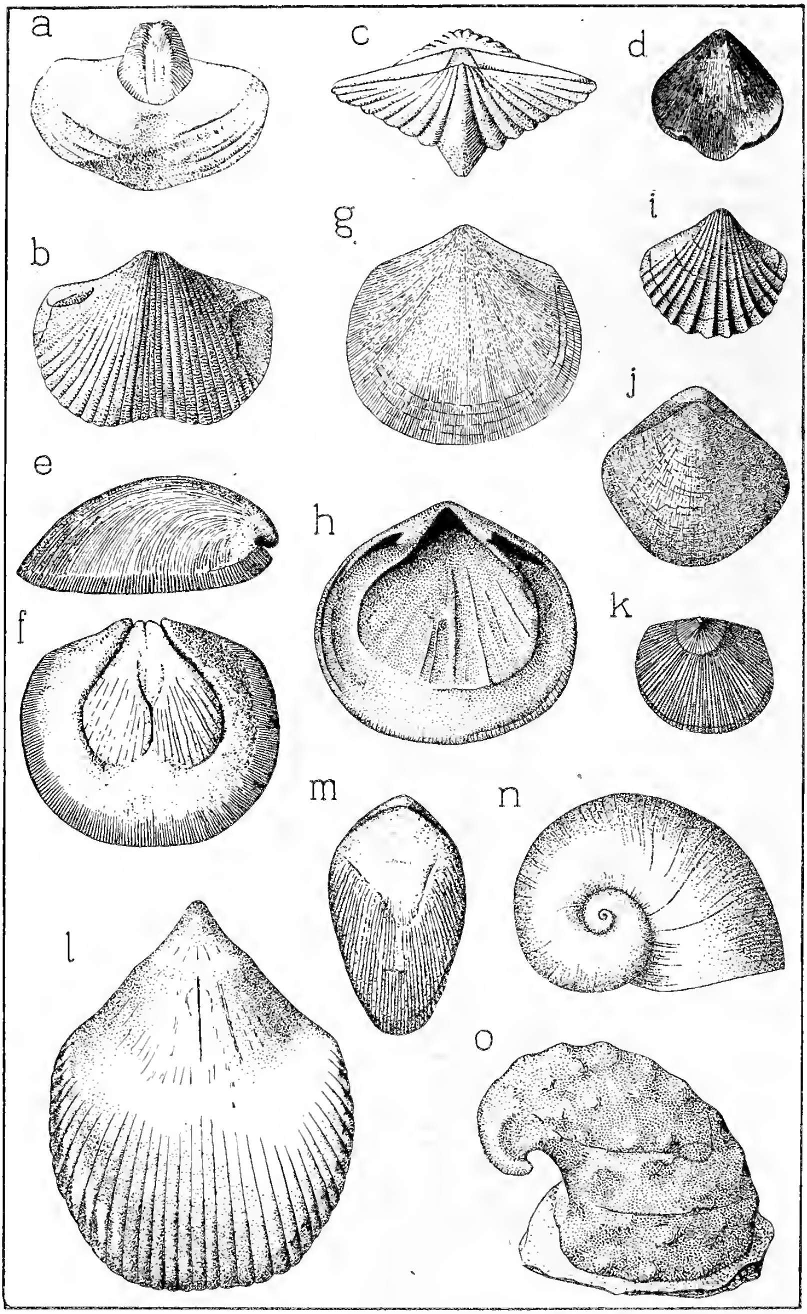

Figure 36 Oriskany sandstone and Glenerie limestone fossils. (Brachiopods, *a-m*; gastropods, *n, o*). *a, b "Spirifer" arenosus*, x ½. *c "S." murchisoni*, x ¾. *d Eatonia peculiaris. e, f Hipparionyx proximus*, x ½. *g, h Rhipidomella musculosa. i Leptocoelia (Anoplotheca) flabellites. j Meristella lata*, x ¾. *k Schuchertella becraftensis. l Straelenia [Plethorhyncha] barrandii*, x ¾. *m Rensselaeria ovoides*, x ½. *n Platyceras gebhardi*, x ¾. *o P. nodosum*, x ½.

Esopus Shale

The Esopus shale or grit is the *"Cauda-galli grit"* or *"Cock-tail grit"* of Vanuxem ('42) and other earlier geologists, so-called from the abundant markings on the bedding planes which resemble a rooster's tail. The present name was given by Darton ('94, p. 403), because of the excellent exposures near the Esopus settlement (Kingston), Ulster county, and along the creek of that name. The Esopus shale is not found west of Otsego county, but it is a persistent formation in eastern New York, New Jersey and Pennsylvania. Elevation followed the deposition of Oriskany time with the result that in eastern New York we have only the coarse sands and grits of a mud delta constituting the Esopus formation (Oriskanian).

The Esopus shale or grit is neither a true shale nor a true grit. It is in general a blackish or dark-gray grit or sandy shale of a very uniform character which readily crumbles into a gravelly mass and weathers to a dark-brown color. Darton describes this formation as

in greater part, a fine-grained arenaceous desposit of dark gray color and with more or less completely developed slaty cleavage. About Schoharie and westward to its termination it is a moderately hard, sandy shale varying in color from dark gray or buff to light olive, but east and south with increasing thickness the color becomes darker, the texture of the rock is harder and slaty cleavage general. In the Helderberg mountains and westward the shales constitute a slope between shelves of Onondaga limestone above and Oriskany sandstone below . . . but from the southern part of Albany county, southward, it constitutes high rough ridges. (*ref. cit.*)

The aspect of the rock varies according to the way in which cuts are made. The surfaces of weathered cuts are covered with small, cubical blocks, resembling a pile of stone, but other cuts are made in such a way that the rock appears very solid and resistant. Jointing in the Esopus is prominent and characteristic, and when viewed at one of these joint surfaces the rock gives the appearance of being very massive and hard. In this system of intersecting joints, some groups are more prominent. Stratification is absent or, when present, often difficult to detect, partly due to the striking development of slaty cleavage. In the northern Helderberg area the lower eight to ten feet of this shale in places has been found to be highly siliceous or flinty and filled with *Taonurus*-markings (worm burrows), an indication of a close relationship with the Oriskany sandstone of which it is considered a facies, in part at least. The middle beds are more argillaceous, but the uppermost beds again are more strongly siliceous and pass gradually into the grit above. In some places the last five or six feet of the formation are found to be a heavy sandstone. The more cherty character of the Esopus has been found in a greater thickness (40 feet) in the lower beds in the Catskill area (Chadwick) and in the Esopus creek these beds are very flinty.

Westward toward Otsego county the Esopus shale loses in thickness. Grabau ('06, p. 170) cites a thickness of 80 to 90 feet for the Schoharie region. For Albany county Darton ('94*a*, p. 438) found an average thickness of 100 feet, and measurements of 80 to 120 feet were made for the northern Helderberg area in particular (Prosser & Rowe, '99, p. 348; Prosser, '00, p. 55, 61; Ruedemann, '30, p. 59; Goldring, '35, p. 133). At Becraft mountain (Catskill quadrangle) a thickness of 300 feet has been allotted by Grabau to the combined Esopus and Schoharie, of which about one-third is considered as belonging to the Esopus, with the dividing line drawn on lithic characters ('03, p. 1034, 1069); but in the light of the work of G. H. Chadwick the thickness of the Esopus appears to be underestimated. Chadwick (in field; Catskill bulletin) estimates 250 to 300 feet for the thickness of this formation on the Catskill quadrangle to the south of our area. The greatest thickness occurs in southeastern New York. In the Rondout-Kingston area 300 to 325 feet have been measured (Van Ingen & Clark, '03, p. 1204; Darton, '94, p. 407) and at Port Jervis 550 to 700 feet (Shimer, '05, p. 192), whence it extends into New Jersey and Pennsylvania. Weller ('03, p. 102) describes the Esopus grit as "one of the most persistent formations in the Delaware Valley region of New Jersey," forming "the crest of the Wallpack ridge throughout the greater part of its extent in the State," and cites the average thickness of the formation as about 375 feet. (*See* supplementary note at end of Schoharie chapter.)

As already pointed out, the Esopus shale, due to its softer character, forms characteristic slopes between the terraces formed on the Oriskany sandstone below and the Onondaga above in undisturbed areas such as the northern Helderbergs. In its broader areas it is often given up to grazing, though the vegetation is sparse in places. In much disturbed areas the Esopus becomes harder and develops a strong slaty cleavage with the result that it stands out in very sharp ridges of barren aspect, as seen two miles south and southwest of South Bethlehem on the Albany quadrangle and thence southward.

Except for the worm burrows, *Taonurus* [*Spirophyton*] *cauda-galli* (figure 37), the Esopus shale has been found to be in general barren of organic remains. The *Taonurus* markings were formerly regarded as impressions of "fucoids" or seaweeds and Grabau more recently ('06, p. 168) suggested that they might be "inorganic, representing wave-marks of a peculiar type." Since then it has been shown (Sarle) that they were produced by mud-swallowing worms and Ruedemann has pointed out ('30, p. 59) the presence in the State Museum collection of two specimens of *Taonurus* from the Hamilton shale of Western New York which "actually show the worms in place at the outer edge of the markings."

No fossils have been reported from the Schoharie region (Grabau, *ref. cit.*). A small brachiopod was collected some years ago in the Helderbergs, but never recorded (Ruedemann; Albany quadrangle). Chadwick (in conversation and letter 1938) has found a few fossils, mostly brachiopods, in the lower siliceous beds of the Catskill area: *Ambocoelia* ? sp., *Chonostrophia complanata* Hall, *Leptocoelia flabellites* Conrad var., *Orbiculoidea* sp. among the brachiopods and the gastropod *Platyceras* sp. Van Ingen and Clark ('03, p. 1204) list

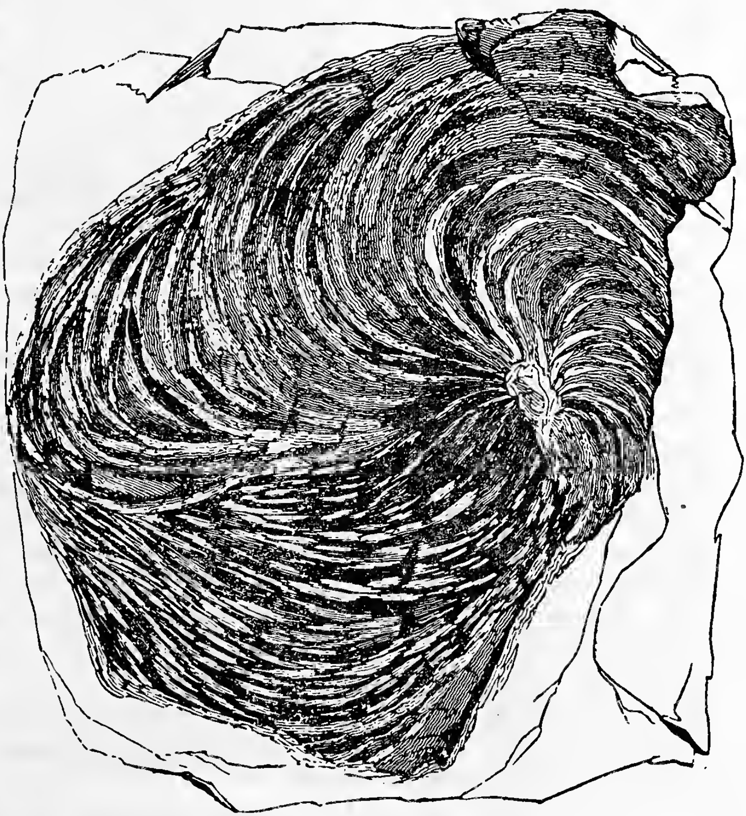

Figure 37 Esopus shale fossil. The worm burrow or "Cocktail", *Taonurus cauda-galli* (Vanuxem).

a few brachiopods for the Esopus creek (Rondout-Kingston) area, namely: *Anoplotheca* (*Leptocoelia*) *acutiplicata* (Conrad), *Atrypa spinosa* Hall, and an obscure discinoid brachiopod. From this same area (Rosendale-Kingston) Professor B. F. Howell of Princeton has described, in a recent bulletin of the State Museum ('42, p. 87-91), the coral *Zaphrentis* cf. *tabulata* Hall; a species of worm represented by burrows only; the brachiopods *Anoplotheca* (*Leptocoelia*) *flabellites* (Conrad), *Meristella goldringae* sp. nov. *Nucleospira concinna* Hall, *Orbiculoidea ruedemanni* sp. nov.; the gastropod *Loxonema chadwicki* sp. nov.; and the conularid *Conularia ulsterensis* sp. nov. Shimer ('05, p. 192) reports no fossils for the Port Jervis region. Dr G. Arthur Cooper and the writer, while working on the Hamilton of this area in the summer of 1938, noted brachiopods and other fossils in the supposed Esopus of the Rondout valley about 25 miles north of Port Jervis, one and one-half miles north-northeast of Wawarsing. There is, however, need for study of the Esopus and Schoharie of this region and determination of the contact. An imperfect brachiopod was listed by Weller ('03, p. 102) from New Jersey and he also cites White as reporting brachiopods from this formation in Pennsylvania.

There are numerous excellent exposures of Esopus on the Coxsackie quadrangle. Just south of the northern boundary the outcrop occupies a width of a mile and a half due to a series of small anticlines and synclines with a roughly north-south direction. Due to the strong folding there is more or less induration of the Esopus in this area and strong cleavage has been developed, but certain areas still show good *Taonurus* surfaces as in the woods along the north side of the Ravena road, one-quarter of a mile northeast of Aquetuck. There are good exposures in the northward trending cliff just east and a very good road cut in the northern end of this same ridge, about one-half mile south of the northern border of the area. About one mile south-southeast of Aquetuck along the first east-west road the relation of the Esopus and Schoharie may be seen, and there are good exposures northward. Strong, almost vertical cleavage and good *Taonurus* surfaces are displayed. Just a mile south, at Little Falls on the west side of Greene creek, is an excellent locality for studying the Esopus, Schoharie and Onondaga.

South of Aquetuck the Esopus belt quickly narrows and continues as a narrow belt between the Oriskany sandstone and Schoharie grit to the Roberts Hill-Coxsackie Reservoir area. Excellent exposures occur north of the Roberts Hill-Medway road and in the cliffs bordering the west side of the reservoir. The Esopus-Schoharie-Onondaga

Figure 38 Cut in the Esopus shale on the north side of Coxsackie-Bronks Lake road in the vicinity of the New York State Vocational School reservoir. The Esopus is massive looking in a fresh exposure, but soon breaks down into a gravelly appearance (seen at right). Cleavage is shown at nearly right angles with the bedding. (Photograph by E. J. Stein)

succession may be studied in this area one-quarter of a mile south-southeast of the reservoir where a woods lane leads east of the junction of the road to Medway with the north-south road.

One of the broader belts of Esopus extends north and south of the Coxsackie-Bronks Lake road in the vicinity of the reservoir of the New York State Vocational Institution. This is an accessible and interesting area. Just north of the reservoir are good road cuts showing beautifully developed cleavage (figure 38), and a short distance to the west the road passes over excellent glaciated surfaces. North of the road the Esopus covers a width of one-half mile; south of the reservoir it narrows rapidly until it reaches the Flint Mine Hill-Urlton road south of which it forms a broad belt extending nearly to Limestreet. The northern end of this latter belt is formed by an anticlinal ridge with a syncline to the east; the southern area is underlain by a series of small anticlinal ridges.

An interesting feature is the hollow or valley, developed on the softer Esopus between steeply dipping limestones, which extends roughly north-south from the vicinity of the junction of the Greens Lake and Limestreet-West Athens roads to the north end of Black lake where a thickness of at least 150 feet is shown in the ridge to the north and west. Three-eighths of a mile south of Limestreet is another exposure worth noting. In the woods east of the road the north-south anticline is seen to be broken by a fault. The bowing uplift of the area to the east has developed a cliff of Esopus, with easterly dipping beds, which is bordered on the west by Onondaga with a more gentle easterly dip.

The Esopus forms rather broad areas on both sides of the northward pitching anticline that extends north from Leeds through the Greens Lake area. Excellent exposures may be studied along the road at the northwest border of the lake and on both sides of the road from Greens lake southward past Black lake to the junction with the Leeds-Athens road. On the west side of the anticline along the lane extending southeast from the Greens Lake-Leeds road the Esopus-Schoharie-Onondaga succession may again be studied.

Unquestionably the most interesting and instructive Esopus outcrop and one very accessible to students is that found in the Leeds gorge east of the falls. Chadwick has estimated for this area a thickness of at least 250 feet for the Esopus (personal communication). On the south side of the creek may be seen, even from the road above, a beautiful, almost perfect, arch in the Esopus with some five feet of Glenerie involved at the base. Both are involved in a thrust which has carried them forward (west) over other Esopus beds. Due to the folding and thrusting there has been considerable crumpling of the Esopus in the stream bed and in the cliff toward the falls. Calcite veins, some of considerable thickness, are numerous and slickenside surfaces as well. The crumpling is pronounced in the south cliff at the dam where a nearly vertical fault plane separates the crushed and contorted westerly dipping Esopus beds from Esopus and Schoharie dipping S. 57° E. at an angle of 76° and forming with the Onondaga (to the west) the east arm of a pinched syncline which underlies the old mill pond.

The writer has made no intensive search for fossils. Fragments of what appeared to be *Leptocoelia* (*Anoplotheca*) *flabellites* Conrad were noted in the lower beds.

Schoharie Grit and Limestone

The Schoharie grit (Vanuxem '40) received its name from the type locality in Schoharie county (at Schoharie) where it is characteristically developed. It is somewhat local in development, but it occurs as well in Albany and Otsego counties, in the Hudson valley and the southeastern area between Kingston and Port Jervis (*see* page 208). It is apparently not everywhere continuous as the Onondaga and Esopus in places have been found in direct contact, as in certain areas, in the Capital District (*see* Ruedemann '30, p. 60, 62; Darton, '94, p. 438).

In its characteristic development in the Schoharie valley the Schoharie is an impure, siliceous limestone, of a dark bluish gray color when fresh but weathering to a dark buff or brown porous sandstone. In contrast to the Esopus it is, in general, characterized by a great wealth of fossils, particularly in the Schoharie region, but some parts of the rock are shaly and rather sparingly fossiliferous.

Grabau ('06, p. 180, 254) reports a thickness of five to eight feet for the Schoharie area; in the northern Helderberg and Capital District area it varies from nothing to a thickness of eight feet (Ruedemann, '30, p. 60; Goldring, '35, p. 136). The variable occurrence of the Schoharie grit and its character in the latter areas led Doctor Ruedemann and the writer to the belief that it is a sandy facies of the Onondaga. It was found, as previously noted by Darton, not only merging into the overlying Onondaga, with the basal Onondaga somewhat sandy, but interfingering with the limestone with fossils (corals and cephalopods) passing freely across the welded contacts. On the other hand G. H. Chadwick (in conversation and abstract of Geological Society meeting, '27) has reported for the Catskill region disconformities at the top and bottom of the Schoharie formation, indicated by the presence of glauconite.

The Schoharie, if such it proves to be upon further study (*see* page 222), thickens southward in the Hudson valley, where it has more of the appearance of a shaly limestone. Chadwick (personal communication) has found a thickness of 60 to 80 feet in the Catskill area. For Becraft mountain Grabau ('03, p. 1069; '06, p. 181) has assigned 150 to 200 feet of shale to the Schoharie, because some of the characteristic fossils have been found in it, though in rock aspect it is more similar to the Esopus. Chadwick's measurements for the Esopus and Schoharie on the Catskill quadrangle, recently obtained, would indicate that Grabau has assigned too little thickness to the Esopus grit in Becraft mountain and too much to the Schoharie formation. (*See* supplementary note, page 224.)

The occurrence of the Schoharie in southeastern New York between Kingston and Port Jervis was noted by Dr G. A. Cooper of the U. S. National Museum and the writer while making field studies of the Hamilton beds in the summer of 1938. Van Ingen and Clark ('03, p. 1180, 1204) for Ulster county (Kingston region) record a thickness of 300 to 325 feet for the Esopus. In discussing its character they state (*ref. cit.*, p. 1204): "Its upper layers become more limy and finally, through gradual changes, they merge into the argillaceous limestones of the lower portion of the Onondaga beds." This may indicate the inclusion of some Schoharie in the thickness given for the Esopus grit. For the Trilobite Mountain section (Orange county) Shimer ('05, p. 179, 192) includes the Schoharie in the 550+ feet cited for the thickness of the Esopus shale "on account of the absence of fossils and the lithic similarity of the two formations."

Although a thin formation for much of its extent the Schoharie grit is remarkable for its great wealth of fossils. From the Schoharie-Helderberg area (largely the former) have been listed 128 species of fossils as follows (Grabau, '06, p. 327; Prosser and Rowe '99, p. 352; Goldring, '35, p. 137):

Plants

Ischadites bursiformis Hall

Corals

Favosites sp.
Zaphrentis sp.
Streptelasma sp.

Bryozoans

Ptiloporina sinistralis (Hall & Simpson)

Brachiopods

Amphigenia elongata (Vanuxem)
Atrypa reticularis impressa Hall
Centronella glans-fagea (Hall)

Chonetes hemisphericus Hall
Coelospira camilla Hall
Cyrtina biplicata Hall
C. hamiltonensis Hall
Elytha [*Reticularia*] *fimbriata* (Conrad)
Leptaena rhomboidalis (Wilckens)
Lingula ceryx Hall
Meristella doris Hall
M. nasuta (Conrad)
Nucleospira concinna Hall
Pentamerella arata (Conrad)
Pholidops areolata Hall
Rhipidomella alsa Hall
R. mitis Hall
R. peloris Hall
Schizophoria propinqua Hall (?)
Schuchertella pandora (Billings)
"*Spirifer*" *duodenarius* (Hall)
"*S.*" *grieri* Hall
"*S.*" *macrus* Hall
"*S.*" *raricosta* (Conrad)
Stropheodonta alveata Hall
S. callosa var. Hall
S. crebristriata (Conrad)
S. demissa (Conrad)
S. hemispherica Hall
S. inaequiradiata Hall
S. parva Hall
S. patersoni Hall
S. perplana (Conrad)
Strophonella ampla Hall

Pelecypods

Actinopteria eximia Hall
Conocardium cuneus (Conrad)
Cypricardinia planulata (Conrad)
Goniophora ? alata Hall
G. perangulata (Hall)
Grammysia praecursor Hall
Lyriopecten parallelodontus Hall
Modiomorpha putilla Hall
M. regularis Hall
M. schohariae Hall
Mytilarca pyramidata Hall
Panenka dichotoma Hall
Plethomytilus arenaceus Hall
Schizodus ? fissus Hall

Gastropods

Bellerophon curvilineatus Conrad
B. pelops Hall
Callonema (?) *primaevum* Hall
Cyclonema doris Hall
Diaphorostoma aplatum Hall
Loxonema robustum Hall
L. solidum Hall
L. ? subattenuatum Hall
Pleurotomaria arata Hall
Straparollus clymenoides Hall
S. inops Hall
Strophostylus unicus Hall

Conularids

Hyolithes ligea Hall
H. principalis Hall

Cephalopods

Acleistoceras? [*Gomphoceras*] *illaenus* (Hall)
A.? [*Orthoceras*] *varum* (Hall)
Brevicoceras? [*Gomphoceras*] *beta* (Hall)
B.? [*G.*] *cruciferum* (Hall)
B.? [*G.*] *rude* (Hall)
Cophinoceras [*Gyroceras*] *spinosum* (Conrad)
Cyrtospyroceras [*Cyrtoceras*] *morsum* (Hall)
Geisonoceras [*Orthoceras*] *carnosum* (Hall)
Keionoceras [*Orthoceras*] *creon* (Hall)
Micronoceras [*Gomphoceras*] *fax* (Hall)
Michelinoceras ? [*Orthoceras*] *cingulum* (Hall)
M. ? [*O.*] *collatum* (Hall)
M. ? [*O.*] *duramen* (Hall)
M. ? [*O.*] *masculum* (Hall)
M. ? [*O.*] *medium* (Hall)
M. ? [*O.*] *pelops* (Hall)
M. ? [*O.*] *pervicax* (Hall)
M. ? [*O.*] *pravum* (Hall)
M. ? [*O.*] *procerum* (Hall)
M. ? [*O.*] *stylus* (Hall)
M. ? [*O.*] *tantalus* (Hall)
M. ? [*O.*] *tetricum* (Hall)
M. ? [*O.*] *zeus* (Hall)
Naedyceras ? [*Trochoceras*] *barrandei* (Hall)
N. [*T.*] *eugenium* (Hall)
N. ? [*T.*] *expansum* (Hall)
N. ? [*T.*] *obliquatum* (Hall)
N. [*T.*] *orion* (Hall)
N. ? [*T.*] *pandion* (Hall)
Ormoceras ? [*Orthoceras*] *fluctum* (Hall)
O. [*O.*] *luxum* (Hall)
O. [*O.*] *oppletum* (Hall)
O. [*O.*] *vastator* (Hall)
Rhadinoceras [*Gyroceras*] *validum* (Hall)
Ryticeras [*Cyrtoceras*] *aemulum* (Hall)
R. [*C.*] *eugenium* (Hall)
R. [*C.*] *jason* (Hall)
Sphyradoceras [*Trochoceras*] *clio* (Hall)
S. [*T.*] *discoideum* (Hall)
Spyroceras [*Orthoceras*] *thoas* (Hall)
S. ? [*O.*] *multicinctum* (Hall)
Turnoceras [*Gomphoceras*] *absens* (Hall)

Tyrrelloceras [*Trochoceras*] *biton* (Hall)
Verticoceras? [*Gomphoceras*] *clavatum* (Hall)

Trilobites

Acidaspis callicera H. & C.
Calymene platys Green
Conolichas [*Lichas*] *hispidus* H. & C.
Cordania arenicolus H. & C.
Corycephalus [*Dalmanites*] *regalis* (Hall)
Cyphaspis minuscula (Hall)
Hausmannia concinna H. & C.
Phacops cristata (Hall)
Proetus angustifrons Hall
P. crassimarginatus Hall
P. conradi Hall
P. hesione Hall
Synphoria [*Dalmanites*] *anchiops* (Hall)
S. anchiops var. *armatus* (Hall)
S. anchiops var. *sobrinus* (H. & C.)
Terataspis [*Lichas*] *grandis* (Hall)

To this list Flower recently ('38) has added the following new species of cephalopods from the Schoharie region: *Acleistoceras schohariae, Brevicoceras compactum, B. rotundatum, Exocyrtoceras sinuatum, E. constrictum, E. micron, Wissenbachia gebhardi.*

Grabau listed no corals for the Schoharie region but Doctor Ruedemann and the writer found corals as well as cephalopods abundant in the northern Helderbergs area (Albany and Berne quadrangles). *Zaphrentis* is cited as common and *Streptelasma* as abundant in the Clarksville section (Albany quadrangle) by Prosser and Rowe ('99, p. 352). In his discussion of the Schoharie fauna in the Capital District bulletin ('30, p. 62) Ruedemann writes:

The largest biota of this fauna is the cephalopods which prevail so much in individuals and species, as well as size of the fossils, that the Schoharie grit is a distinct cephalopod facies. To this must

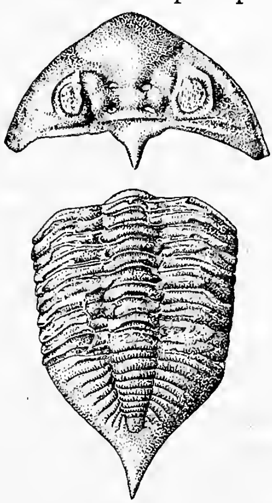

Figure 39 *Synphoria anchiops* (Green), x ½. A trilobite occurring in the Schoharie and Onondaga limestones.

be added that there appear a number of species that are rare in general, as seven species of *Gomphoceras,* two of *Gyroceras,* and no less than nine species of the aberrant *Trochoceras* whose shells are coiled in gastropod fashion and which is known practically only from this formation. To these may be added 16 species of trilobites, among them such monstrous and rare forms as *Lichas* (*Terataspis*) *grandis* Hall and *Lichas* (*Conolichas*) *hispidus* Hall & Clarke. No wonder the Schoharie grit has been the stamping ground of collectors from all over the world, especially in the Schoharie valley and is yet as far as the increasing rarity of the stone fences and of favorable outcrops does not discourage or stop the pursuit.

For the less characteristic shaly limestone beds of the Hudson valley the largest fauna (figures 39, 43), listed below, has been brought together by Chadwick for the Catskill quadrangle area (letter, 1938):

Sponges

Clionolithes radicans Clarke (boring)

Bryozoans

Monotrypa sp. etc.

Brachiopods

Atrypa impressa Hall
Chonetes hemisphericus Hall
Elytha [*Reticularia*] *fimbriata* (Conrad)
Leptaena rhomboidalis (Wilckens)
Lingula cf. *ceryx* Hall
Orbiculoidea sp.
Rhipidomella peloris (Hall)
Schuchertella pandora (Billings)
"Spirifer" macrus Hall
"S." raricosta (Conrad)
Stropheodonta demissa (Conrad)
Strophonella ampla Hall

Gastropods

Orthonychia cf. *arcuata* (Hall)
Platyceras sp.

Cephalopods

Michelinoceras ? [*Orthoceras*] *zeus* (Hall)

Trilobites

Calymene [*Dalmanites*] *calypso* (Hall)
Synphoria anchiops (Hall)

Clarke ('00, p. 14) adds to this list from Becraft mountain the brachiopods *Coelospira* cf. *camilla* Hall and *Eodevonaria* [*Chonetes*] cf. *arcuatus* Hall; the trilobite *Phacops* cf. *bombifrons* Hall.

There are many exposures on the Coxsackie quadrangle where the Schoharie may be studied with its changes from north to south. The maximum thickness has been estimated as between 60 and 70 feet. In the northern part of the area, northwest of Aquetuck it is exposed over larger areas than anywhere else on the quadrangle, spreading out from the broad exposure north and south of the Hannacrois creek in northward trending extensions which in general follow the crests of anticlinal ridges. Three-eighths of a mile south of the northern border, just north of the road fork in the woods back of the farmhouse, the more typical sandy, brownish weathering Schoharie is seen in the hillside under the Onondaga limestone. Just one mile south, beyond the second east-west road, a ridge of Onondaga borders the road on the east and in the vicinity blocks were found 18 and 33 inches in thickness which showed interfingering of

Onondaga limestone with the typical, brownish weathering, sandy Schoharie in bands up to 24 inches in thickness. Other specimens were located farther south and east in this area, and the writer came across loose blocks of the same character while mapping the western part of the quadrangle, at the Ludwig homestead near the road junction on the east side of Indian ridge and in gateposts along the road three-quarters of a mile south of Gayhead. Except for the exposures mentioned the Schoharie of this region is a very siliceous lime rock, of a drab color when fresh and resembling a true limestone, but weathering buff to brownish in color and gritty. The upper two to five feet or more are characterized by chert seams and nodules, white-weathering on long exposure, and only in these beds has the writer found fossils. The siliceous character of the rock continues southward until in the southern portion of the quadrangle upon weathering it has the appearance of a siliceous shaly limestone, sometimes suggesting the New Scotland beds in appearance. Fossils may be seen (and collected with difficulty) in a number of places in these northern outcrops, four of them quite accessible: (1) five-eighths of a mile west of Aquetuck along the road to Coeymans Hollow at the junction with the first road north; (2) one-quarter of a mile west of this on the east side of the northwesterly trending road (to Feura Bush and South Bethlehem), just north of the junction; (3) in a road cut on the east side of this same road one-quarter of a mile northwest; (4) along the brook flowing in the north-south synclinal trough, on the north side of the road, one-quarter of a mile beyond the previous locality. The last-named exposure is characterized by crinoid stems and cup corals. At the third locality mentioned, about 10 feet of Schoharie are exposed from the cut to the brook. The road cut shows about five feet of this thickness, the upper two feet carrying chert nodules and fossiliferous. In this locality, just beneath the Onondaga, surfaces show a *Taonurus*-like worm burrow, more irregular and less compact than the form characterizing the Esopus and Oriskany surfaces. At locality (2) about 10 feet of rather fresh rock are exposed along the road. In the field to the east where it has been scooped up for road material it may be seen as large and small masses of a buff-colored, gritty, rotted rock, packed with chert nodules and lenses in which many of the fossils are found. The fresh exposure along the road has the appearance of a drab-colored fine-grained limestone.

An interesting feature found in the area under discussion deserves mention here. A roughly north-south minor fault crosses the road to Aquetuck just east of the first-mentioned fossil locality, continues across the creek and follows the short lane southward past the farmhouse. On the west side of the lane, Onondaga, with the upper beds quite shattered, dips S. 82° E. at an angle of 48°; on the east side, Schoharie, with practically the same direction and angle of dip, has been raised through the faulting of a small swell or fold. To the south and east of this area, on the south side of the southerly bend in the creek a thickness of about three and a half feet of more typical Schoharie underlies the Onondaga in the cliff.

A 15-foot exposure of Schoharie was found at Aquetuck at the north side of the road under the barn, just west of the junction. Beneath this are exposed about 35 feet of strongly cleaved beds showing numerous *Taonurus*-surfaces (figure 40). These beds, mapped with the Schoharie, have been regarded as uppermost Esopus and recently have been set apart as a new formation (*see* supplementary note). They are also well shown just one mile west on the south side of the Coeymans Hollow road at the junction with the second road north. South of Aquetuck the Schoharie quickly narrows to a ribbon-like belt and continues as such to the area west of Roberts Hill. It soon narrows again, broadening out only in the areas north and south of Limestreet, north and east of Greens lake and in the vicinity of Leeds. One mile south of Aquetuck along the east-west road, the Schoharie may be seen in its relation to the Esopus below and the Onondaga above. The same relationship is well displayed at the Little falls one mile south. The Schoharie is exposed in the stream above the falls. At the four corners southwest of Albrights the Schoharie, with an estimated thickness of 20-23 feet, outcrops on the south side of the junction of the roads to Medway and Roberts Hill, along the edge of the woods. About three-eighths of a mile south, on the west side of the swamp in the woods, there are a number of boulders, apparently not far out of place, showing an interfingering of Schoharie and Onondaga.

West of Roberts Hill the Schoharie broadens out extending south-southwest, roughly parallel with the road leading south to Climax. It may be studied at the falls near the junction with the road to Roberts Hill and one-eighth of a mile east of the junction in the stream bed on the south side of the road. One-quarter of a mile south of this junction the Schoharie, with chert, outcrops just beneath the Onondaga on the west side of the road and again in the ridge to the east. A thickness of at least 35 feet is estimated. Eastward in the ridge the slopes both in the woods and fields are covered with pieces of Schoharie, often cherty, which have weathered quite whitish and very much resemble limestone.

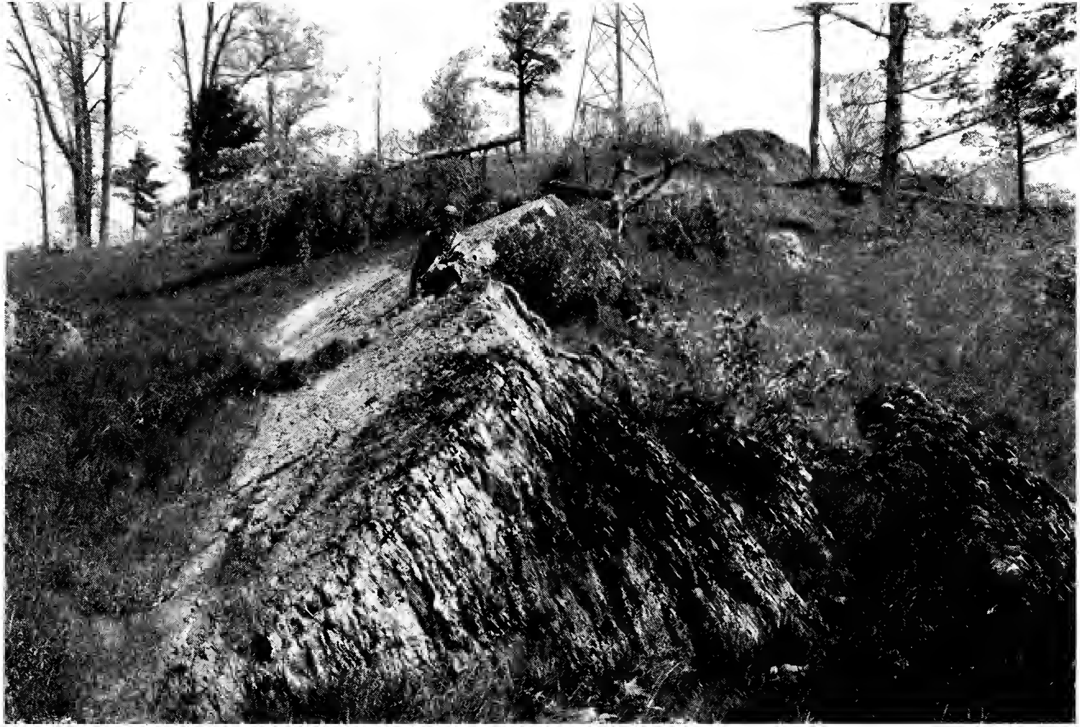

Figure 40 Exposure of Sharon Springs formation on the north side of the road at Aquetuck, view northeast. The figure marks the bedding plane; the cleavage is well shown in the foreground. (Photograph by E. J. Stein)

Three-eighths of a mile west of Climax on the Medway road Schoharie outcrops on both sides of the road with an estimated thickness of 30 feet. A large part of this thickness is exposed again in the falls along the lane three-eighths of a mile south-southeast. The abundance of chert in the upper beds is well displayed. From the cut at the four corners three-quarters of a mile south-southwest of Climax on the Urlton road the Schoharie extends on both sides of the road as far south as Bronks lake and the beds immediately under the Onondaga are well exposed on the west side of the road.

One-quarter of a mile west of Limestreet, toward Hollister lake, the Schoharie through uplift forms a cliff on the east side of a fault which continues south through the Greens Lake region. The beds dip in a northeasterly direction and cleavage and slickensides are well developed. This is part of the east arm of an anticline extending to the south and east. Fossils may be collected along the east side of the road one-quarter of a mile south of Limestreet and again just north of the junction with the Greens Lake road to the south and east of this on the west side of the Greens Lake road. South (one-eighth mile) of the junction with the Limestreet-West Athens road on the east side of the Greens Lake road in the vicinity of the spring there is an estimated thickness of 55 to 60 feet of Schoharie, perhaps more. Fossils are found sparingly in the field to the west in the first ridge.

In the Greens Lake region the Schoharie may be studied along the lake at the east end where it has a very low angle of dip (3° to 4°) and southward along the woods road, with a high angle of dip and good cleavage. Northward from the lake it forms the heart of a pitching anticline with exposures along the lake in the vicinity of Bruggemann's hotel and at the west end. At the southwest corner approximately 45 feet have been measured under the Casino and between 70 and 80 feet have been estimated, in the vicinity. At the Casino the rock where fresh has the appearance of a fine-grained, drab-colored limestone with seams of chert and fossils are sparingly present. Along the road south from the Casino about half a mile south of the lane to Black lake, is an exposure worth study. A thickness of 34 feet is exposed. The beds have weathered whitish buff in color and show two to three-inch chert bands.

At Leeds the Schoharie outcrops for a quarter of a mile to the northeast on both sides of the Athens-Leeds road and is well displayed in the vicinity of the church at the junction with the main street. It is beautifully exposed in the bed of the Catskill west of the mill pool where it is involved with the Onondaga in a domed area or anticline and exposed through erosion. To the east the Schoharie (about 70 feet) crosses the stream at the falls which it forms with a part of the Onondaga. These beds dip S. 45° E. at an angle of 76° and constitute part of the east arm of the pinched synclinal fold that underlies the pool. Here in its upper portion in shaly beds beautiful *Taonurus*-surfaces are exposed.

As indicated above there are a number of places where fossils (*see* figure 43) may be collected. For the quadrangle as a whole the writer has compiled the following list:

Corals

Streptelasma sp.

Crinoids

Large stems

Worms

Taonurus-like burrows

Brachiopods

Atrypa impressa Hall
Chonetes hemisphericus Hall
Elytha [*Reticularia*] *fimbriata* (Conrad)
Leptaena rhomboidalis Wilckens
Lingula sp.
Meristella sp.
Schuchertella pandora (Billings)
"*Spirifer*" *macrus* (Hall)
"*S.*" *raricosta* (Conrad)

Gastropods

Orthonychia sp.
Platyceras dumosum Conrad
P. cf. *undatum* Hall
Stroparollus cf. *clymenoides* Hall

Conularids

Hyolithes sp.

Cephalopods

"*Gyroceras*" sp.
Michelinoceras ? [*Orthoceras*] cf. *zeus* Hall

Trilobites

Synphoria anchiops (Hall)

While mapping the Schoharie formation on the Coxsackie quadrangle the writer, again and again, was impressed with the dissimilarity in character between the beds outcropping in this area and those found in the type area and the Helderberg region. In the Wolf Hill section of the latter area about three feet of a hard siliceous limestone are referred to the Schoharie grit (Ruedemann, '30, p. 60; Goldring, '35, p. 136). Fossils are abundant, particularly cephalopods and corals, and there is an interfingering of Schoharie and Onondaga. In the vicinity of Clarksville on the south side of the Onesquethaw gorge and on the west side of the road three-quarters of a mile south of Callanans Corners (Albany quadrangle) the same conditions were found, with a thickness in the latter locality of six to eight feet (*ref. cit.*). As already pointed out, it was these observations which led Doctor Ruedemann and the writer to consider the Schoharie as a basal, sandy phase of the Onondaga. From the thickness of six to eight feet found south of Callanans Corners, two and a half miles north of the northern boundary of the Coxsackie quadrangle, the more typical, sandy Schoharie has dwindled to a thickness of three and a half feet in the Hannacrois valley, just west of Aquetuck and about three miles south of the northern boundary. The interfingering of the sandy Schoharie phase, however, occurs at least as far south as the vicinity of the four corners south-southwest of Albrights, about six miles south of the northern boundary of the quadrangle.

All these facts have led the writer to the belief that we may be dealing mainly with a formation that does not properly belong with the Schoharie. While rechecking the mapping of his Catskill quadrangle in the fall of 1938, Chadwick found "grit bottoming the Onondaga at a point near Katsbaan plainly distinct from [his] so-called Schoharie beneath it" and wrote (letter, Nov. 30): "While you have been tracing southward across your quadrangle what Grabau and I have called the Schoharie formation, have you had any reason to suspect that it did not exactly correlate with the true Schoharie grit in the Helderbergs?" Whether the grit is gradually replaced by the siliceous limy mudrock which carries some Schoharie fossils in its upper cherty beds and may still be considered as Schoharie or whether the Schoharie grit formation dwindles away southward and a new formation has come in, perhaps in the southern portion of the Albany quadrangle, can only be decided by tracing the Schoharie formation and its relationships from the Helderbergs, through the Hudson valley and southwestward from the Kingston area to Port Jervis, with due consideration given to the fossil content. The writer, while working on the Hamilton beds with Dr G. A. Cooper of the U. S. National Museum in the summer of 1938, had the opportunity of seeing the Schoharie and Esopus in a number of outcrops between Port Jervis and Kingston which only added to the conviction that we were not dealing here and through the Hudson valley with the true Schoharie formation, a conviction shared by Doctor Cooper. For the Catskill quadrangle Chadwick reports a break between the Esopus and the "Schoharie." That there are local breaks between the Esopus and the "Schoharie" there is no question, but the writer has found the Esopus grading up into the "Schoharie" and found it difficult always to draw the boundary. The limy character of the "Schoharie" increases upward and fragments of the higher beds weather whitish, giving the appearance of limestone. We may, therefore, be dealing with two members of a formation instead of two formations. Southwest of Kingston, near Kerhonkson Doctor Cooper and the writer found Esopus grading into "Schoharie" beneath the Onondaga with no break. Beds which Doctor Cooper was inclined to call Esopus, on the basis of the fossils present, would, on the lithologic characters, be the "Schoharie" of our region. In the Port Jervis area beds immediately beneath the Onondaga were "Schoharie" to the writer, as much as any "Schoharie" in the Hudson valley; but on the evidence of the fossils could be placed with the Esopus, even though Onondaga forms already appeared in the upper bed.

In discussing these formations, together with the Onondaga, Kindle ('12, p. 21, 22) writes:

> In the northeastern part of the Helderberg region the Schoharie grit and Esopus shale are readily distinguishable. . . . Farther south, however, the distinctions between these two formations become vague and finally disappear . . .
>
> A very gradual transition of the Esopus shale into the Onondaga limestone at Kingston clearly indicates that the Schoharie is not represented by an unconformity in this region, but has become an integral part of the Esopus.
>
> From the preceding summary of the more important facts concerning the relations of the Onondaga and subjacent formations in southeastern New York it appears that there is no stratigraphic break between either the Onondaga and Esopus or the Esopus and Schoharie. It is probable that sedimentation continued without interruption from the Oriskany into the Onondaga in at least a part of this area.

This is an interesting problem for the future.

Supplementary Note

The writer and Dr Rousseau Flower of Cincinnati University have recently made a detailed study of the Schoharie and Upper Esopus formations, tracing them from the Schoharie Valley region and westward through the Hudson valley and southwestward to Trilobite mountain in the Port Jervis region, Orange county. The Schoharie, best exposed in the Helderberg region of the Capital District, begins to change in character near the southern border of the Albany quadrangle and in the northern part of the Coxsackie quadrangle, where in a thickness of 15 to 20 feet, the upper three feet is fairly typical Schoharie, the next 5 to 10 feet a siliceous, limy mudrock with bands of chert nodules, the basal 7 feet a massive, unfossiliferous grit. The Schoharie, thickening southward, loses the typical lithology entirely and becomes a shaly limestone with chert seams in the upper portion. Nevertheless there is no question that it is Schoharie. At Leeds on the southern border of the Coxsackie quadrangle, there are 55 feet of the Schoharie typical of the Hudson valley and above this 17 feet of transitional beds showing bands of dark blue, fine-grained limestone interbedded with bands of siliceous, shaly limestone. For this facies of the Schoharie in the Hudson valley the writer and Doctor Flower in a recent paper ('42) have proposed the name

Leeds facies. In Becraft mountain the thickness of the Schoharie has been found to be the same as that for the Catskill quadrangle area, no more than 80 feet. The Schoharie thickness is included in the estimate for the Esopus in the Kingston area, whence its thickness steadily increases southwestward to Trilobite mountain where between 215 and 235 feet are estimated. Here the Schoharie proves to be represented in those beds previously identified as basal Onondaga (Shimer, '05).

A study of the Esopus immediately beneath the Schoharie was made because there was a question whether these beds belonged to the Schoharie, to the Esopus, or might constitute a separate formation. In an abandoned quarry just east of Cobleskill along the Carlisle Center road the upper beds of the "Esopus" were found to be separated from the Schoharie by about three inches of glauconite; and in a cut along the state road three miles west of Sharon Springs these beds are separated from the softer, blocky-breaking Esopus below by another three-inch layer of glauconite. This upper hard bed, at least 20 feet thick in this region, is drab-colored when fresh but weathers buff colored. It is composed of extremely thin-bedded siliceous shale, breaking platy, and with the surfaces closely covered with *Taonurus*. The softer less siliceous Esopus beds beneath do not carry the *Taonurus*. The lower cherty beds of the Esopus in the Hudson valley carry the *Taonurus* though less abundantly, but they do not break in the large, thin, platy pieces and weather differently. This hard bed has likewise been traced through the Hudson valley to Port Jervis. It is very characteristic and can be readily distinguished, constituting a prominent topographic feature. To this hard bed Goldring and Flower (*ref. cit.*) have given the name *Sharon Springs formation.* Like the Schoharie and the Esopus, *sensu stricto,* this formation thickens through the Hudson valley and southwestward. Here there is a transition between the Esopus and the Sharon Springs and again between the latter and the Schoharie. The Sharon Springs thickens to a little over 100 feet just north of Kingston and to 200± feet in the Port Jervis area (Trilobite mountain).

On the geological map of the Coxsackie quadrangle, the Sharon Springs formation, with a thickness in the northern part of the sheet of about 35 feet (see figure 40) and in the Leeds gorge of about 75 feet, is largely included with the Schoharie formation, and is particularly noticeable where this area broadens out east of Coeymans Hollow, west of Roberts Hill, southeast of Greens lake and south of Limestreet.

Onondaga Limestone

The Onondaga limestone derived its name (Hall, '39) from its occurrence in Onondaga county. It has a wide distribution, extending with a very uniform character of rock and fauna from New Jersey in the southeast across the State into Ontario, Canada, and in this respect it far surpasses all the other Helderberg formations. The names "Onondaga" (Hall), "Corniferous" (Eaton) and "Seneca" (Vanuxem) were applied in western New York by geologists of the first survey to the divisions of the formation, all now included under the present name, proposed by Hall. The cherty division was known as the "Corniferous" and the purer upper limestone as the "Seneca."

This is the third and uppermost of the Helderberg limestones, often forming cliffs or terraces, strikingly displayed in the Helderberg mountains where it forms the second great cliff of the Helderberg escarpment, more interrupted than the one below formed by the Coeymans-Manlius limestones. Terraces, sometimes extensive, are developed upon the Onondaga where the softer overlying black shales of the Marcellus formation (Hamilton) have been extensively eroded away. It is a moderately pure limestone of light bluish color, weathering whitish, generally massive but often thinly bedded in the lower portion. It is also characterized by lenses of black chert that occur in parallel layers. The uppermost beds ("Seneca") are free from chert and also the lowest beds (*see* Goldring, '35, p. 140); but the lenses are very irregular in distribution and have been found to be abundant in some places, sparse in others. They may be seen whereever the upper beds of the formation outcrop, but quarries usually offer the best opportunity for study. In the Helderberg region (*ref. cit.*) the chert bands have been found bordered by a black calcite, with interfingering of the two, both of which are considered of secondary origin.

Like the other Helderberg limestones (Coeymans and Becraft) the Onondaga is characterized everywhere by a well-developed system of joint fissures which produce blocks that break away along the vertical joints, tending to produce cliffs. Through solution the fissures are broadened and deepened and underground drainage is developed. Caves and sinkholes are characteristic, the latter formed by surface cave-ins. Such phenomena developed in limestone regions are known as "karst phenomena" from their occurrence in the Karst region of the Dalmatian Alps along the eastern coast of the Adriatic.

The Onondaga limestone has an east-west extension of over a thousand miles, reaching into southwestern Illinois, and the southern extension (New York to Tennessee) is comparable (Kindle, '12, p. 5, 6). In the western part of New York State the maximum thickness of the Onondaga varies between 150 and 200 feet; 95 feet were measured by Prosser at East Cobleskill and 100 feet by Grabau ('06, p. 193, 254) for the Schoharie region (Dann's hill 105 feet). The thickness in the northern Helderberg area (Goldring, '35, p. 143; Prosser and Rowe, '99, p. 336, 347) is 85 to 100 feet, but from this area southward to the Kingston region (Ulster county) it thins somewhat. Darton ('94, p. 396; table; 94*b*, p. 491) gives the thickness as about 90 feet for Greene county and 60 feet for Ulster county, with an enormous thickening in northern New Jersey (400± feet). Chadwick, for the Catskill quadrangle has estimated a thickness of 80 feet (personal communication). Van Ingen and Clark ('03, p. 1180, 1205) found 70 to 75 feet in the Kingston area, with the lower 40 feet an impure limestone and the purer upper portion characterized by considerable black chert. For Trilobite mountain, Port Jervis region (Orange county), Shimer gives a thickness of 235 feet for the Onondaga ('05, p. 192, 193; White, 1882: 250 feet for Port Jervis). Of this thickness about 200 feet were laid down before the deposition of "the typical heavy bedded limestone usually associated with the formation." The lowest beds are arenaceous shales which "except for the fossils would be placed in the Esopus," between which and the Onondaga there is a very gradual transition. Above these first 30 feet are over a hundred feet of calcareous shales with thin limestone bands, more frequent near the top; these in turn followed by 40 to 50 feet of "limestone and calcareous shale beds . . . about equal in number and thickness" before the heavy limestone with thin shale seams appears. (*See* supplementary note, page 224.)

Kindle has fully discussed the unconformity at the base of the Onondaga limestone and part of this discussion ('13, p. 302, 303) is pertinent here:

The unconformity at the base of the Onondaga though widely extended seems not to have been universal in eastern New York. In southeastern New York there appears to have been no interruption between the Esopus-Schoharie epoch of sedimentation and that of the Onondaga limestone. . . . There is, too, more resemblance between the fauna of the Onondaga and that of the preceding fine siliceous sediments than could be expected if a physical break had intervened between the periods of their deposition.

While in southeastern New York it appears that the Onondaga limestone sedimentation followed Schoharie sedimentation without interruption of marine conditions, in central and in a portion of eastern New York the evidence is conclusive that the Onondaga limestone was deposited over an extensive area which was submerged shortly before its deposition. . . . In the east-central New York region the Onondaga limestone rests upon an old eroded land surface composed sometimes of the Oriskany sandstone, but more frequently of limestone of the Helderberg group. The basal beds of the Onondaga if followed westward across New York are seen to rest successively on conformable Schoharie in southeastern New York, disconformable Oriskany sandstone and limestone of the Helderberg group and finally upon Silurian strata in the western part of the state.

Willard ('36, p. 581) defines the Onondaga formation in Pennsylvania as including "all stratigraphic units between the overlying Marcellus and the underlying Oriskany formations. It is faunally and lithologically closely allied with the Hamilton group and is quite distinct from the Oriskany." His proposal to include the Onondaga in the Hamilton group was dropped in his more recent publication on the Middle Devonian of Pennsylvania ('39, p. 142ff). In eastern Pennsylvania about 200 feet of cherty limestone rest upon 250 feet of Esopus shale; in central Pennsylvania a maximum of 65 feet of noncherty limestone rests upon 100 to 150 feet of limy shale into which it grades downward ('36, p. 583-90). Of the correlations he writes (p. 593):

Everywhere the Onondaga is succeeded by the Marcellus black shale through a normally transitional contact which may become disconformable locally. Studies of the Marcellus, except where it is incomplete, show its base to be essentially synchronous throughout. Below, the Onondaga limy shale and the Esopus shale are in disconformity with the Oriskany. [*See* page 205.]

The largest Onondaga fauna listed for any area in eastern New York is that published by Grabau ('06, p. 328, 329) for the Schoharie region. It includes:

Corals

Cyathophyllum robustum Hall
Favosites basalticus Goldfuss
F. epidermatus Rominger
F. hemisphericus distortus Hall
Zaphrentis prolifica Billings

Bryozoans

Monotrypa tabulata (Hall)
Ptiloporina pinnata (H. & S.)
Thamniscus multiramus Hall

Brachiopods

Amphigenia elongata (Vanuxem)
Athyris spiriferoides (Eaton)
Atrypa reticularis (Linnaeus)
A. pseudomarginalis Hall
Coelospira camilla Hall
Cyrtina hamiltonensis Hall
Elytha [*Reticularia*] *fimbriata* (Conrad)
Leptaena rhomboidalis (Wilckens)
Meristella nasuta (Conrad)
Pentagonia unisulcata (Conrad)
Pentamerella arata (Conrad)
Productella navicella Hall
Schuchertella pandora (Billings)
"*Spirifer*" (*Paraspirifer*) *acuminatus* (Conrad)
"*S.*" *divaricatus* Hall
"*S.*" *duodenarius* (Hall)
"*S.*" *raricosta* Conrad
Stropheodonta hemispherica Hall
S. inaequiradiata Hall
S. patersoni Hall
Strophonella ampla Hall

Pelecypods

Aviculopecten pectiniformis (Conrad)

Gastropods

Diaphorostoma lineatum (Conrad)
D. turbinatum (Hall)
D. unisulcatum (Conrad)
Euomphalus decewi Billings
Phanerotinus laxus Hall
Platyceras crassum Hall
P. dumosum Conrad
P. nodosum Conrad
P. undatum Hall

Pteropods

Tentaculites scalariformis Hall

Cephalopods

Halloceras [*Gyroceras*] *matheri* (Conrad)
H. [*G.*] *paucinodum* (Hall)
H. [*G.*] *undulatum* (Vanuxem)
Ryticeras [*Cyrtoceras*] *citum* (Hall)
R. [*C.*] *eugenium* (Hall)
R. [*C.*] *jasoni* (Hall)
R. [*Gyroceras*] *trivolve* (Conrad)

Trilobites

Ceratolichas [*Lichas*] *dracon* (H. & C.)
C. [*L.*] *gryps* (H. & C.)
Conolichas [*Lichas*] *eriopis* Hall
Dalmanites (*Coronura*) *diurus* (Green)
D. (*C.?*) *macrops* Hall
D. (*C.*) *myrmecophorus* (Green)
Odontocephalus selenurus (Eaton)
Proetus clarus Hall
P. folliceps (H. & C.)
Synphoria [*Dalmanites*] *calypso* (Hall)

For Orange county (Port Jervis region) Shimer has published ('05, p. 262-68) a list of 19 species, consisting of four corals, 12 brachiopods, one gastropod and two trilobites. Van Ingen and Clark ('03, p. 1205) list only a few of the common forms for the Kingston area. From the Helderberg region of the Capital District, to the north of our area, 38 Onondaga species have been collected (Goldring, '35, p. 148; Prosser & Rowe, '99, p. 352):

Corals

Cyathophyllum sp.
Eridophyllum sp.
Favosites basalticus Goldfuss
F. epidermatus Rominger
F. cf. *helderbergiae* Hall
Syringopora sp.
Zaphrentis corniculum (LeSueur)
Z. gigantea (LeSueur)
Z. prolifica Billings

Crinoids

Stem joints

Bryozoans

Fenestella biseriata Hall

Brachiopods

Atrypa reticularis (Linnaeus)
A. cf. *spinosa* Hall
Leptaena rhomboidalis (Wilckens)
Meristella nasuta (Conrad)
M. sp.
"Orthothetes" sp.
Pentamerella arata (Conrad)
Pentagonia unisulcata (Conrad)
"Spirifer" divaricatus Hall
"S." duodenarius (Hall)
"S." macrus Hall ?
"S." raricosta Conrad
"S." varicosus Hall
Stropheodonta concava Hall
S. hemispherica Hall
S. inaequiradiata Hall
S. cf. *patersoni* Hall
S. textilis Hall

Pelecypods

Pterinea sp.

Gastropods

Diaphorostoma cf. *lineatum* (Conrad)
Diaphorostoma sp.
Euomphalus decewi Billings
Platyceras dumosum Conrad

Cephalopods

"Cyrtoceras" sp.
Halloceras [*Gyroceras*] *paucinodum* Hall

Trilobites

Dalmanites sp.
Proetus cf. *clarus* Hall
Proetus sp.
Synphoria [*Dalmanites*] cf. *anchiops* (Hall)

From the Catskill area to the south of our quadrangle Chadwick has collected (letter, fall 1938) three corals, various bryozoans, 10 brachiopods, two gastropods, two trilobites, and a fish tooth (*Ony-*

chodus sigmoides Newberry). Species additional to the lists given above are the corals *Favosites emmonsi* Rominger, *Striatopora cavernosa* Rominger and *Synaptophyllum simcoense* Billings, various forms of bryozoans (unnamed); the brachiopods *Chonetes lineatus* Conrad?, *Schuchertella pandora* (Billings) and *Schizophoria propinqua* (Hall); and the trilobite *Phacops cristata* Hall. Additional species from Shimer's list are the corals *Blothrophyllum promissum* Hall, *Ceratopora* sp. and *Favosites sphaericus* Hall; the brachiopods *Anoplotheca* [*Leptocoelia*] *acutiplicata* (Conrad), *A. concava* (Hall), *A. grabaui* (Shimer), *Chonetes hemisphericus* Hall?, *C. yandellanus* Hall, *Levenea* [*Dalmanella*] *subcarinata* (Hall)?, *Eatonia medialis* (Vanuxem); the gastropod *Loxonema* sp., and the trilobite *Phacops pipa* H. & C.

The Onondaga fauna is characterized by corals, numbers of individuals rather than species, and to a considerable extent the limestone has been formed by coral reefs. Such reefs may be seen well developed in the western part of the State and coral stocks from one of these reefs in the vicinity of LeRoy, south of Rochester, have been used in the restoration of a portion of a reef in the State Museum. In the Thompsons Lake region of the Helderbergs (Capital District), reef rock with corals is well shown at the boat landing near the hotel and in the cliffs to the south. There is a very rich fauna here, including such coral genera as *Zaphrentis, Cyathophyllum, Syringopora, Eridophyllum* etc. (Goldring, '35, p. 147). In the bulletin on the Capital District, Ruedemann ('30, p. 65) in his discussion of the fauna and coral reef origin of the Onondaga limestone states:

The abundance of the corals and the purity of the limestone indicate that the Onondaga sea offered very congenial conditions for coral growth and marine life in general in this region. Grabau ('06, p. 328) extracted a list of 57 species for the Onondaga limestone of the Schoharie region. . . . While numerically the brachiopod species prevail, in individuals the corals are the most prominent element of the fauna. . . . Among the brachiopods very large forms as *Stropheodonta hemispherica, Spirifer divaricatus* and the index fossil of the Onondaga, *Amphigenia elongata,* testify to the favorable life conditions. The pelecypods, which, as a rule, prefer muddy bottoms, are little represented. Among the gastropods we find again large and strikingly spinose forms as *Platyceras dumosum,* which is represented in the case of restorations of Helderberg life in the State Museum. The cephalopods show, in distinction to the prevailingly straight form (Orthoceras) of the Schoharie grit, curved (Cyrtoceras) or involute forms (Gyroceras); and also the trilobites have afforded peculiarly spinose (*Conolichas eriopis, Ceratolichas gryps, C. dragon*) forms and the largest known representative of the genus *Dalmanites* (*D. myrmecophorus*), all facts which point to an extremely rich invertebrate life. Besides remains of fish have also been obtained in the Onondaga limestone.

In the northern quarter of the Coxsackie quadrangle the Onondaga spreads over a belt one-half mile to one mile wide. About a mile south-southwest of Aquetuck this belt narrows to a width of a quarter of a mile (or less) which it maintains southward with a slight broadening just south of Limestreet and in the vicinity of Leeds. The wider northern part of the Onondaga belt, particularly south of the Aquetuck-Coeymans Hollow road has numerous outcrops and is characterized by roughly north-south trending small swells or anticlines. These are well-shown one-half mile east of the Coeymans Hollow four corners and along the road running south-southeast from School No. 16, particularly that portion of the road south of the county line which follows close to the Hamilton slopes. Interfingering with the Schoharie in this area, as well as to the south, has been noted under the discussion of that formation (*see* pages 212, 216) ; also, the minor fault five-eighths of a mile west of Aquetuck which separates the Onondaga and Schoharie along the farm lane. Attention might be called to a few other exposures. One-quarter of a mile south of the northern boundary, in the hill north of School No. 11, the Onondaga is exposed in the west arm of an anticlinal fold. Numerous black chert bands and cup corals characterize the limestone here. Just north of the second road junction to the south and east a cliff of Onondaga in the woods back of the farmhouse displays large heads of such colonial forms of coral as *Eridophyllum* and *Syringopora*. At a point one mile farther south a road turns almost due west. Near this junction, in the lowest beds of the Onondaga, the rock is decidedly gray in tone, finely crystalline and carries a noticeable amount of gray chert. Three-eighths of a mile west, near the sharp bend to the south collecting proved quite profitable because the rock was broken up in the course of road work. Here the limestone is a decided blue-gray in color and is characterized by black chert bands, two to six inches thick. Three-quarters of a mile south and east of the above junction and north-northwest of the junction with the Coeymans Hollow road, a spur of Onondaga limestone extends northward. This is a small anticlinal ridge, complicated by a small thrust that is emphasized by the presence of chert bands. These characteristic black bands are well exposed and numerous in outcrops on the south side of the Coeymans Hollow road west of School No. 16. One of these exposures, in a quarry, shows a three-foot massive bed of chert. Across the road from the schoolhouse an 18-foot cliff face in a quarry exposes practically chert-free limestone.

Very interesting exposures may be studied along the road leading south to Climax from the junction with the Roberts Hill-Medway road. One-quarter of a mile south of the junction the lowest Onondaga is exposed and its contact with the Schoharie. This basal Onondaga is light gray in color and shows numerous specimens of cup corals and heads of *Favosites*. Less than a quarter of a mile beyond this, along the woods on the east side a road cut exposes a three-foot reef bed packed with corals, striking among which are a large species of *Cyathophyllum* and huge heads of *Favosites*. There is a fair representation of other species here and in a quarry about half a mile south on the west side of the road. One-half mile north of the junction of this road with the Climax-Medway road a 20-foot cliff with black chert is exposed on the west side of the road, a 30-foot cliff on the east side over the ridge. Chert bands are particularly numerous, varying in width from two inches to six inches and very close together. Weathered surfaces of enormous loose blocks (figure 41) display these bands to advantage.

The relations with the Schoharie at the fault just west of Limestreet have been discussed above (page 221). Good slickensides in the Onondaga in the vicinity of the fault may be seen along the more northern of the two roads leading westward from Limestreet.

Interesting exposures of Onondaga may be seen on the east side of the road to Greens lake south of the junction with the Limestreet-West Athens road. At the spring, three-sixteenths of a mile from the junction, the Onondaga dips almost due west (S. 83° W.) at an angle of 68°. These steeply dipping beds continue southward along the east side of the road for about three-quarters of a mile, separated by a fault from the beds to the west which form the east arm of an anticline. At the bend just south of the spring a minor fault, roughly following the road, cuts off a "splinter" of Onondaga in which the beds are much crumpled and dip N. 78° E. toward the steeply inclined beds at angles of 38°-48°.

A similar interesting exposure of Onondaga occurs at the southeast end of Greens lake and extends southward. This is another "splinter" of Onondaga cut off by minor faults. To the west the beds dip N. 67° W. at an angle of 12°. In the "splinter" the beds stand at an angle of 84°, dipping from S. 86° W. to N. 84° W., and form a narrow ridge 50 to 75 feet wide.

One of the most interesting and picturesque exposures of Onondaga in the area covered by the Coxsackie quadrangle is that in the vicinity of Leeds along the Catskill. The millpond is located in a pinched syncline in the Onondaga. At the falls the beds dip S. 57° E.

Figure 41 Joint block of Onondaga limestone showing numerous chert bands. Along the east side of a north-south road one mile north-northwest of Climax. (Photograph by E. J. Stein)

Figure 42 Glaciated ledge of Onondaga limestone which shows well the massive character of the beds. Along the east side of the Greens Lake-Leeds road about one and one-half miles south of the lake. (Photograph by E. J. Stein)

at an angle of 76°. At the "narrows" at the western side of the pond the beds dip S. 62° E. at an angle of 72°. Above the "narrows" an opened-up dome or anticline in the Onondaga (figure 56) has exposed the Schoharie in the bed of the stream. The domed Onondaga beds are beautifully displayed in the hill on the south side of the stream where at least 65 feet are exposed. At the "narrows" there is an estimated thickness of 92 feet, which may not represent the total thickness here. About an eighth of a mile upstream from this point the Onondaga crosses the stream again and is so full of chert bands that the rock resembles a mass of chert. The lowest 30 feet in this area show a great abundance of chert, particularly where weathered. Interfingering of Schoharie and Onondaga is seen at the falls, with bands of Onondaga two to six inches thick appearing in the uppermost Schoharie.

Fossils are difficult to collect in the Onondaga. The best collections have been made where the rock has been broken up in connection with road-building and some of these localities have been noted above. The total fauna (figure 43) compiled for the area is as follows:

Corals

Ceratopora sp.
Cyathophyllum cf. *robustum* Hall
Cystiphyllum vesiculosum Goldfuss
Eridophyllum sp.
Favosites basalticus Goldfuss
F. emmonsi Rominger
Streptelasma (*Enterolasma*) cf. *rectum* Hall
Striatopora sp.
Synaptophyllum simcoense Billings
Zaphrentis prolifica Billings ?

Crinoids

Joints and stems

Bryozoans

Fenestella cf. *biseriata* Hall
F. sp. (several species)

Brachiopods

Amphigenia elongata (Vanuxem)
Atrypa reticularis (Linnaeus)
A. spinosa Hall
Camarotoechia sp.
Coelospira camilla Hall
Leptaena rhomboidalis (Wilckens)
Meristella sp.
Rhynchotreta sp.
"Spirifer" divaricatus Hall
"S." duodenarius (Hall)
"S." macrus Hall
"S." raricosta Conrad
Stropheodonta concava Hall
S. sp.
Strophonella ampla Hall

Pelecypods

Cypricardella cf. *complanata* Hall

Gastropods

Diaphorostoma lineatum (Conrad)
Diaphorostoma sp.
Euomphalus decewi (Billings)
Platyceras dumosum Conrad

Cephalopods

Ryticeras [*Gyroceras*] *trivolve* (Conrad)

Trilobites

Dalmanites sp.
Odontocephalus selenurus (Eaton)
Phacops cf. *cristata* Hall
Synphoria cf. *anchiops* (Hall)

Hamilton Beds

The Hamilton shales and flags, constituting the rock of the western half of the Coxsackie quadrangle, received their name from typical exposures at West Hamilton, Madison county (Vanuxem, '40). In

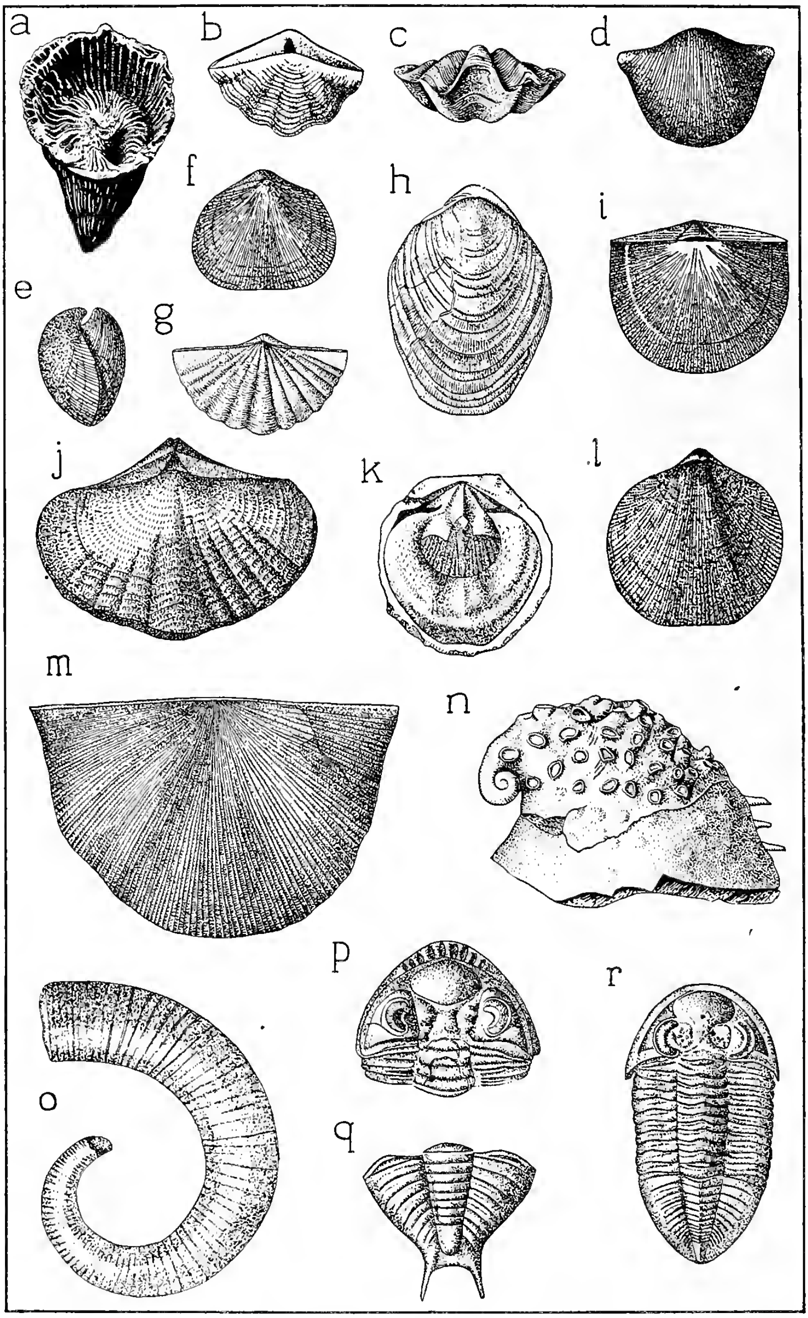

Figure 43 Schoharie and Onondaga limestone fossils. (Coral, *a;* brachiopods, *b-m;* gastropod, *n;* cephalopod, *o;* trilobites, *p-r.*) *a Zaphrentis prolifica,* x ½. *b, c "Spirifer" raricosta,* x ¾. *d Chonetes hemisphericus,* x ¾. *e, f Schizophoria propinqua,* x ¾. *g "Spirifer" duodenarius,* x ¾. *h Amphigenia elongata,* x ½. *i Schuchertella pandora,* x ¾. *j Elytha fimbriata. k, l Atrypa impressa,* x ¾. *m Strophonella ampla,* x ¾. *n Platyceras dumosum,* x ¾. *o Ryticeras trivolve,* x ⅓. *p, q Odontocephalus selenurus,* x ¾. *r Calymene calypso,* x ½.

the western part of the State the Hamilton beds are represented by black shales, calcareous shales and sandstones, in the east by sandstones and arenaceous shales, and on the whole they are richly fossiliferous. These beds form a thick wedge of clastic materials which thin westward, accompanied by numerous shifts or facies both in the character of the rock and the fauna. In the final reports of the early geologists the Hamilton beds included, in ascending order, the Skaneateles shale, Olive shale, Ludlowville shale, Encrinal limestone and the Moscow shale. In Dana's "Manual" the term was enlarged to include the Marcellus shale at the bottom and the Tully limestone at the top. Until the recent studies of Cooper which revealed the need for revision of the Hamilton, the term has been used to include everything between the Cardiff (upper Marcellus) shale and the Tully limestone, that is, the Skaneateles, Ludlowville and Moscow formations. For details of the revision the reader is referred to Cooper's paper ('30). He points out that

. . . the black muds of the Marcellus, often affiliated with the Onondaga, thicken eastward and are gradually replaced by gray arenaceous shale. Concordantly the Marcellus fauna grades eastward into one of Hamilton aspect. These phenomena have made it necessary to place the Marcellus formation in the Hamilton group, which, therefore, now consists in ascending order of the Marcellus, Skaneateles, Ludlowville and Moscow formations. The Skaneateles formation and several members in the higher formations show a similar westward shift of faunal facies from one of Hamilton aspect in the east to a modified Marcellus fauna in the west ('29; Geol. Soc. meeting abstract).

In the East the formation boundaries can not all be distinguished (*see* Cooper, '33, '34). Cooper has traced all formations from "their type sections in central and western New York into Chenango valley, type section for the group"; but east of this in the Unadilla valley and eastward it was found impossible to separate the Skaneateles from the Ludlowville and east of the Unadilla valley the Marcellus could not be separated from the Skaneateles ('33, p. 543). As pointed out by Cooper (*ref. cit.*),

This circumstance is due to failure of the delimiting members of the formations to retain their characteristic lithological features east of the type section, but on faunal evidence it is possible, in all sections studied, to say where the dividing lines of each formation are located . . . Owing to the persistence of the Portland Point lithology and fauna the base of the Moscow was recognized in all of the eastern New York sections.

The Hamilton of the Schoharie and Hudson valleys was partially known through the writings of Prosser ('99, '00; with Rowe '99), Grabau ('06, '19) and Darton ('94*a*, '94*b*). In the Schoharie valley were identified the Marcellus black shale, Hamilton shales, "Sherburne" and "Ithaca" beds, rocks of the last two groups now proving to be of Hamilton age. In his more recent studies ('33, '34), Cooper recognized in this region the Union Springs (70 feet), Cherry Valley (16 feet?) and the Chittenango (185 feet) members of the Marcellus formation. To the part of the Marcellus included between the *Meristella bed* and the top of the *Athyris zone* Cooper has given the name *Otsego member* (from the type section at Otsego lake, 256 feet thick), which in the Schoharie valley has a thickness of 385 feet, in the Helderbergs (Berne quadrangle) 505 feet. That portion of the Hamilton beds of the Schoharie region between the top of the Otsego member and the Portland Point or basal Moscow, which includes shales and sandstones of the upper part of the Marcellus, the Skaneateles and the Ludlowville which can not be separated lithologically, has been named by Cooper the *Panther Mountain shale* and *sandstone* (1303 feet thick). For convenience Cooper proposed that the name also be used in the Susquehanna (830 feet), Cherry and Unadilla valleys. In the Schoharie valley fingers of continental beds (reds and greens) occur at several levels in the Panther Mountain member. The Portland Point member has been located on the Durham quadrangle in the vicinity of Potter hollow (Greene county) which gives an estimated thickness of 1400 to 1500 feet, mostly red beds, for the Berne-Durham quadrangle. For the region east of Schoharie Cooper proposed the name *Berne member* for the shale interval between the Onondaga limestone and the Otsego member (282 feet near East Berne) an interval considered the equivalent of the Union Springs, Cherry Valley and Chittenango members of the Marcellus formation. Recent work (Cooper & Goldring, in field 1938) has shown the presence of the Cherry Valley or Cherry Valley equivalent in the Helderbergs (Berne and Albany quadrangles) and southward, necessitating a redefinition (Cooper on page 249) of the Berne member and reduction of its thickness by 170 to 180 feet (*see* Cooper, '33, p. 545-51. Goldring, '31, p. 386-96; '35, p. 186-92). In earlier reports (Prosser '99, p. 190; Grabau, '06, p. 213), because the upper part of the Hamilton beds was erroneously identified as Sherburne and Ithaca, their thickness was estimated as 1685 feet. Cooper gives the thickness for the Moscow of the Schoharie region as 519 feet, which added to his other measurements gives a total thickness of about 2500 feet for the Hamilton. The estimated thickness of the Hamilton beds for the Berne-Durham quadrangles, exclusive of the Moscow, is 2385 feet, which even with no increase in the thickness of that formation east of the Schoharie valley would give a total thickness of about 3000 feet for this region.

In the Hudson valley, Ulster and Green counties, the Hamilton beds above the "Marcellus black shale" (Bakoven) have been separated into three divisions. The lowest division includes the fossiliferous marine beds, designated as the *Mount Marion beds;* above these are nonmarine, nonfossiliferous, flagstone-bearing beds, the *Ashokan shales* and *flags,* and at the top are the Hamilton "reds," of continental origin, known as the *Kiskatom beds.* These divisions and the Bakoven shale are discussed below. Two other names have been given to beds of Hamilton age. The *Cornwall shale* (Hartnagel '07; for Darton's "Monroe shale") was named from exposures found in the town of Cornwall, Orange county. These shales. which extend through the town of Monroe into New Jersey, have a thickness of 200 feet and carry fossils indicative of Hamilton age. In his recent work on the Devonian of Pennsylvania Willard places these beds in the Onondaga group ('39, p. 138). Also occurring in Orange county and New Jersey is the *Bellvale shale* (Darton, '94) which overlies the Cornwall shale, with a thickness of 1300 to 2000 feet. The plant remains found in these beds indicate Middle Devonian age, with the upper beds perhaps as late as "Portage." The name was derived from Bellvale mountain, Orange county. These shales are considered by Willard and Cleaves ('33, p. 761) to be of the same age as the Marcellus. In the Green Pond Mountain section of New Jersey they have a combined thickness of 2300 feet (*ref. cit.*).

In their paper on the Hamilton of eastern Pennsylvania, Willard and Cleaves ('33, p. 758; *see* Willard '35, '37, '39) give a "maximum thickness of at least 2300 feet . . . in northern New Jersey, with only part of the group known to be present. From there it diminishes to nearly 1500 feet in Perry county." In the Brodhead Creek Valley section from Stroudsburg northward, where all Hamilton formations are recognized, a total of 2234 feet is recorded (*ref. cit.* p. 761-63). The writer was in the field with Doctor Cooper through the summer of 1938, tracing the Hamilton beds from Port Jervis (Orange county) to Kingston, northward through the Hudson valley and westward. For the Port Jervis region Cooper made a rough estimate of about 2400 feet for the total thickness of the Hamilton.

In the vicinity of Napanoch, Ulster county (Ellenville quadrangle), along the Rondout creek (west), Cooper estimated a thickness of 3150 feet (highest estimate no more than 3300 feet) from the top of the Onondaga limestone to the *Rhipidothyris* bed which he located above the powerhouse at Honk falls, marking the top of the Hamilton. A thickening was expected northward with the maximum to be found in the Catskill front in the Hudson valley, but north of Napanoch no fossils were found marking the top of the Hamilton. For the Catskill region Chadwick (personal communication) estimates 3800 feet between the top of the Onondaga and the base of the heavy conglomerate bed which he regards as the base of the Upper Devonian (Geneseo), with the upper 300 feet of heavy sandstones considered the Tully equivalent, thus giving 3500 feet for the Hamilton including the Bakoven shale. Cooper's estimates at the time, made on dips and rate of thickening to the south and west, were slightly lower, a negligible amount. His figures would give a thickness of about 2500 feet for the Hamilton above the Mount Marion beds.[1] The thickness of the Hamilton beds is thus found to have increased enormously eastward, from 285 feet at Lake Erie to 1115 feet in Onondaga county (Cooper, '30, p. 121), 2450 feet in the Schoharie Valley section (*auth. cit.*, '33, p. 540) and between 3000 and 3500 feet in the Catskill front, by far the larger portion of continental origin.

Bakoven shale. This name was given by Chadwick ('33, p. 483) to "the black shale heretofore passing as 'Marcellus,' below the Mount Marion formation, since it [remained] unidentified by Doctor Cooper with any of his Hamilton units . . ." It is derived "from the local Dutch name of the valley it produces, with its type section (partial) where the Catskill-Palenville road crosses the Kaaters Kill." The "Marcellus black shale" typically is a black bituminous, pyritiferous, very fissile shale, which is also characterized by the presence, through certain portions, of numerous concretions of carbonate of lime arranged in layers or scattered. Concretions have been found varying in size from a few inches to several feet in diameter and are most abundant in the upper portion.

Grabau for the Schoharie region ('06, p. 206) recorded 180 feet of black, fissile shale. Cooper's work ('33, p. 546) has shown that the Chittenango shale, in large part, is included in this figure. The "black" shale as here used refers to that shale between the top of the Onondaga and the Cherry Valley limestone, the Union Springs member of the Marcellus formation or its equivalent. At Cherry Valley the Union Springs is 35 to 40 feet thick; at Cobleskill there are 60 to 70 feet and in the Schoharie region about 70 feet. Eastward

[1] In a recent paper Cooper (1941, p. 1893) has estimated the thickness of the Hamilton as 2600 feet at Port Jervis, 3200 feet at Napanoch, 4000 feet or more at Catskill, "which means that most of the mountain front west of Catskill is of Hamilton age."

from the Schoharie valley Cardiff lithology appears in this member and in the Helderbergs there is an interfingering of black and gray shales (Goldring, '35, p. 158, 186). Darton ('94*b*) in his Preliminary Report on the Geology of Albany County divides the beds between the Onondaga limestone and the continental red beds into the Hamilton black shales (lower 600 feet) and the Hamilton flags and shales. Prosser and Rowe ('99, p. 335) made no attempt to separate these beds in their Countryman Hill section (Helderbergs); in the Clarksville-Onesquethaw Creek section (*ref. cit.* p. 346) 300+ feet were designated as Marcellus shales and above these beds were the "Hamilton shales." These divisions were used by Ruedemann ('30) in his Capital District bulletin. Prosser ('00, p. 56) assigned 170 feet to the Marcellus black shale in the Indian Ladder section (Helderbergs), and the writer found a thickness of 170 to 180 feet here and elsewhere on the Berne quadrangle and in the Onesquethaw Creek-Wolf Hill section of the Albany quadrangle (*ref. cit.*, p. 152).

In the Hudson valley (Catskill region) Chadwick has found 140 to 200 feet of his Bakoven shale member (conversation in field), which forms the Bakoven valley between the Kalkberg range (Onondaga limestone at top) and the hill range composed of the Hamilton shale and sandstone. When this name was assigned to these beds there was still doubt as to whether they represented only the so-called "black Marcellus shale" of the Helderberg area or included some of the Cardiff shale above. In the summer of 1938 Doctor Cooper and the writer visited, with Chadwick, several exposures of the Bakoven shale on the Catskill quadrangle. It was found, as already noted by Chadwick, that above the Bakoven occurred a "hard bed," calcareous looking but sandy to feel, which tended to break up into small gravelly pieces and weather yellowish rusty. An excellent exposure was seen at Houck's glen on the east side of the road one and one-half miles north-northeast of High falls and one-half mile south of Timmerman hill. Here 45 feet of the typical hard, limy bed cap 35 feet of transition beds with Chittenango lithology, below which are 25 feet of black shales (the old "coal mine").

One and one-half miles west of Quarry hill and one-half mile south of the right-angled bend in the road on the west side of the Kaaterskill a ravine on the east side of the road exposes 95 feet of this hard bed in the falls. The soft shales are covered in the flat. The hard bed seen here was traced with the same relationships by Cooper and the writer all the way from Port Jervis in Orange county into the Catskill area, northward on the Coxsackie quadrangle and westward into the Helderberg area. In Camp Pinnacle hill, Helderbergs (two miles south-southeast of Thompson's lake, Berne quadrangle), along the road, 162 feet (aneroid) above the Onondaga is the base of the hard bed, 13 feet of which is exposed along the new road. The rock here is a calcareous sandstone with some lenses of a very hard, coarsely crystalline limestone. In the falls of the Onesquethaw (Wolf Hill section, Berne quadrangle), 165 feet (aneroid) above the Onondaga is the base of the hard bed, similar to that seen at Camp Pinnacle hill, with a thickness of 24½ feet. A description of the hard bed and its relationship to the Cherry Valley limestone is given in a short discussion by Doctor Cooper at the end of this section.

It is clear from Cooper's discussion (*see* page 247), that the Bakoven shale of the Hudson valley, as well as the "Marcellus black shale" of the Helderbergs and Capital District area, is the equivalent of the Union Springs member, but with grayish shales of Cardiff lithology replacing the black shales in the upper portion. In the Onesquethaw-Wolf Hill section the lower 50 feet of the Bakoven consist of black shales with the characteristic brown streak and are followed by grayish, sandier beds with a white streak to the last 10 feet of shale below the "hard bed," exposed in the falls and bank, which are very black and sooty in character. On the Catskill quadrangle, at Webber's bridge over the Kaaterskill, along the Rip Van Winkle trail, Chadwick (conversation in field) found true blacks with a brown streak 75 feet above the Onondaga.

The black shale of the Marcellus formation in places in the east follows the Onondaga very abruptly; in western New York the boundary is not so sharp owing to the presence of calcareous beds in the Marcellus. The lower part of the Marcellus in eastern New York was regarded by Clarke ('01, p. 115-38) as the equivalent of the Upper Onondaga limestones of western New York, that is that "the Onondaga limestone grades upward into the Marcellus shale with the Marcellus overlapping the Onondaga toward the west." (Cooper, '30, p. 123). As pointed out in the discussion of the Onondaga limestone (page 228), Willard, for Pennsylvania, finds that the Marcellus black shale succeeds the Onondaga with a normal transition contact, though it may become disconformable locally. Chadwick, on the other hand (abstract for Geological Society meeting, '27; conversation in field recently), reports an unconformity between the Onondaga and the Marcellus in the Catskill region which to his mind "appears to dispose finally of the theory of 'contemporaneous overlap'" of the Marcellus black shale. In this connection Cooper (*ref. cit.*) writes

Chadwick has found evidence of an unconformity between the Onondaga and Marcellus in eastern New York. It is therefore possible that there was an interruption in sedimentation at the end of Onondaga time, but it is equally possible that Chadwick's unconformity is actually only a marginal break such as would be expected in the shore region and did not affect sedimentation in the deeper and more distant portion of the geosyncline. In such an instance part, at least, of the Onondaga in western New York would be equivalent to the lower part of the Marcellus and should be referred properly to the Hamilton. However, till the true significance of the "break" is understood, the division line between the Hamilton and the Onondaga is drawn at the base of the Marcellus.

At the type section of the Bakoven shale at Webber bridge Chadwick notes that the basal one-half inch in contact with the Onondaga is a calcarenite, black in color, composed of tiny crinoidal fragments and containing comminuted fish remains with an occasional shell, which he considers as reworked from the limestone below. He also notes corrosion hollows filled with this limestone. The writer in brief visits to the locality with Cooper and Chadwick noted three limy (calcarenite) layers alternating with black shale layers. In the Onesquethaw-Wolf Hill section in the Helderbergs, visited by the writer alone and with Doctor Cooper, above the Onondaga was found one foot of black shale with *Styliolina;* seven inches of limestone, shaly in the upper three inches; three inches of shaly limestone with *Styliolina;* 10 inches of black shale; three inches of limestone followed by shale. This would seem to indicate for this area a transition from the Onondaga limestone below. The limestones carry an Onondaga fauna and an Oriskany type of *Leptocoelia.* Cooper thought (in field) that the zone corresponded to Cleland's *Anoplotheca camilla zone* at the base of the Union Springs (*see* Cleland, '03, p. 22). Nowhere on the Coxsackie quadrangle has the writer found the Bakoven shale in contact with the Onondaga.

The fauna of the "Marcellus black shale" or Bakoven equivalent is not very large. Grabau ('06, p. 329) lists 12 species (four brachiopods, one pelecypod, two pteropods, five cephalopods) from the Schoharie region. From the Helderbergs and Capital District area have been collected (Goldring, '35, p. 158, largely; Prosser and Rowe, '99, p. 353; Ruedemann, '30, p. 69):

Bryozoans

Bryozoan sp.

Brachiopods

Chonetes cf. *mucronatus* Hall
Leiorhynchus limitare (Vanuxem)
L. mysia Hall
Lingulodiscina cf. *exilis* (Hall)
Nucleospira concinna Hall

Pelecypods

Glyptocardia speciosa Hall
Leiopteria laevis Hall
Leptodesma cf. *rogersi* Hall

Lunulicardium marcellense Vanuxem
Modiella pygmaea (Conrad)
Nucula cf. *bellistriata* (Conrad)
Panenka cf. *ventricosa* Hall
Pterochaenia fragilis (Hall)

Conularids

Coleolus tenuicinctus Hall
Conularia sp.

Pteropods

Styliolina fissurella Hall
Tentaculites gracilistriatus Hall

Cephalopods

Bactrites clavus Hall
Centroceras [*Nautilus*] *marcellense* Vanuxem
"*Orthoceras*" sp.
Tornoceras (*Parodoceras*) *discoideum* (Conrad)

Chadwick cites only a few species from the Bakoven shale of the Catskill quadrangle: the brachiopods *Atrypa spinosa* Hall, *Leiorhynchus limitare* (Vanuxem); the pteropods *Styliolina fissurella* Hall, *Tentaculites gracilistriatus* Hall; the crustacean *Estheria* n. sp.?; the fish *Onychodus hopkinsi* Newberry; the plant *Protosalvinia huronensis* Dawson, besides stipes, roots and possibly an aphlebia.

On the Coxsackie quadrangle the Bakoven forms a narrow belt for the full length of the area. In the upper portion it is entirely included in the Hamilton escarpment which rises abruptly above the Onondaga flats. Farther south, in part it forms the east face of the Hamilton hills and in part underlies a hilly valley, occupied in the extreme south by Hollister lake and a branch of the Catskill. The thickness of this member for the area is between 180 and 200 feet. Outcrops are not numerous, because the hill slopes and the valleys both have a considerable mantle of glacial deposits, but enough exposures may be found in ravines, stream beds, road cuts and gravel pits to give a good idea of the rock. As in the northern Helderberg and Catskill areas an alternation of the black shales with the gray shales of Cardiff lithology is found.

A few of the exposures of the Bakoven might be mentioned. In the ravine one-half mile below the northern boundary of the quadrangle about 60 feet of the lowest beds are exposed in the stream and bank and at least 70 feet more are indicated in the banks by the abundant occurrence of the rock in the soil. At Coeymans Hollow a good and more accessible exposure of the lower beds may be seen west of the bridge one-quarter of a mile north of the four corners. A less accessible, but nearly complete section of the upper portion is exposed in the stream bed, banks and side ravines (east, particularly), of the north-south valley located east of Stanton hill. The ravine which follows the road three-quarters of a mile north-northwest of this valley shows a broken section in the upper beds, as also the ravines in the Hamilton front one-half mile and one mile to the east along the north-south road. The uppermost beds are exposed in the upper reaches of the east-west stream valley one mile to the south of the last locality, on the south side of the road to Stanton Hill. South of this point exposures are few and minor in character. The uppermost black beds are exposed in the lower end of the ravine one-half mile west-northwest of the southwest end of Greens lake on the south side of the road. These beds are only a few feet below the base of an excellent section in the Stony Hollow ("hard bed") member of the Marcellus formation (pages 247, 256).

By far the best section in the Bakoven shale, and a nearly complete one in alternating dark and gray shales, is found in a ravine on the north side of an old road to Medway one mile south-southwest of Roberts Hill. At the junction with the north-south road from Roberts Hill the Onondaga outcrops. Just to the west in the brook the sooty black strata of the Marcellus outcrop just above (west of) the Onondaga, but not exposing the contact zone. These lower beds are fissile, breaking into paper-thin sheets, very much crumpled, contorted and slickensided, as is usual in this portion, indicating slipping within the mass. *Styliolina* is abundant in certain layers. The presence of pyrite is indicated by yellowish or rusty weathering. The beds here dip at a high angle of 23° to 24° for about 25 feet. About 40 feet up in the section the lithology is decidedly of the Cardiff type, and the next 20 feet are very fossiliferous. Below the transition beds of the "hard bed" are 12 feet of thin-bedded, flat-bedded, dark gray shales with a white streak. The upper three feet of the 12-foot zone of shales is strongly cleaved, nearly vertically, due to the weight of the heavy beds above. The upper six feet, at least, are sooty looking with a greasy streak, as has been pointed out for Bakoven sections elsewhere. Below the 12-foot shale zone is a five-inch limestone band with cephalopods, with a layer of lime concretions (six to eight inches in diameter) two feet below. On the limestone band the dip, which in the lower beds was N. 73° W. at an angle of 23° to 24°, has changed to N. 80° W. at an angle of 7°. The section is estimated to cover at least 180 feet of rock though the vertical distance (aneroid) is only 62 feet.

A fauna (figure 44) which practically duplicates the one found in the northern Helderbergs has been collected in the Coxsackie area. A cut of any extent will usually yield some specimens, but only where the beds are broken down into gravelly slopes is fair collecting possible. The best collections were made in the section last described. Several species were found in the rock outcropping in the bed of the Hannacrois west of the bridge in Coeymans Hollow; a few species from beds well up in the Bakoven were collected from another gravel pit on the left side of the road to Deans Mills, seven-eighths of a mile

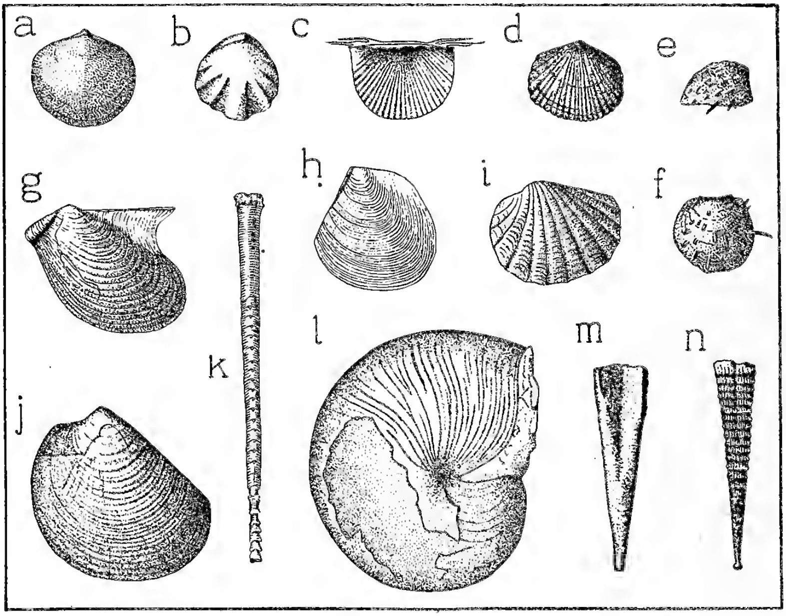

Figure 44 Bakoven shale fossils. (Brachiopods, *a-f;* pelecypods, *g-j;* cephalopods, *k, l;* pteropods, *m, n*). *a Nucleospira concinna,* x ¾. *b Leiorhynchus mysia. c Chonetes mucronatus,* x ¾. *d Leiorhynchus limitare. e, f Strophalosia truncata,* x ¾. *g Leiopteria laevis,* x 2. *h Pterochaenia fragilis. i Glyptocardia speciosa. j Lunulicardium marcellense,* x ¾. *k Bactrites clavus,* x ½. *l Tornoceras* [*Parodoceras*] *discoideum,* x ¾. *m Styliolina fissurella,* x 6. *n Tentaculites gracilistriatus.*

north of the junction with the Albrights-Stanton Hill road. The list compiled by the writer, in large part from the first locality, is as follows:

Bryozoans

Bryozoan sp.

Brachiopods

Chonetes cf. *mucronatus* Hall
Leiorhynchus limitare (Vanuxem)
L. mysia Hall
Nucleospira concinna Hall
Strophalosia truncata (Hall)

Pelecypods

Aviculopecten cf. *invalidus* (Hall)
Glyptocardia speciosa Hall
Leiopteria laevis Hall
Lunulicardium marcellense Vanuxem
Modiella pygmaea (Conrad)
Pterochaenia fragilis (Hall)

Conularids

Coleolus tenuicinctus Hall

Pteropods

Styliolina fissurella Hall

Cephalopods

Bactrites clarus Hall
Centroceras [*Nautilus*] *marcellense* Vanuxem
Tornoceras (*Parodoceras*) *discoideum* (Conrad)

Stony Hollow Member

By

G. Arthur Cooper,

Associate Curator, U. S. National Museum

The Cherry Valley limestone is one of the least known members of the New York Hamilton group. It extends from Flint creek, Ontario county, to Schoharie valley, a distance of about 140 miles. Although the Cherry Valley has been doubtfully identified in Maryland, the member has hitherto not been reported from Pennsylvania and the Catskill region of eastern New York. Field work by W. Goldring and G. A. Cooper during the summer of 1938 revealed a sandstone equivalent of the Cherry Valley limestone that forms conspicuous waterfalls and cliffs in the foothills of the Catskills from southern Albany county to Kripplebush, N. Y., and was seen as far south as Echo lake near Stroudsburg, Pa. It is here proposed to name this sandy equivalent of the Cherry Valley the Stony Hollow member of the Marcellus formation for the fine exposures at the entrance to Stony Hollow, about three miles northwest of Kingston, N. Y., railroad station.

Distribution. Exposures of the Stony Hollow member occur in most parts of the Catskill Hamilton outcrop belt, but are best developed northward from Kripplebush (about 10 miles southwest of Kingston). In New York the member appears first on U. S. Highway 209 from two to three miles northeast of Port Jervis. From this point to Kripplebush, about 30 miles, no outcrops were seen. When next encountered near Kripplebush the member has all the characteristics seen at Port Jervis. On the west side of Esopus creek it forms resistant cliffs and waterfalls from Kripplebush to Stony Hollow near Kingston. North of here it can be seen in the Plattekill at Mt Marion, in many of the glens and on the roadside west of the Beaverkill and Kaaterskill from Mt Marion to Leeds. It occurs just north of Leeds (figure 45) and about one and one-half miles north of Climax.

In its typical form the Stony Hollow member is last seen poorly exposed in Coeymans Hollow. At the falls of Onesquethaw creek southwest of Albany and on Camp Pinnacle hill east of Thompsons lake the member contains thin limestone layers like those of the Cherry Valley as exposed in Stony creek, one and one-half miles south-southeast of Schoharie.

Lithological characters. Two important qualities particularly identify the Stony Hollow member: (1) its compact, calcareo-arenaceous composition and consequent resistance to erosion, and (2) its strong cleavage. The member is composed chiefly of fine calcareous sandstone showing the bedding on cleavage surfaces in bands of varying shades of gray. Everywhere it is strongly and closely cleaved, thereby showing great resemblance to the Esopus formation lying just under the Onondaga. When fresh the rock has a dark gray color and very fine texture but upon weathering it alters to a light gray. Leaching of the lime content produces a punky, fine-grained sandstone.

Thickness. The thickness of the Stony Hollow member is known only in the middle and northern parts of its outcrop belt in New York. Exposures are too poor in the vicinity of Port Jervis to permit accurate measurements. The thickness at the type section in Stony Hollow is estimated to be 75 to 80 feet and west of Catskill, and in the vicinity of Leeds and Climax it is 95 to 100 feet. At the falls of Onesquethaw creek 24 feet of sandstone and thin limestone represent this member and show the lateral passage to the Cherry Valley limestone.

Structure. The Stony Hollow member generally dips to the northwest throughout the Catskill region. At Port Jervis the dip is about 15 degrees. From Kripplebush to Stony Hollow the dip varies from three and one-half degrees to 13 degrees. In the Stony Hollow railroad cut and in the exposures west of Kingston the dip is to the north and northeast where the strike swings to the east. North of Kingston the strike remains slightly east of north and dips vary from a few degrees to 29 degrees. The north-northeast strike prevails to Climax but north of that place it gradually swerves to the northwest around the northeast front of the Catskills where the dip becomes lower and its direction to the southwest.

The Stony Hollow member overlies the soft Bakoven shale and at the contact considerable slickensiding and distortion of bedding occurs, no doubt caused by slipping during folding. This black and contorted zone has often been mistaken for coal.

Fossils. Fossils are not abundant in the Stony Hollow member and most of those at present known are new species. Few specimens aside from the coral *Ceratopora* were seen in the lower part of the member. Near the top a few kinds of brachiopods are fairly common, including a shell resembling *Kayserella,* a large *Schizophoria,* small *Pentamerella, Leptaena, Productella, Chonetes,* a very fine-ribbed *Atrypa* and a small *Atrypa* of the *spinosa* stock. The trilobite *Dechenella* was found at several localities. This trilobite and the small new species of *Pentamerella* also occur in the Cherry Valley limestone at Chittenango Falls and near Jamestown, N. Y., as well as in the Stony Hollow member.

Note on the Berne Member

By G. Arthur Cooper

Discovery of a Cherry Valley equivalent in eastern New York affects the nomenclature of the strata of eastern Schoharie and Albany counties. The Berne member was proposed by Cooper for the shale between the Onondaga and the *Meristella*-coral bed of the lower Otsego member. The name Berne was thus designed to cover the gray sandy equivalents of the Union Springs, Cherry Valley and Chittenango members. Now that the Cherry Valley equivalent has been definitely recognized the name Berne must be restricted wholly to the Chittenango sandy shale equivalent about 100 to 150 feet thick. The Bakoven shale of Chadwick now represents the gray shale facies of the Union Springs.

As thus restricted the Berne member extends from its type locality around the northeast end of the Catskills at least as far south as Mt Marion and Halihan hill north of Kingston. At these two places a coral bed about 140 feet above the Stony Hollow represents the *Meristella*-coral zone. Unfortunately for mapping these are the only two places yet discovered where the *Meristella*-coral zone appears in the eastern Catskill region. Undoubtedly other localities will be discovered in future work. Until then the Berne member of the eastern Catskill region should be mapped with the Mount Marion.

Mount Marion beds. This is a local name used in Ulster and Greene counties to designate the fossiliferous marine beds above the Bakoven shale. The name was derived from the type section in Mt Marion, west of Saugerties in Greene county (Grabau, '19). These sandstones and shales have been cited by authors as having a thickness of 400 to 500 feet (Grabau, *ref. cit.,* p. 470. *See* Goldring, '31, p. 395; '35, p. 179). They constitute the Hooge Berg range with peaks rising to 600 feet A. T. and over (719 feet A. T. in Mt Marion) and Chadwick has estimated their thickness as possibly over 800 feet. Cooper, in the field, roughly estimated a thickness between 700 and 800 feet. The heavy ledges seen exposed in the upper part of Mt Marion are the same as those found at High falls and upstream, seven and one-half miles north and still farther north in the Potic mountains of the Coxsackie quadrangle.

Various correlations have been suggested for the Mount Marion beds: Cardiff in whole or part, Cardiff and Skaneateles, in whole or part (*see* Cooper, '30; Goldring, '35, p. 179, 189) and Otsego plus upper Berne (*see* Chadwick, '36, correlation chart p. 99). In the summer of 1938 the starfish (*Devonaster eucharis*) horizon was relocated (*see* Clarke, '12*a*, '12*b*) in the shoulder of Mt Marion east side, at an elevation of 530 feet A. T. (Cooper, Mrs Henry Dunbar of Hurley and the writer) and a second locality was discovered by Cooper upstream from and 100 feet above the ledge capping High falls. The association of fossils, including a large *Camarotoechia, "Spirifer" acuminatus, Grammysia magna, Paracyclas lirata, Tropidoleptus carinatus, "Pterinea" flabellum* etc. suggested the top of the Otsego member to Doctor Cooper. The fossiliferous beds of this area, therefore, while still belonging to the Marcellus formation, extend for a considerable thickness above the Otsego, and the term Mt Marion beds then includes the "hard bed" (Stony Hollow member), the Berne member (restricted; *see* Cooper, page 249), the Otsego member, and an estimated 200+ feet of upper Marcellus beds corresponding to basal beds of the Panther Mountain member of the Berne (northern Helderbergs) and Durham quadrangles. The situation is practically the same for the southern portion of the Coxsackie quadrangle, but in the northern part of this area all, or nearly all, of the Marcellus formation is represented by the fossiliferous marine beds and the name Mount Marion beds is not strictly applicable.

In the lower portion of the Mount Marion beds, above the Stony Hollow member, soft argillaceous sandstones and sandy shale predominate and they break up into blocky pieces. When fresh they are dark blue-gray in color, weathering to tan or coffee-brown colors. In the higher horizons the heavier sandstones predominate, with sandy blue shales interbedded. Pebble zones and several heavy storm roller beds appear near the top of the Mount Marion beds, that is near the top of the fossiliferous marine beds. Much of the sandstone is dark gray but the upper beds tend to be lighter in color and weather light brownish. Darton, first, ('94*a*, p. 434) and, later, Ruedemann ('30, p. 70) have pointed out that the sandstones and shales of these marine Hamilton beds

change into each other horizontally in a very irregular manner. This fact as well as the crossbedding observed at times and the prevalence of brachiopods and lamellibranchs in the fauna indicate shallow muddy water with frequent changes in direction of currents. In western New York the Hamilton beds are more calcareous, the formation consisting of calcareous shales and limestones; eastward it becomes arenaceous, until along the Hudson River arenaceous shales and sandstones prevail.

In the Helderberg area (Goldring, '35, p. 159) flag beds are numerous in the upper part of the marine Hamilton (upper Marcellus).

The sandstone is moderately fine-grained and splits readily along the bedding planes into slabs of varying thickness. Such heavy beds, termed "flags" or "flagstones," gave rise to the flagstone industry that flourished in the northern Helderberg area for so many years. In these beds were noted mud pebble zones, ripple marks, tide markings, rill markings and other shore phenomena, and certain beds were found filled with plant remains.

The fauna of the marine Hamilton beds comprises a large number of species. Grabau lists 123 species from the Schoharie region, but the beds involved comprise more than the equivalent of Mount Marion beds or even the entire Marcellus formation. For the Mount Marion beds of the Catskill quadrangle, the equivalent of the marine Hamilton (above the Bakoven) of the southern portion of the Coxsackie quadrangle, Chadwick has brought together the following fauna (letter, 1938):

Plants

Unidentified remains

Corals

Ceratopora distorta
C. intermedia (Nicholson)?
Cyathophyllum nanum Hall

Crinoids

Stems

Starfishes

Devonaster eucharis (Hall)

Worm Burrow

Taonurus velum (Vanuxem)

Brachiopods

Atrypa reticularis (Linnaeus) var.
Camarotoechia congregata (Conrad)
C. prolifica (Hall)
C. sappho (Hall)?
Chonetes coronatus (Conrad)
C. lepidus Hall
C. setigerus (Hall)
C. vicinus (Castelnau)
Cyrtina hamiltonensis Hall
Dignomia alveata Hall
Leptostrophia perplana (Conrad)
L. junia (Hall)?
Lingula cf. *compta* Hall & Clarke
L. densa Hall
Orbiculoidea sp.
Rhipidomella penelope Hall
R. vanuxemi Hall
Schizophoria striatula (Schlotheim)
Schuchertella pandora (Billings)
"Spirifer" (Brachyspirifer) audaculus (Conrad)
"S." (Tylothyris?) consobrinus d'Orbigny
"S." (Spinocyrtia) granulosus Conrad
"S." (Mucrospirifer) mucronatus (Conrad)
Strophalosia truncata (Hall)
Tropidoleptus carinatus (Conrad)

Pelecypods

Actinodesma [Glyptodesma] erectum (Conrad)
Actinopteria boydi (Conrad)
Aviculopecten princeps (Conrad)
Cornellites [Pterinea] flabellum (Conrad)
Cypricardella complanata Hall
C. tenuistriata Hall
Elymella nuculoides Hall
Goniophora hamiltonensis Hall
Grammysia alveata Conrad
G. bisulcata (Conrad)
G. circularis Hall
G. constricta Hall
G. magna Hall ?
Leiopteria dekayi Hall
Modiella pygmaea Conrad
Modiomorpha concentrica (Conrad)
M. macilenta Hall ?
M. mytiloides (Conrad)
Nucula bellistriata (Conrad)
N. corbuliformis Hall
N. varicosa Hall
Nuculites oblongatus Conrad
N. triqueter Conrad
Nyassa arguta Hall
N. recta Hall
Orthonota (?) *parvula* Hall
O. undulata Conrad

Palaeosolen siliquoideus Hall ?
Palaeoneilo constricta (Conrad)
P. emarginata Conrad
P. fecunda Hall
P. maxima Conrad
P. plana Hall
Paracyclas lirata (Conrad)
Plethomytilus oviformis Conrad
Prothyris lanceolata Hall
P. planulata Hall
Schizodus appressus Hall
Sphenotus subtortuosus Hall ?
S. truncatus (Conrad)

Gastropods

Bembexia sulcomarginata (Conrad)
Bucanopsis lyra (Hall)
Diaphorostoma lineatum (Conrad)
Trepospira rotalia Hall ?

Pteropods

Tentaculites bellulus Hall

Trilobites

Greenops [*Cryphaeus*] *boothi* (Green)

On the Berne quadrangle (northern Helderberg region) where the marine beds include all or practically all of the Marcellus formation, as in the northern part of the Coxsackie quadrangle, the writer collected the following 125 species above the Bakoven shale (Goldring, '35, p. 171-79):

Plants

Protolepidodendron sp.
Stipes, etc.

Corals

cf. *Cyathophyllum* sp.
Cystiphyllum sp.
C. vesiculosum Goldfuss
Favosites sp.
Streptelasma (*Enterolasma*) *rectum* Hall

Crinoids

Ancyrocrinus bulbosus Hall
Camerata genus ?
Inadunate genus ?
Stem joints

Worm Burrow

Taonurus velum (Vanuxem)

Bryozoans

Fenestella sp.
Fistulipora sp.
Taeniopora exigua Nicholson

Brachiopods

Ambocoelia umbonata (Conrad)
Athyris cora Hall
Atrypa reticularis (Linnaeus)
Camarotoechia congregata (Conrad)
C. prolifica (Hall)
C. sappho (Hall)
Chonetes coronatus (Conrad)
C. mucronatus Hall
C. scitulus Hall
C. setigerus (Hall)
C. cf. *vicinus* (Castelnau)
Cyrtina hamiltonensis Hall
Dignomia alveata Hall
Eunella lincklaeni Hall
E. sp.
Leiorhynchus sp.
Leptostrophia perplana (Conrad)
Lindstromella aspidium Hall & Clarke
Lingula sp.
Meristella sp.
Nucleospira cf. *concinna* Hall
Orbiculoidea cf. *humilis* (Hall)
O. sp.
Pholidops hamiltoniae Hall
P. sp.
Productella dumosa Hall
P. sp.
Rhipidomella cyclas Hall
R. vanuxemi Hall
Schizophoria cf. *striatula* (Schlotheim)
"*Spirifer*" (*Paraspirifer*) *acuminatus* (Conrad)
"*S.*" (*Brachyspirifer*) *audaculus* (Conrad)
"*S.*" sp. near *Tylothyris ? consobrinus* d'Orbigny
"*S.*" (*Spinocyrtia*) *granulosus* Conrad
"*S.*" (*Mucrospirifer*) *mucronatus* (Conrad)
Stropheodonta demissa (Conrad)
S. inaequistriata Conrad
S. sp.
Tropidoleptus carinatus (Conrad)

Pelecypods

Actinodesma [*Glyptodesma*] *erectum* (Conrad)
Actinopteria boydi (Conrad)
Aviculopecten princeps (Conrad)
Cimitaria corrugata (Conrad)
C. elongata (Conrad)
Cornellites [*Pterinea*] *flabellum* (Conrad)

Cypricardella bellistriata Conrad
C. complanata Hall
C. gregaria Hall
C. tenuistriata Hall
Elymella levata Hall
Goniophora glauca Hall
G. hamiltonensis Hall
Gosseletia triquetra (Conrad)
Grammysia bisulcata (Conrad)
G. circularis Hall
G. magna Hall
G. nodocostata Hall
Leiopteria dekayi Hall
L. greeni Hall
Lunulicardium marcellense Vanuxem
Lyriopecten interradiatus Hall
Modiomorpha concentrica (Conrad)
M. mytiloides (Conrad)
M. sp.
Nucula bellistriata (Conrad)
N. corbuliformis Hall
N. lamellata Hall
N. lirata (Conrad)
N. cf. *varicosa* Hall
Nuculites oblongatus Conrad
N. triqueter Conrad
Nyassa arguta Hall
N. (?) *subalata* (Conrad)
Orthonota undulata Conrad
Palaeoneilo constricta (Conrad)
P. maxima Conrad
Paracyclas lirata (Conrad)
P. tenuis Hall
Parallelodon hamiltoniae Hall
Pholadella radiata (Conrad)
Phthonia sectifrons Conrad
Prothyris lanceolata Hall
Pterinopecten cf. *undosus* Hall
P. vertumnus Hall
Schizodus chemungensis (Conrad)
Sphenotus cuneatus (Conrad)
S. cf. *solenoides* Hall
S. truncatus (Conrad)
Tellinopsis subemarginata (Conrad)

Gastropods

Bembexia sulcomarginata (Conrad)
Diaphorostoma sp.
Euryzone cf. *lucina* (Hall)
Loxonema hamiltoniae Hall
Platyceras thetis Hall
Pleurotomaria cf. *filitexta* Hall
Ptomatis patulus (Hall)
P. rudis (Hall)

Conularids

Coleolus tenuicinctus Hall
Conularia sp.
Hyolithes aclis Hall
Hyolithes sp.

Pteropods

Styliolina fissurella Hall
Tentaculites attenuatus Hall
T. bellulus Hall

Cephalopods

Centroceras [*Nautilus*] *marcellense* Vanuxem
"Nephriticeras" sp.
"Orthoceras" sp.
Tornoceras (*Parodoceras*) *discoideum* (Conrad)
"Spyroceras" sp.

Trilobites

Greenops [*Cryphaeus*] *boothi* (Green)
Homalonotus dekayi (Green)
Phacops rana (Green)

(*Note:* The writer is indebted to Dr G. Arthur Cooper of the U. S. National Museum for the "Spirifer" genera used here and elsewhere. At Doctor Cooper's suggestion quotation marks are used about the name "Spirifer" throughout this bulletin because of the considerable changes that will result from revision, already under way.)

In his discussion of the Hamilton beds for his Capital District bulletin, Ruedemann ('30, p. 71) sums up the fauna as follows:

The fauna of the Hamilton beds is exceedingly rich . . . Grabau ('06, p. 329-31) has enumerated 123 species from the Hamilton of the Schoharie region; in central New York the fauna is still larger. Of these are: wormtrails, 1; brachiopods, 27; pelecypods, 76; gastropods, 9; pteropods, 3; cephalopods, 2; trilobites, 4. The Hamilton is therefore a typical pelecypod or lamellibranch facies. It has furnished the multitude of mussels so beautifully illustrated by Hall in volume V of the Paleontology, with thin striking species of Aviculopecten, Leiopteria, Modiomorpha, Goniophora, Palaeoneilo, Grammysia, Sphenotus and Orthonota. I have heard members of the old Survey, as R. P. Whitfield and G. B. Simpson, tell with enthusiasm of their lamellibranch hunting expeditions into the Hamilton in preparation of volume V. Many of the figured specimens are exhibited in the Hamilton cases in the State Museum. The brachiopods which prevail in the limestone formations are the next in abundance but attain only one-third the number of the lamellibranchs.

On the Coxsackie quadrangle the "Mount Marion" beds form a broad belt between the unfossiliferous Ashokan flags and shales and the softer dark or gray shales of the Bakoven. This belt extends roughly north-northeast from the southern border of the quadrangle where it has a width of about three-quarters of a mile. The dip at the south is slightly north of west at an angle of 7°; but northward it changes from west-northwest, with angles of 6° and 7° (locally higher) to almost due west in the vicinity of Medway, where the dip is about 7° and the belt has a width of nearly one and three-quarters miles. Farther north towards Coeymans Hollow the dip swings around to the south and the angle of dip falls to 3° and even to 2° westward (S. 5° W.) in the vicinity of Alcove (figure 46). Along with the change in angle and direction of dip the belt at the north widens to between three and four miles with an extension on the Albany quadrangle that gives a width of between five and six and a half miles. Thicknesses have been computed that range from something over 800 feet at the south end of Potic mountain, through 1050+ feet in the latitude of Urlton, about 1100 feet in the latitude of Medway, 1120± feet in the vicinity of Coeymans Hollow and between 1200 and 1300 feet west of Coeymans Hollow (neighborhood of Alcove to Newrys). The entire thickness of the fossiliferous Hamilton, therefore, is about that found on the Berne quadrangle, something over 1400 feet (maximum in Bradt Hill section; *see* Goldring, '35, p. 189).

As in the type area, above the Stony Hollow member, the Mount Marion beds here consist of soft argillaceous sandstones and sandy shales (predominant in the lower portion), dark blue-gray in color when fresh, and heavier sandstone beds (predominant in higher horizons), blue-gray in color or lighter, tending to weather brownish. The heavier sandstone beds are well displayed in the cliffs of Potic mountain. Pebble zones and storm rollers have been seen in a number of places in the upper portion of the formation. Along the south side of the Catskill in the Leeds flat, one-quarter of a mile east of the upper boundary, and one-eighth of a mile north of the house along the lane, storm rollers and a coarse conglomerate are well exposed. The conglomerate is three to four inches thick and has pebbles up to two inches and more in diameter. It is full of macerated remains of fossils, particularly *"Spirifer"* of the *mucronatus* type, and impressions of *Orthonota* and other pelecypods occur. The sandstone here has a greenish tinge. Along a small brook on the south side of the road three-eighths of a mile north of this locality tidal markings are seen on blue Hamilton flags. Just to the east at the road junction storm rollers occur. On the west side of the road five-eighths of a mile south-southeast of Medway storm rollers were located in flags associated with cross-bedded sandstone. At Alcove, above and below the old mill, they are found associated with strongly ripple-marked surfaces, and higher up at the spillway of the Alcove reservoir they are found along with large concretions and strata showing macerated remains of *"Spirifer" mucronatus* and *Camarotoechia,* as well as the ripple marks. All these features are studied to best advantage in the Alcove Reservoir area. At Dormansville tide flat surfaces are exposed near the school; and in the floor of the large quarry on the south side of the road above Dormansville (Albany quadrangle) a sun-cracked surface may be seen. At the top of Dickinsons falls east of Dormansville are found storm rollers and surfaces showing clay balls, strong ripple marks and fossils (large *"Spirifer," Chonetes* sp.). On the south side of the hill just south of these falls in two abandoned quarries a storm roller bed is capped by a pebble bed four inches thick, the pebbles up to two inches in length and mainly of quartz. Fragments of fossils were found in the pebble bed. A very accessible cut and one in which, when fresh, storm rollers were exposed most advantageously is located one-half mile south-southeast of Dormansville at the junction of the Greenville road with the road west to the Basic reservoir. A sun-cracked surface is exposed in the ditch.

The "hard bed," Stony Hollow member of the Marcellus formation, constitutes the basal 100± feet of the Mount Marion beds on the Coxsackie quadrangle. Portions of this member may be seen in a number of places, as the upper reaches of the ravine five-eighths of a mile south of the northern boundary, the north-south valley east of Stanton Hill and the first ravine on the east, ravines and road cut in the Hamilton escarpment southeast of the last locality as far as the east-west Stanton Hill-Albrights road, the ravine west of Roberts Hill on the south side of the road to Medway and the ravine west of Climax. Four other exposures are very accessible, two of them giving complete sections and studies are best confined to these. Along the road running west under the southern escarpment of Potic mountain the top of the Stony Hollow member is exposed between the first and second house and in the farmyard on the south side of the road. The entire thickness is covered in less than one-tenth (.075) of a mile. The top of the hard bed is again exposed at Coeymans Hollow, on the south side of and 21 feet above the road, three-tenths of a mile west of the junction with the road south past the cemetery. The spinose type of *Atrypa* occurs at the top. A few hundred feet west a quarry on the south side of the road exposes the thin, flat-bedded, sandy shales, with interbedded sandstones that are found just above the hard bed. Three-eighths of a mile west of the junction of the Greens Lake-Leeds road with the road crossing Potic mountain a complete section of the Stony Hollow member is exposed in the falls of the ravine on the south side of the road (figure 45). There is a thickness of 82 feet, not counting dip, which at the top of the section is 8° N. 68° W. This would give an actual thickness of well over 100 feet of which the lower 35 feet are thinner-bedded. Three falls are shown with a five-foot capping bed in the uppermost one, in which cleavage is nearly vertical and strongly pronounced. Below this thick bed the sandstone is thinner-bedded, breaking rather blocky though flat-bedded. About 150 feet down-stream from the base of the third falls Bakoven with *Styliolina* out-crops in the stream bed. In between are the soft transition beds, 35 feet of which were seen at the top of the Bakoven on the Catskill quadrangle. The beds composing the Stony Hollow member are dark bluish in color when fresh, but weather brown. No fossils were found here. Above the heavy capping bed are the typical soft sandy shales, cut by many joint planes, dark blue in color, thin-bedded and breaking fine blocky. The second complete section is located in the ravine one mile south-southwest of Roberts Hill on the north side of the road to Medway, where the best Bakoven section is found. The "hard bed" section begins as above with thin-bedded basal beds, followed by a heavy bed. About 45 feet above the base, close to where the stream crosses the road fossils were found in an outcrop in the right bank. These include the characteristic species of *Schizophoria, Dechenella* sp. and a fine-lined *Atrypa* sp. This member continues in the section for 35 feet more, giving a total thickness of 80 feet (aneroid) without counting dip (7°, N. 84° W.). There is at least 100 feet of actual thickness here.

In the latitude of the southern end of Potic mountain the Mount Marion beds do not include any considerable thickness above the Otsego member of the Marcellus formation. In the small ravine on the south side of the road, one-eighth of a mile west of the junction

Figure 45 Falls at top of the "hard" bed or Stony Hollow member of the Marcellus formation (Hamilton) in ravine along south side of road west of Greens lake. Cleavage is well developed in the capping bed and the characteristic blocky weathering may be seen at the left in the beds just beneath. (Photograph by E. J. Stein)

Figure 46 Alcove reservoir surrounded by typical Hamilton hills. View looking north-northwest, taken from the south side of the reservoir, three-quarters of a mile south-southwest of Alcove. (Photograph by E. J. Stein)

with the first road north, the flags contain a large type of *Camarotoechia* and large pelecypods as *Grammysia* and *"Glyptodesma."* These flags are above the storm roller zone at the road junction to the east and are thought to be at the top or near the top of the Otsego which would there be 615+ feet above the top of the Bakoven. In the northern Helderbergs (Berne quadrangle) the top of the Otsego is 610 to 615 feet above the top of the Bakoven, 505 feet above the Berne member (restricted). The *Meristella* bed (coral bed) marking the top of the Berne member in the northern Helderbergs has not been found on the Coxsackie quadrangle but was located in the summer of 1938 by Cooper and the writer on the Rosendale quadrangle four and a quarter miles north of Kingston near the bottom of the road up Halihan hill, five feet above the junction and farther north, on the Kaaterskill quadrangle, in the bed and south bank of the Plattekill, downstream from the bridge, one and five-eighths miles north of Ruby post office and five-eighths of a mile west of the hamlet of Mt Marion (Catskill quadrangle), in the latter locality approximately 140 feet above the Stony Hollow member (Cooper, page 249). In an outcrop along the road one and one-eighth miles east of Medway, on the east slope of the hill, were found *"Spirifer" acuminatus, Chonetes coronatus, Tropidoleptus carinatus, "Glyptodesma" erectum.* This also is believed to be near the top of the Otsego member, 715+ feet above the top of the Bakoven, approximately 615 feet above the hard bed, giving a thickness of 505+ feet for the Otsego member here if the Berne member maintains the thickness it has on the Berne quadrangle. Along the east bank of the Hannacrois below the gorge at Alcove, at an elevation of about 500 feet (300 feet upstream from the first house), were found the brachiopods *"Spirifer" acuminatus* (abundant in limy nodules), *"Spirifer" mucronatus, Chonetes coronatus, Chonetes* sp., *Camarotoechia* sp. (small), *Tropidoleptus carinatus, Leptostrophia perplana, Rhipidomella* sp.; the pelecypods *"Pterinea" flabellum, Glyptodesma erectum, Goniophora hamiltonensis, Modiomorpha concentrica, Gosseletia triqueter, Aviculopecten princeps, Actinopteria boydi, Paracyclas lirata;* the gastropods *Ptomatis rudis, Bucanopsis leda;* fishbones; the worm burrow *Taonurus velum,* and crinoid joints. This assemblage of fossils suggested to Cooper (in field) the High Falls section on the Catskill quadrangle. Under the bridge at Alcove, 100 feet above the preceding locality occurs a three-foot storm roller zone capped by sandstones with large *Camarotoechias* and small *"Spirifers,"* such as were seen in the starfish zone 100 feet above High falls. Above the bridge a similar bed caps a second storm roller zone. If, as indicated, this is the top of the Otsego, the top of this member here is 635 feet above the Bakoven, approximately as in the northern Helderbergs where the Stony Hollow member is thinner, and the same thickness for the Otsego may be expected.

The fossiliferous Hamilton ("Mount Marion" in an extended sense) in the northern portion of the Coxsackie quadrangle includes all or practically all of the Marcellus formation. For the Berne quadrangle (northern Helderbergs) Cooper and the writer regard the exposures along the road south of Westerlo as representing approximately the top of the Marcellus (Goldring, '35, p. 175, 180, 189). In the quarry along the road one-half mile south of Westerlo the floor is formed by a heavy sandstone bed filled with *"Spirifer" mucronatus* and large specimens of *Chonetes coronatus,* mainly, and some specimens of *Camarotoechia congregata.* Above this layer are softer sandstones, breaking blocky and containing a large fauna of brachiopods, pelecypods and gastropods, with the pelecypods predominant (species of *Actinodesma* [*Glyptodesma*], *Grammysia, Goniophora, Modiomorpha, Pterinea, Paracyclas* etc.). In the quarry along the road one mile south of Westerlo, in beds just above those in the first quarry, a six-inch hard sandstone forms the floor. In this bed *Schizophoria* is abundant and associated with it are *Nyassa subalata* and *"Spirifer" acuminatus* in abundance, also *"Spirifer" mucronatus.* About five feet above this bed a three-inch hard bed also carries *Schizophoria.* The sandy shales between the two sandstone beds are dark; the five feet above the second bed have a greenish hue. *Orthonota undulata* is abundant in the green shales and also occurs in the lower shales. Cooper thought (in field) that the lower *Schizophoria* zone may correspond with the *Schizophoria* zone located in the summer of 1938 along route 28 (new), about five miles north-northwest of Kingston, which carries much the same association of fossils and is about 1000 feet up in the section. In the Westerlo quarry were collected by the writer ('35, p. 175):

Crinoids

Ancyrocrinus bulbosus Hall
Stem joints

Bryozoans

Fenestella sp.

Brachiopods

Athyris cora Hall
Atrypa reticularis (Linnaeus)
Camarotoechia sp.
Chonetes coronatus (Conrad)
C. scitulus Hall
Cyrtina hamiltonensis Hall
Orbiculoidea sp.
Leptostrophia perplana (Conrad)
Schizophoria cf. *striatula* Schlotheim
"Spirifer" (*Paraspirifer*) *acuminatus* (Conrad)
"S." sp. near *Tylothyris? consobrinus* d'Orbigny
"S." (*Mucrospirifer*) *mucronatus* (Conrad)
Stropheodonta demissa (Conrad)
S. inaequistriata (Conrad)
Tropidoleptus carinatus (Conrad)

Pelecypods

Cimitaria cf. *elongata* (Conrad)
Cypricardella complanata Hall
Goniophora glauca Hall
G. hamiltonensis Hall
Gosseletia triqueter (Conrad)
Grammysia bisulcata (Conrad)
G. sp.
Modiomorpha mytiloides (Conrad)
Nucula bellistriata (Conrad)
N. cf. *varicosa* Hall
Nuculites oblongatus Conrad
Nyassa subalata (Conrad)
Orthonota undulata Conrad
Paracyclas lirata (Conrad)
P. tenuis Hall
Pholadella radiata (Conrad)
Pterinopecten vertumnus Hall
Sphenotus sp.

Gastropods

Platyceras thetis Hall
Ptomatis patulus (Hall)
P. rudis (Hall)

Pteropods

Tentaculites bellulus Hall

Conularids

Coleolus tenuicinctus Hall
Hyolithes aclis Hall

Cephalopods

"Orthoceras" sp.

Trilobites

Phacops cf. *rana* (Green)

In the summer of 1938 Cooper and the writer located these two *Schizophoria* zones in a fresh road cut on the north side of the road one-half mile west of Westerlo and farther south on the Durham quadrangle, again in a fresh road cut, in the ditch on the west side of the road one and four-tenths miles south of Westerlo in the hill just above where the first road turns east. Above are soft shales with *Orthonota undulata* etc. Four miles south-southeast of this locality on the west side of Gulf creek, three-quarters of a mile north-northeast of School 15, the top of the fossiliferous Hamilton was located on the north side of the abandoned road at an elevation of about 800 feet, capped by a foot and a half of heavy grayish brown sandstone. For about 15 feet below are typical soft sandy shales with abundant fossils (*Camarotoechia* sp., *"Spirifer" mucronatus, Paracyclas lirata, Actinopteria boydi, Pterinopecten vertumnus, Grammysia,* sp. etc.), beneath which is a layer, eight inches to a foot thick, so full of *"Spirifer" mucronatus* and *Camarotoechia congregata* as to give the appearance of a shell rock. A layer about five feet above carries with the *"Spirifer"* and *Camarotoechia* an abundance of *Chonetes coronatus* (large form). This horizon is near the top of the Marcellus, certainly, but no *Schizophoria* zone was located. *Schizophoria* was found, however, in two places on the Coxsackie quadrangle. One locality is near the head of Cole hollow, one and three-quarters miles south-southeast of Alcove (or south-southwest of Coeymans Hollow) along the west fork of the road, at the bend near the top of the first hill. In the road bed on the east and in the cut at the west, just above the ditch (870 feet A. T., aneroid), is a two-foot bed of shell limestone composed of *"Spirifer" mucronatus, Chonetes coronatus, Chonetes* sp. and very large specimens of *Camarotoechia congregata.* Above are less than 10 feet of dark, blocky-breaking, soft sandy shales full of fossils (*Tropidoleptus carinatus, Paracyclas lirata, Orthonota undulata, "Pterinea" flabellum, "Glyptodesma" erectum, Goniophora hamiltonensis, Pterinopecten vertumnus, Actinopteria boydi, Cypricardella complanata, Palaeoneilo* sp. etc.), capped by a two-inch sandy zone with *Schizophoria.* This section compares with that seen in the two quarries south of Westerlo. One-eighth of a mile west, at the base of the next hill, a few specimens of *Camarotoechia* were found in crumbly, sandy greenish shale. The same *Schizophoria* zone was located about seven-eighths of a mile due south along the east-west road to School 12 and Stanton Hill, at the sharp bend by the old cemetery. At the house opposite the cemetery the *"Spirifer" mucronatus* bed occurs (820 feet A. T.) in several bands, full of *Camarotoechia* and *Chonetes coronatus* as well. Above are the typical dark Hamilton shales, full of fossils; below the beds are dark when fresh, but weather greenish. In the cemetery on the north side of the road *Schizophoria* cf. *striatula* was found loose in material thrown from graves. This zone is located in the hill occupied by the cemetery, about ten feet above the *"Spirifer"* zone. Above this level along the road are heavy cross-bedded, gray sandstones and above them, at the road junction occur the typical olive shales of the Ashokan. East across the hollow in the vicinity of the four corners a number of fossils were found, but the highest zone exposed was at least 20 feet below the horizon of the *"Spirifer"* bed to the west. Just below the road junction, along the west and north roads, pebble zones a few inches thick were found. *Pterinopecten macrodonta,* found about 10 feet below the top of the fossiliferous beds at Rensselaerville falls (Berne quadrangle, northern Helderbergs), was collected here. One and a quarter miles almost due west of the *Schizophoria* zone, along the road to Staco school, the *"Spirifer"* zone was located at the brow of the first rise east of Grapeville creek in a new road cut at an elevation of about 720 feet (aneroid), with fossiliferous dark, blocky-breaking sandstones above (*"Spirifer" mucronatus, Camarotoechia congregata,* large *Chonetes coronatus, Chonetes* sp.; *Goniophora hamiltonensis, Grammysia bisulcata, Modiomorpha* sp., *Actinopteria* cf. *boydi, Cypricardella* sp., *Palaeoneilo* sp., *Nucula bellistriata, Nuculites oblongatus, Lingula* sp.).

Three-quarters of a mile east of Medway, along the road across the high hill, blue sandy shales and thin sandstones occur between 800 and 810 feet A. T. In the sandstone at about 800 feet A. T. were found *"Spirifer" mucronatus, Camarotoechia* and *Chonetes;* in the darker sandy shales *Camarotoechia congregata, Camarotoechia* sp.

Orthonata undulata, Nuculites oblongatus, Grammysia sp., *Cypricardella* sp. and *Tentaculites bellulus.* In a road metal quarry in dark-blue, blocky sandy shales at the summit, 820+ feet A. T., were found *Camarotoechia congregata, "Spirifer" mucronatus, Tropidoleptus carinatus, Chonetes coronatus* (large), *Camarotoechia* sp., very large specimens of *Paracyclas lirata, "Pterinea" flabellum, Orthonata undulata* and *Nuculites oblongatus.* This zone may represent the dark shales below the *Schizophoria* bed. At Urlton the top of the fossiliferous Hamilton was located along the road running south-southeast over the northern end of Potic mountain, three-eighths of a mile out of Urlton along the east bank of the creek, upstream. Here thin sandstone beds are interbedded with dark, blocky sandstones, and *"Spirifer"* cf. *mucronatus, Paracyclas lirata* and *Chonetes coronatus* were collected. On the opposite side of the creek, under the bridge, occur thin-bedded sandstones and sandy shales weathering distinctly olive. From a point three-eighths of a mile southeast along this road to the junction with the road south, near the summit of Potic mountain, there is good collecting. In the sandstone layer near the junction *"Spirifer" mucronatus, Chonetes coronatus, Camarotoechia congregata* and *Paracyclas lirata* are abundant. In flags below on the north side of the road a number of species of pelecypods many of them large form (*Grammysia bisulcata, "Glyptodesma" erectum, Goniophora hamiltonensis, Pterinea flabellum, Modiomorpha* sp., *Limoptera* sp., *Cypricardella* sp. etc.) were collected and a large *"Spirifer"* cf. *audaculus.*

In addition to the localities discussed above fossils may be collected to advantage along the Potic Mountain roads west of Greens and Hollister lakes; east of Urlton, about opposite School No. 8; north-northeast of Medway along the road to Roberts Hill; along the north-south roads west of Stanton Hill; in a quarry along the creek, following the north-south road one mile west of Coeymans Hollow; at various places along the road between Newrys and Alcove and along the abandoned north-south road (and side roads) that follows the ridge on the west side of the main body of the Alcove reservoir. An excellent place in this neighborhood for collecting some large pelecypods was found along the Newrys-Alcove road, three-quarters of a mile to one mile and a quarter north-northeast of the second road junction east of Newrys. Here in the flags exposed in new road cuts were collected the brachiopods *Camarotoechia congregata, C. prolifica, Chonetes coronatus* (large), *C. lepidus, "Spirifer" audaculus, "S." granulosus, "S." mucronatus, "S." sculptilis, Tropidoleptus carinatus;* the pelecypods *"Glyptodesma" erectum, Gonioph-*

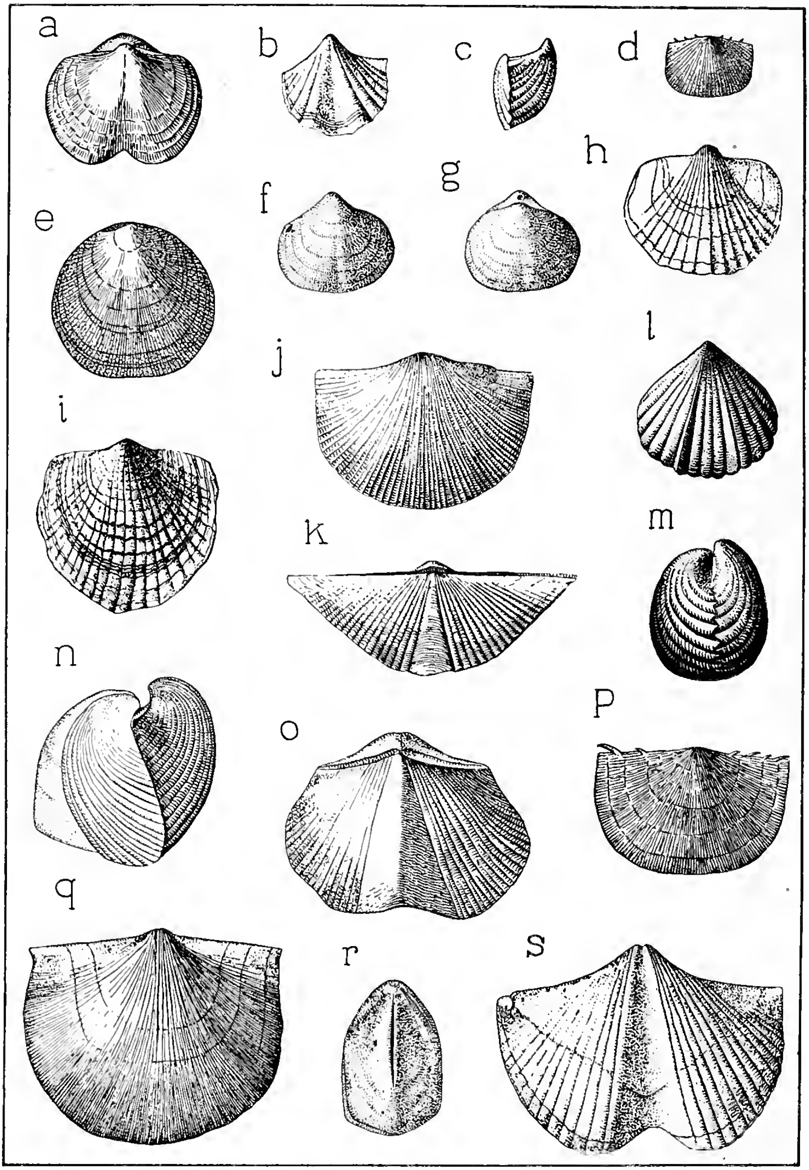

Figure 47 Mount Marion beds brachiopods. *a Schizophoria striatula*, x ¾. *b, c Cyrtina hamiltonensis. d Chonetes scitulus. e Rhipidomella vanuxemi. f, g Athyris cora. h Tropidoleptus carinatus*, x ¾. *i Atrypa spinosa*, x ¾. *j Stropheodonta inaequiradiata*, x ¾. *k "Spirifer" (Mucrospirifer) mucronatus*, x ¾. *l, m Camarotoechia congregata. n, o "Spirifer" (Paraspirifer) acuminatus, p Chonetes coronatus. q Stropheodonta demissa*, x ¾. *r Dignomia alveata*, x ¾. *s "Spirifer" (Spinocyrtia) granulosus*, x ¾.

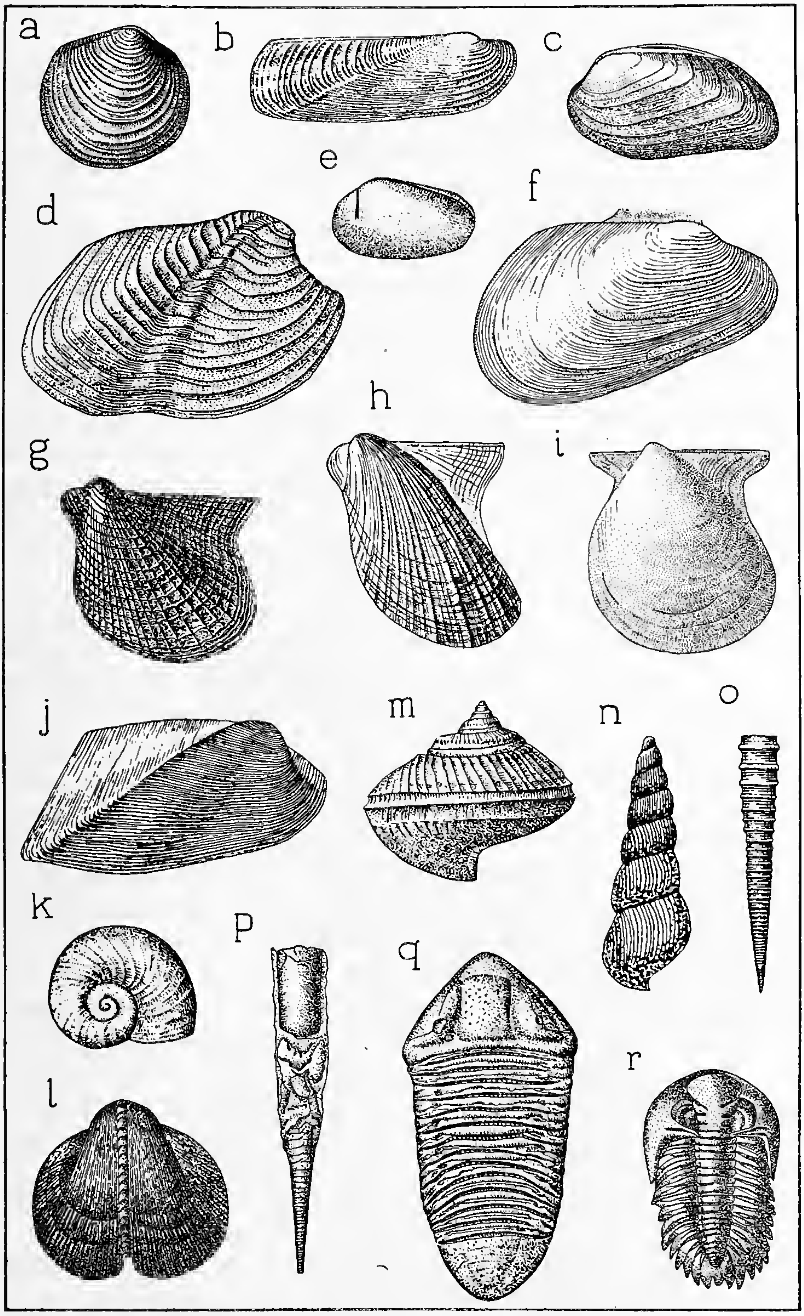

Figure 48 Mount Marion beds fossils. (Pelecypods, *a-j;* gastropods, *k-n;* pteropod, *o;* cephalopod, *p;* trilobites, *q. r.*) *a Paracyclas lirata,* x ¾. *b Orthonota undulata,* x ½. *c Nyassa arguta,* x ¾. *d Grammysia bisulcata,* x ¾. *e Nuculites oblongatus,* x ¾. *f Modiomorpha mytiloides,* x ½. *g Actinopteria boydi,* x ¾. *h Cornellites* [*"Pterinea"*] *flabellum,* x ½. *i Glyptodesma* (*Actinodesma*) *erectum,* x ½. *j Goniophora hamiltonensis,* x ¾. *k Diaphorostoma lineatum,* x ¾. *l Bucanopsis lyra. m Bembexia sulcomarginata,* x ¾. *n Loxonema hamiltonensis. o Tentaculites bellulus. p Michelinoceras?* [*Orthoceras*] *subulatum,* x ½. *q Homalonotus dekayi,* x ⅜. *Greenops* [*Cryphaeus*]

ora hamiltonensis, Grammysia bisulcata, G. magna, Nucula sp. *Nyassa arguta, N. subalata, Orthonota parvula, Palaeoneilo constricta Pholadella* cf. *radiata,"Pterinea" flabellum, Pterinopecten macrodonta Sphenotus subtortuosus;* the gastropods *Diaphorostoma* sp., *Ptomatis patulus* the conularid *Coleolus* sp. and the trilobite *Homalonotus dekayi.* As pointed out above *Pterinopecten macrodonta* was also found about 10 feet below the top of the fossiliferous Hamilton at Rensselaerville falls on the Berne quadrangle. One-eighth of a mile west of the above-mentioned junction, near the base of the hill, the last fossils below the olive shales were found in the ditch on the north side of the road (the brachiopods *"Spirifer" mucronatus, "S." audaculus, "S." sculptilis, Chonetes coronatus, Chonetes* sp. *Camarotoechia prolifica, Tropidoleptus carinatus;* the pelecypods *Grammysia bisulcata, Paracyclas lirata, Nucula bellistriata, Leiopteria* cf. *dekayi, Sphenotus* sp.; the pteropod *Tentaculites bellulus;* the cephalopod *Spycroceras* cf. *crotalum,* and the trilobite *Greenops* [*Cryphaeus*] *boothi*).

Though the Ashokan is the flag-bearing formation, flags are also characteristic of the upper Mount Marion beds and many abandoned quarries testify to the wide use to which they have been put in the past. These quarries show plant remains and surfaces with clay balls, ripple marks and tidal markings. A series of such quarries may be studied south of the Alcove reservoir, one mile south-southwest of Alcove; on the east side of Gulf creek west of the fossiliferous flags along the Newrys-Alcove road; along the east side of West Medway creek, two miles north-northwest of Medway; in the northern end of Potic mountain along the road south-southeast of Urlton; and in the west slope of Potic mountain west of Greens lake and west of the north end of Hollister lake, on the west side of the road.

From all the fossiliferous localities visited on the Coxsackie quadrangle the following species (figures 47, 48) were collected:

Plants

Protolepidodendron sp.
Stipes, etc.

Corals

Favosites sp.

Crinoids

Stem joints

Worm Burrow

Taonurus velum (Vanuxem)

Brachiopods

Athyris cora Hall
Atrypa spinosa Hall
Camarotoechia congregata (Conrad)
C. prolifica (Hall)
C. sappho (Hall)
C. sp. (small)
Chonetes coronatus (Conrad)
C. lepidus Hall
C. sp. (small)
C. vicinus (Castelnau)
Leptostrophia perplana (Conrad)
Lindstromella aspidium Hall & Clarke
Lingula sp.
Rhipidomella sp.
Schizophoria cf. *striatula* Schlotheim
"Spirifer" (*Paraspirifer*) *acuminatus* (Conrad)
"S." (*Brachyspirifer*) *audaculus* (Conrad)

"S." (*Spinocyrtia*) *granulosus* (Conrad)
"S." (*Mucrospirifer*) *mucronatus* (Conrad)
"S." (*Tylothyris?*) *sculptilis* (Hall)
Tropidoleptus carinatus (Conrad)

Pelecypods

Actinodesma [*Glyptodesma*] *erectum* (Conrad)
Actinopteria boydi (Conrad)
Aviculopecten princeps (Conrad)
A. sp.
Cornellites [*Pterinea*] *flabellum* (Conrad)
Cypricardella complanata Hall
C. sp.
C. tenuistriata Hall
Goniophora hamiltonensis Hall
G. sp.
Gosseletia triqueter (Conrad)
Grammysia cf. *arcuata* (Conrad)
G. bisulcata (Conrad)
G. magna Hall
G. obsoleta Hall
G. sp.
Leiopteria dekayi Hall
Limoptera sp.
Lyriopecten interradiatus Hall
Modiomorpha concentrica (Conrad)
M. cf. *mytiloides* (Conrad)
M. sp.
Nucula bellistriata (Conrad)
N. sp.
N. varicosa Hall
Nuculites oblongatus Conrad
Nyassa arguta Hall
N. subalata (Conrad)
Orthonata parvula Hall
O. undulata Conrad
Palaeoneilo constricta (Conrad)
P. sp.
Palaeosolen siliquoideus Hall
Paracyclas lirata (Conrad)
Parallelodon hamiltoniae Hall
Pholadella cf. *radiata* Hall
Pterinopecten macrodonta (Hall)
P. vertumnus Hall
Sphenotus truncatus (Conrad)
S. subtortuosus Hall

Gastropods

Bucanopsis leda Hall
Diaphorostoma sp.
Ptomatis patulus (Hall)
P. rudis (Hall)

Conularids

Coleolus tenuicinctus Hall

Pteropods

Tentaculites bellulus Hall
Tentaculites sp.

Cephalopods

Spyroceras cf. *crotalum* (Hall)

Trilobites

Greenops [*Cryphaeus*] *boothi* (Green)
Homalonotus dekayi (Green)

Ashokan shales and flags. These nonmarine typically nonfossiliferous, flagstone-bearing beds, Grabau's *Ashokan formation* ('19, p. 468-70), were named for the Ashokan district west of Kingston. In Ulster and Greene counties this is the principal flagstone-bearing formation of the Hudson River bluestone region and comprises 500 feet of Hamilton between the marine beds and the continental red beds in the type section. The flagstones of the Ashokan are laminated, arkosic "bluestones" in contrast to the typically nonlaminated and generally less resistant sandstones of the Mount Marion beds, and the interbedded shales have changed from a bluish tone to olive, weathering reddish or brown. For the area of the Catskill-Kaaterskill quadrangles Chadwick has calculated a thickness of 300 feet in the northern portion, approaching the thickness of the type section at the south. On the northern part of the Catskill quadrangle and northward this formation thins and the flag beds are less typical. In the northern Helderbergs (Berne quadrangle) equivalent beds have a thickness of only 65 to 80+ feet and consist of bluish or greenish sandstones, sometimes very coarse, alternating with smooth, greenish or olive-colored shales often blocky. On the Durham quadrangle immediately to the south of the Berne area were found typical Hamilton beds, with fossils, that unquestionably hold a position above these nonmarine flags and shales (Goldring, '35, p. 164). In general and typically these nonmarine beds, as is to be expected, are unfossiliferous and carry only plant remains. Some of the beds are very coarse with layers of pebbles; cross-bedding in the less typical areas is also characteristic and very strikingly brought out by weathering and storm roller zones occur. The olive shale beds in places show sun-crack surfaces.

Prosser ('99) described and mapped these beds as Sherburne. Grabau ('06, 303) followed Prosser in his summary of the Ulster county section in the Schoharie guide, but in his discussion of the Ashokan formation ('19, p. 469-70) he concludes that these beds represent "a continental phase of the Upper Hamilton," a conclusion previously reached by Darton ('94*b*, p. 491). Recent investigations corroborate the Hamilton age of these beds, but indicate a lower position. Both the lower and the upper limits of the Ashokan are drawn on lithological features. The top of the Mount Marion beds in Greene county (Catskill quadrangle area) is found in the Marcellus formation 200± feet above the Otsego member. West of Kingston, in Ulster county, the fossiliferous marine beds apparently represent practically the entire Marcellus formation as they do in the northern Helderberg area (Albany county). The continental reds, the Kiskatom beds, appear lower down in the Hamilton going north from the type section where the Ashokan must include all of the Skaneateles, at least. In the Catskill region the upper Marcellus formation and lower part of the Skaneateles formation are represented,[1] but in the northern Helderbergs the 65 to 80+ feet of nonmarine beds below the reds (Rensselaerville falls; Goldring, *ref. cit.*) can only represent the lowest Skaneateles beds.

In the dark shales interbedded with the sandstone species of small crustaceans, *Beyrichia* sp. and *Estheria membranacea* Pacht are found. Two such zones were found in the Helderbergs (Rensselaerville section). Chadwick reports ostracods from the Catskill area and Cooper and the writer located, within the bounds of this formation, six *Estheria* zones, with ostracods, in both black and greenish shales in the area west of Kingston (Ulster county). These occurrences of branchiopods (*Estheria*) and ostracods (*Beyrichia*) with

[1] In a recent paper, Cooper (1941, p. 1893) considers the Ashokan of upper Marcellus age.

no other fossils indicate invasions of brackish water, through change in elevation.

These changes in Hamilton lithology have been summed up by the writer in a previous paper ('35, p. 167) as follows:

The changes in Hamilton lithology discussed above may be explained by the conditions under which sedimentation took place. Indications are that deposition took place in a bay widely open to the west with the source of sediments to the north and east. Thus coarser sediments should be expected eastward, nearer the source of supply. Enormous quantities of materials were deposited and the bay landward was gradually being filled in by nonmarine deposits, in the process becoming narrower and shorter. These deposits, therefore, encroached upon previous marine deposits. At times changes in level permitted marine waters to cover areas of previous nonmarine sedimentation with the deposition again of beds with marine fossils.

For the Catskill area Chadwick reports, besides the ostracods found in the dark shales, *Archaeopteris* and *Protolepidodendron* among the plant remains, vertical burrows (*Scolithus*) and coiled burrows (*Planolithes clarkii* Prosser).

The equivalent of the Ashokan formation on the Coxsackie quadrangle covers a broad belt in the northern portion of the quadrangle, reaching a maximum width of about four miles north of the Grapeville area. The belt narrows to a width of one mile west of Urlton, five-eighths of a mile on the north side of the Catskill valley and three-eighths of a mile at the southern boundary where there is a thickness of at least 275 feet, probably more. In the northern portion of the area the thickness seems to be variable and has been estimated as between 250 and 350 feet. The "Ashokan" of the Coxsackie quadrangle shows an alternation of flags, with thin-bedded sandstones, olive shales and grayish, cross-bedded sandstones, sometimes noticeably coarse. Occasional pebble beds are seen. The flag beds are not typical but in many places have been quarried for flagstones. They are gray, bluish gray and greenish in color, with an occasional heavy bed weathering rusty or reddish brown. Clay balls mark certain surfaces and the heavier-bedded sandstones show tide flat surfaces and ripple marks. Thin beds of dark shale occur occasionally but olive shales are predominant. Sometimes these shales are thin-bedded but usually they are sandy and break blocky or give a "knotty" appearance and they tend to weather rusty brown or decidedly reddish brown. Plant remains are abundant and worm burrows are found; in one locality (*see* below, page 273) fossils were collected in the flag quarries, indicating a marine invasion.

Several localities are excellent for study. In the southern portion of this belt on the north side of the Catskill valley, in the gorge of the Potic creek immediately north of School No. 10, a section about one-half mile long is exposed. In the gorge itself are found greenish and gray sandstones and olive, sun-cracked, blocky-breaking shales. Ripple marks and tidal markings are exposed on the surfaces of the heavy sandstone beds, one of which, three feet thick, is exposed in the west bank. Certain of the greenish sandstone beds and even some of the darker ones have a "knotty" appearance, as though the materials were stirred up by currents. The olive shales have weathered rusty brown. The gray flags, which when fresh have a greenish tinge, display an abundance of plant remains. All the characteristics displayed in this section indicate continental and nearshore conditions expected in the area of an encroaching delta.

South from Urlton, along the west side of Potic creek, almost continuous exposures are seen on one side or the other of the road from a point about five-eighths of a mile south-southeast of the village. The usual alternation of shales and sandstones is shown. About an eighth of a mile south of the junction with the lane to the west, old flag quarries in the woods on the east side of the road are worth study. Tide flat surfaces are well displayed on the heavy sandstones. One six-foot bed has weathered brownish red, but when broken is quite olive-green or has a mottled appearance. This bed occurs in the lower portion of the "Ashokan." In the spillway of the Potic reservoir (Catskill village water supply) there is a fine exposure of olive-green, sandy shales with sun-cracked surfaces, "knotty" shales and sandstones (figure 49). Plant remains are abundant, probably in large part *Eospermatopteris* since a flattened trunk of that seed-fern, eight inches in diameter, was located here. Worm burrows are also present in some of the shales, particularly the "knotty" ones. Near the top of the spillway is a six-inch seam of blue-black shale. Joint planes are seen to cut in many directions. Downstream from the spillway, above and below the bridge, the section continues through cross-bedded gray sandstone, heavy-bedded green sandstone and "knotty" olive shale. Turning east from the junction for a quarter of a mile along the Limestreet-Gayhead road sun-cracked olive, micaceous, sandy shales are found well displayed along the east bank of the stream south of the bridge. Turning west, up the hill, from this junction old flag quarries may be seen on both sides of the road in cross-bedded, blue-gray sandstone with heavier flag beds. The one on the south side of the road is more extensive, and in the heavier flag beds fossils are found, quite numerous on certain

Figure 49 Ashokan olive shale and sandstone constituting the spillway of the Potic reservoir (Catskill village water supply), about two miles south-southeast of Urlton. Trunks of the seed-fern *Eospermatopteris* have been located here. (Photograph by E. J. Stein)

surfaces and indicating a return of marine conditions. *"Spirifer" granulosus* is fairly common; *Modiomorpha (Nyassa?) subalata* is not infrequent; a smaller fine-ribbed *"Spirifer"* also occurs and crinoid stems. Plant remains are abundant on certain surfaces, others show clay balls. The lower boundary of the Kiskatom beds has been drawn one-quarter of a mile to the west on the basis of outcrops to the north and south, but typical red beds are first found in this section in the hill five-eighths of a mile to the west.

North from here to the Medway-Grapeville-East Greenville road and to a large extent beyond to within a mile and a half of the Albany-Greene county line the area covered by the "Ashokan" formation has a mantle of glacial deposits with only an occasional rock outcrop. Typical exposures may be seen along the east-west road from Stanton Hill to Newrys and the roads joining it from the north and south. One mile and a half due east of Newrys and five-eighths of a mile east of the junction with the road to Alcove plant remains were found in layers about one inch thick. They are undoubtedly the foliage of a tree fern and strongly suggest *Eospermatopteris*.

From a point about a mile north of Newrys, where the lowest "reds" appear, a fairly continuous section may be studied along the road north-northeast past School No. 15 and then to the right along the abandoned road leading to the western arm of Alcove reservoir where the highest fossiliferous beds of the Hamilton (Marcellus) appear about at the 800-foot contour line.

Near the southern boundary of the quadrangle the "Ashokan" beds include at least the uppermost portion of the Marcellus formation and possibly the lowest part of the Skaneateles formation. In the northern part, where the fossiliferous Hamilton extends practically to the top of the Marcellus, the "Ashokan" beds represent the Skaneateles, but apparently not all of it. Though the flag beds are not typical, it has seemed advisable in mapping, to continue northward from the Catskill area the separation of these nonred, nonfossiliferous (practically) strata from the red beds above.

Kiskatom beds. The continental red beds of the Catskill front and the northern Helderberg area (Prosser, '99; Darton, '94) were long regarded as the Oneonta beds (*Onteora* of Chadwick, '33), of Ithaca age. It is now known that in the Catskill front the Ithaca is to be looked for in the "Catskill" beds (*see* Chadwick, '32, Geological Society meeting abstract; also, '33, '36). The base of the Upper Devonian (Geneseo), according to Chadwick, is marked by a heavy (25-foot) conglomerate bed seen in North mountain, near the Catskill House, with the 300 feet of heavy sandstone below regarded as the Tully equivalent (Chadwick).

The Kiskatom beds (Chadwick, '32), typically, consist of an alternation of red and greenish or gray sandstones with interbedded green and red shales, sometimes dark shales. The sandstones are in general heavy-bedded, sometimes very coarse and carry pebble beds in places, particularly in the upper part of the formation; cross-bedded, gray sandstones are also characteristic and storm roller zones occur. Chadwick (conversation in field) has estimated about 2300 feet of these beds in the Catskill front where they apparently have their maximum thickness. In this area they include the entire Ludlowville and Moscow formation and the upper part of the Skaneateles formation (*see* footnote page 268); west of Kingston, probably no more than the Ludlowville and Moscow, if all of the former; in the northern Helderbergs and on the Durham quadrangle the major part of the Skaneateles, the Ludlowville and Moscow. In the Schoharie valley red beds appear first in the equivalent of the upper Ludlowville in the Panther Mountain member; in southeastern New York, the Port Jervis region (Orange county), no reds appear in the Hamilton beds.

As typically seen in the Catskill front and west of Kingston no marine fossils occur in the Kiskatom beds. Plant remains are abundant. Chadwick cites for the Catskill-Kaaterskill area species of *Archaeosigillaria, Sigillaria* ?, *Archaeocalamites, Archaeopteris, Eospermatopteris, Psilophyton, Rachiopteroides* and *Protosalvinia* (spore cases). He also reports the freshwater clam *Amnigenia* (*Archanodon*) *catskillensis* (Vanuxem), the phyllopod crustacean *Estheria membranacea* Pacht, two species of the ostracod *Beyrichia,* the "worm burrow" (?) *Planolites clarkii* Prosser and a variety of fish remains. On the Durham quadrangle one and one-half miles south-southwest of Potter Hollow, the Portland Point member (basal Moscow) has been located in the stream bed. Above it occur typical soft Hamilton shales with fossils. This zone is located above a great thickness of reds, representing the entire Ludlowville formation and a considerable part of the Skaneateles. Within the red area three *Estheria* zones have been located (Prosser, '99, p. 257-59; Chadwick. *See* Goldring, '35, p. 167). Well up in the Moscow, about 225 feet above the Portland Point on the east slope of Steenburg mountain (Gilboa quadrangle), fish plates were found by Cooper and the writer in a heavy calcareous sandstone, with ostracods occurring in the sandstone and interbedded dark shales. Above this nothing was found in the Hamilton beds except plant remains (*Eospermatopteris, Protolepidodendron*). The same or a similar fish horizon was also located in the summer of 1938 along the road

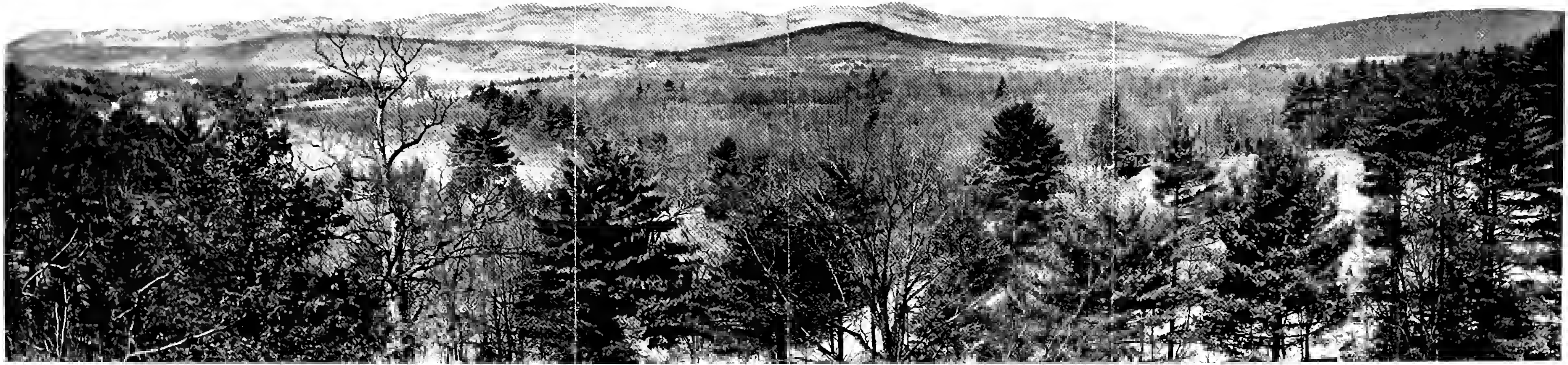

Figure 50 View southwest to northwest from Paradise point just north of the four corners on the Athens-Leeds road. At the left near the square-built house is seen the Esopus bank along the Catskill with Leeds to the right; in the right foreground lies the southern end of the anticlinal hill, capped mainly by Becraft and Alsen limestones. The Hamilton hills in the middle distance, with Potic mountain conspicuous at the right and Cairo Roundtop (Kiskatom beds) at the center, are backed by the "wall" of the Catskills. (Photograph by E. J. Stein)

on the south side of Ohio (Ohayo) mountain north of the Ashokan reservoir. In the reds on the south side were found three *Estheria* zones.

The Kiskatom beds extend along the western border of the Coxsackie quadrangle for almost its full length. This belt has a width of one mile in the north, a maximum width of four miles near the middle of the quadrangle, and a width of about three and one-half miles at the southern border where the greatest thickness is found and dips are higher. At the north there are only a few hundred feet of red beds and probably no more than the upper Skaneateles formation is represented, since the bulk of the thickness of the Kiskatom beds occurs over the border on the Durham quadrangle. West of Urlton, in the latitude of Result, there is an estimated thickness of about 1200 feet, involving the Ludlowville as well as part of the Skaneateles. At the extreme south there must be well over 2000 feet of red beds, more than 1000 feet in Cairo Round Top (figure 50) alone, which means the Kiskatom here includes a considerable portion of the Moscow, as well as the entire Ludlowville and upper Skaneateles.

As typically exposed the "reds" of the Coxsackie quadrangle comprise an alternation of red and green shales with thin or heavy-bedded, sometimes coarse, red, green or gray sandstones and gray cross-bedded sandstones. Sometimes pebble layers are interbedded in the sandstones and storm roller zones occur. Outcrops are numerous, particularly along roads, and quarries make good study localities. In the northern part good outcrops are found west of Newrys along the first roads north and south. The schoolhouse, opposite the road south, rests upon a heavy bed of red sandstone, three or four feet thick, dipping gently south-southwest. Intersecting joint cracks are well displayed, the main ones striking almost at right angles; and the surface shows strong glaciation, with the striae running roughly north and south (S. 8° W.). Seven-eighths of a mile north-northwest along the second road a higher red sandstone bed shows storm roller conditions.

Along the road from Urlton west through Result and Place Corners, and some of the north and south side roads, many outcrops give a good section through the formation. The red beds may be studied to advantage in the quarry on the north side of the road one mile west of Urlton. Another quarry is located one and one-quarter miles north-northwest of Result on the west side of the road and three are found within a distance of half a mile on the west side of the first northerly side road three-quarters of a mile east of

Place Corners. Along the road running south and southeast from Gayhead across Indian ridge, and the roads extending southward from this, outcrops are also abundant and a quarry on the south side of the road near the middle of the ridge exposes about 20 feet of red and green shale and sandstone. On the east side of Indian ridge, one and three-eighths miles south of the road junction, big blocks of conglomerate interbedded in red sandstone have been used in the foundation of an old barn (east side of road). The source of this conglomerate bed was not located and is believed to be higher up in the Kiskatom formation.

The area on the north side of the Catskill valley is heavily banked with glacial material, but south of the Catskill are numerous outcrops, particularly along the northwest-southeast road at the base of Cairo Round Top, the southwesterly road out of South Cairo and the road turning to the west three-quarters of a mile northwest of the village. There are good outcrops along the main highway on the outskirts of Cairo and three-quarters of a mile southeast of South Cairo. In the "gorge" of the Catskill (figure 65) one mile north of Cairo, upstream from the bridge, red and green sandstones are exposed in the stream bed and south bank, with gray, cross-bedded sandstones above. This gorge is interesting also as a post-glacial feature. One mile due south of Cairo a large quarry gives opportunity for the study of red and green shale alternating with thin red sandstone beds. Cairo Round Top shows good exposures higher in the Kiskatom. The cliffs are formed by the heavy red sandstone beds. The hill can be climbed to better advantage from the west side where there is a good trail.

One of the best sections for study, and a most accessible one, is found along the Leeds-South Cairo road in the south bank of the Catskill at the eastern boundary of the formation. Green and red sandstones with interbedded green and red shales are exposed. Some dark shales are interbedded and in one bed at the extreme eastern end of the exposure the little crustaceans *Estheria membranacea* Pacht and *Beyrichia* sp. were found. Here are the typical reds with the "cornstones" which are characteristic of the lower beds. Two layers are exposed, the lower one foot thick, the upper with a thickness of one-half foot. Chadwick (personal communication) reports thicknesses up to three feet. The surfaces of the "cornstone" show clay pebbles and also pebbles of rock (limestone etc.) and such surfaces continue through the entire thickness. Weathering gives to the "cornstone" the appearance of being filled with worm borings. One-quarter of a mile south of the junction of the state road with the side road south, in a ravine on the east side, mottled green and red beds appear. These are the basal Kiskatom beds. One-quarter of a mile west of this road junction the State highway crosses the small ravine formed by the Valje Kilje in which are exposed dark shales of typical Hamilton appearance, which hold a position above the typical reds. The writer searched but found no fossils here. Chadwick collected here in the summer of 1909, and recently donated to the State Museum, a few specimens of plant remains that apparently belong to *Eospermatopteris* and a few fragmentary specimens of thin-shelled clams, unidentifiable and possibly fresh-water species.

STRUCTURAL GEOLOGY

The Coxsackie quadrangle belongs to the same physiographic unit as the Catskill quadrangle of which Ruedemann writes (Catskill bulletin, '42*b*, p. 132):

The Catskill quadrangle in its structural geology is a segment of the Hudson Valley-Lake Champlain depression that extends from north to south between the Green Mountain-Taconic Mountain folds in the east and the Adirondacks and the Helderberg plateau in the west. The quadrangle, therefore, shares its principal structural features with the whole physiographic unit.

The structural geology of the Saratoga and Schuylerville quadrangle to the north has been treated in full by Cushing and Ruedemann ('14), while that of the Capital District (Albany, Cohoes, Troy and Schenectady quadrangles), immediately north of the Coxsackie area has been described by Ruedemann ('30, p. 130-62; *see* Goldring '35, p. 192-99) in a detailed discussion which he has repeated in large part in his Catskill bulletin, since this "area is separated from the Catskill only by the Coxsackie quadrangle" and the description quoted gives "a general survey of the tectonic conditions in the Hudson valley in the (Catskill) area" (*ref. cit.*).

THREE STORIES OF FOLDING

Ruedemann recognizes for the area "three stories of folded rocks one above the other and each separated from the preceding by a distinct plane of unconformity and erosion" ('30, p. 157).

The first period of folding, Precambrian in age, resulted in the formation of "several long barriers running in north-northeast to south-southwest direction across the district and forming two or more troughs." Two of the troughs have been positively recognized and designated (Ulrich and Schuchert, '02) as the eastern or

Levis trough and the western or Chazy trough, each characterized by a series of formations entirely different from that of the other trough (*see* page 45*ff*). In discussing the western trough, to the southern extension of which he has given the name Lower Mohawk trough ('14, p. 140), Ruedemann remarks that "a minor barrier seems to have separated this trough in the west, at least at certain times, from the series of formations found in the upper Mohawk valley" ('30, p. 132). These troughs persisted from Precambrian through Ordovician times. The formations of the two troughs are now in close contact due, principally, to the fact that folding and faulting along numerous fault planes have carried the rocks of the eastern trough westward. Ulrich, according to Ruedemann, soon became convinced of the existence of a third trough farther east which the recent work of Prindle and Knopf seems to corroborate. They distinguish in the Taconian area a "Taconic" series, dominantly argillaceous rocks (the above eastern series) and an "eastern sequence," dominantly carbonate rocks, in the Mt Greylock range ('32, p. 264, 268, 269; *see* page 307).

Of the Green mountain and Quebec barriers which delimited Lower Cambrian sedimentation and which Ruedemann believes "must have been present at the beginning of Lower Cambrian time and arisen, probably as low folds, in Precambrian time," he writes (*ref. cit.*):

They are prenuncial in their direction and location of the much greater folding in Ordovician and Carboniferous time. They arose in a geosyncline, or broader trough (Schuchert's eastern proteozoic geosyncline) that extended in later Precambrian time from the northern Atlantic (or its ancestor Poseidon), beyond Newfoundland, in a southwest direction to the present site of the Gulf of Mexico. To the east of it were still broad "borderlands of the continent" (Nova Scotia in the north, Appalachis in the south), which furnished the material for the great thicknesses of formations in the eastern trough.

According to general assumption the second folding (strike N. 20° E.) which affected the rocks of this region took place at the end of the Ordovician period and has been designated the Taconic folding because the Taconic mountains on the New York-Massachusetts boundary were involved. This folding was termed the Taconic Revolution (Dana) because it was believed to have extended over a wide area in eastern North America. Clark ('21), on the other hand, in a recent paper claims that the folding was localized in eastern and northern New York. In this connection Ruedemann writes:

In this region, however, we have evidence of a very extensive folding first, followed by equally profound and widespread overthrust faulting.

The rocks of the eastern trough are everywhere intensely folded; those of the western trough are only faulted, or but slightly folded, as in the Helderbergs, by a later post-Devonian revolution.

Being for the most part incompetent shales, the rocks are mostly closely folded, the folds turned over or bent over westward, the packed folds producing the so-called isoclinal folding, where all beds, the anticlines and synclines being deeply worn off, seem to incline in the same direction in our shale belt toward the east, and all striking in the general north-northeast direction (N. 20° E.). Where, however, harder and thicker beds are present, as the Cambrian quartzites and grits of the Normanskill shale, the anticlines and synclines are less compressed; broad symmetric folds are often well shown. . . .

The folding dies out gradually toward the west. . . . An excellent section from the folded into the unfolded region was formerly displayed along the canal and the Mohawk river between Cohoes and Rexford. . . . Here could be seen the close, crumpled folds in the eastern section, with occasional broader folds where harder beds were involved, and the gradual opening of the folds westward, until they disappeared rather abruptly near the boundary of the Snake Hill and Schenectady beds, where evidence of overthrust fault-lines becomes visible. West of this zone the Schenectady beds are undisturbed.

At the end of the Taconic folding, or rather as a special phase of it, extensive overthrusting took place. We have recognized two major thrust planes in the Capital District. . . . One of these separates the intensely crumpled sediments of the eastern trough from the undisturbed formations of the western trough, or comes to the surface along the Snake Hill-Schenectady boundary. This fault, which is probably a nearly horizontal thrust fault, is of the character of a "scission" fault or "charriage." The eastern formations have been pushed westward over this plane for an unknown, but probably considerable distance. . . . A considerable portion of the crumpling of the shales which once separated the two troughs has been completely overridden.

It is . . . our conviction that the overthrust is dissolved into a multitude of smaller overthrusts. . . .

The multiple overthrust structure appears to be, on a small scale, what the Germans have called "Schuppenstruktur," the separate "Schuppen" being pushed one over the other like scales. It is an imbricated structure, produced by many small overthrust faults, that has the total effect of a general overthrust. This structure has recently been termed "shingle block."

We ascribe to this structure the rather indefinite boundary line between the Schenectady and Snake Hill beds on one hand, and the Snake Hill and Normanskill on the other. . . .

Logan's Line

While the Schenectady-Snake Hill and the Snake Hill-Normanskill overthrust lines are obscure, the overthrust which brings the lower Cambrian beds on top of the Ordovician east of the Hudson river is very distinct and sharply defined. This overthrust is supposed to be a segment of a more or less interrupted overthrust line that extends from Canada through Vermont and New York south, perhaps to the southern Appalachians. This line has become known as "Logan's line" after the former director of the Canadian Survey, Sir William Logan, who first pointed to its long extension and structural importance. . . .

The Cambrian overthrust line, where the overthrust plane now comes to the surface, passes from the northeast corner of the State, from Easton to Schaghticoke, Grant Hollow, Lansingburg, Troy, where it crosses the Rensselaer Polytechnic Institute campus, Defreestville and Schodack Depot and Schodack Center. We have traced it through the eastern part of the Schuylerville quadrangle, where it is wonderfully exposed. The foremost locality there is Bald mountain, where quarries in the Bald mountain limestone expose this Ordovician limestone at the base, with the Lower Cambrian (Schodack shale and limestone) above forming the mountain. Along the thrust plane a mass of ground-up material (mylonite), in one place 30 feet thick, is seen. That is the fault breccia; here, however, since much of the material was shale, pulverized into a black powder with many rock fragments floating in it. In the Capital District, the fault breccia is splendidly exposed at the Rensselaer Polytechnic Institute campus and in the Poestenkill. . . .

The question of the extent of this overthrust in New York has been a mooted matter. It was the writer's early contention that it is a major thrust ('01; '09, p. 191), while Dale ('04), would rather consider it as of local development only. We have fully discussed this problem before ('14, p. 109) in relation to the exposures on the Schuylerville quadrangle and especially in regard to Bald mountain. . . . We have in the former paper pointed out that the Snake Hill beds and to the south of them the Normanskill beds, pass successively under the Lower Cambrian overthrust plane, thereby indicating the great width of movement of the overthrust mass. . . .

There is considerable and quite conclusive evidence that the thrust plane is irregular in its hade, through folding; for while the thrust plane is very slightly inclined at Bald mountain and the Moses kill, it is steep east of Willard mountain and in the neighborhood of Troy. Also the sinuous form of the fault line near the southern margin of the map in Schodack is due to the unevenness of the plane through later folding. That these irregularities of the line are due to folding of a character transversal to the general northeast strike of the beds is indicated by the fact that, where the hade is steep, the Cambrian rocks descend deeper than where it is flat, these deeper appearances of the Cambrian corresponding to depressions or synclines.

There is considerable evidence extant of folding of the entire region long after the Green mountain or Taconic revolution, marking the Silurian-Ordovician boundary and . . . considered responsible for the principal folding and overthrusting of this region . . . (*ref. cit.*, p. 133-45).

The second story of folding was cut off by a great plane of unconformity and erosion, now seen at the base of the Helderberg cliff in the Capital District westward in the Schoharie valley, and southward through the Hudson valley. Upon this rests the third or last story of folding, feebly displayed in the southernmost part of the Helderberg rocks of the Capital District (Ruedemann, '30, p. 151-57; Darton, '94*a*, p. 447; Prosser and Rowe, '99, p. 343), but strongly affecting the Silurian-Devonian limestone belt of the Middle Hudson valley (*see* Davis, '83*a*; Darton, '94*a*; Van Ingen and Clark, '03; Chadwick, '10) and the Rensselaer grit plateau on the east side of the river in the Capital District (Devonian of Ruedemann, '30, and the writer, '35; Silurian of Dale, '93; Cambrian (?) of Prindle and Knopf, '32). This folding has been assigned to the late Carboniferous to Permian Appalachian Revolution (*see* below).

> During this period [Permian] Appalachia was thrust westward against the geosyncline, crushing and folding the Paleozoic formations into a mountain chain that extended unbroken from Alabama to Nova Scotia. . . . Practically all the structures displayed in the modern Appalachians south of New England date from this disturbance. Farther north the older formations of the geosyncline had been more or less extensively deformed by the Taconic (Late Ordovician) or the Acadian (Devonian) disturbance, and there it is difficult to distinguish in most places between the effects of the Appalachian revolution and those of the earlier orogenies. South of New England, however, the movements in Appalachia had heretofore been confined to a belt wholly east of the geosyncline, and now, in the Permian, all the Paleozoic formations were folded together. (Schuchert and Dunbar, '30, p. 277).

The Cambrian and Ordovician formations of the Capital District and Hudson Valley region, which were already strongly folded during the Taconic Revolution, were again subjected to compressing and lifting forces in the Appalachian Revolution. As noted above, Ruedemann attributed "to this cause the folding of the great overthrust plane and possibly the cross folds observed in the Capital District" ('30, p. 148). In his Capital District bulletin (p. 157) Ruedemann concluded that the Taconic folding, which had a strike N. 20° E. in the Albany area, was but little affected by the later folding for which in the limestone belt south of Albany he had inferred, a nearly north-south trend. In a recent study suggested by Ruedemann, Pepper by measuring the cleavage reached the unsuspected result "that much of the deformation in the Ordovician beds along the Hudson river has been caused by the Appalachian rather than the Taconic orogeny. . . . Northward from Kingston, New York, folding caused by the Appalachian orogeny trends about N. 10° E. . . . parallel to the axis of Taconic (Ordovician) folding" ('34, p. 186). From readings taken "at most of the good Esopus and Schoharie outcrops along the strike for some forty miles" it was found that the "cleavage almost invariably had a trend of N. 25°-30° E."

AGE OF THE FOLDING

The long-prevalent belief that, aside from the Precambrian folding that furnished the grain of the continent, only two orogenies, the Taconic and Appalachian, affected the northeastern area has been modified in recent years. In this connection Schuchert ('30, p. 701) states:

> It has long been clearly established that the Paleozoic formations of the Appalachian geosyncline from Alabama to New York were made into mountains at some time after the early Permian, and this unanimity of opinion has led most geologists to conclude that this orogeny was continued from New Jersey to Newfoundland. On the other hand, the fact that the pioneer geologists of eastern Canada had clearly demonstrated that the Acadian part of the Appalachians was folded in the main during the Devonian, with other orogenic times at the close of the Ordovician and during the late Carboniferous (close of Mississippian = Windsor and during the Pennsylvanian), has never taken rootage among the geologists of the United States as it should have. . . .
>
> The writer has long been trying to break away from this prevalent view, but it was not until the summer of 1929 that observations in the field finally forced him to turn about and face the facts.

Schuchert distinguishes in Greater Acadia (New England states, eastern New York, Maritime Provinces of Canada and Newfoundland) the St Lawrence geosyncline (divided into two channels; the western or Chazy, the eastern or Levis), at the north and west, and the Acadian geosyncline, the two troughs separated by the New Brunswick geanticline which extended through southern Newfoundland, New Brunswick and along the New England coast (p. 703; figures 1, 2). The outer borderland or geanticline of Nova Scotia is now largely warped and faulted into the Atlantic ocean. Four orogenies are distinguished by Schuchert in Greater Acadia: the latest Cambrian "which separated the Saint Lawrence geosyncline into two seaways" and is only known in northwestern Vermont; the late Ordovician or Taconian, "with intense isoclinal folding and overthrusting," that extended from Pennsylvania and eastern New York through the Taconic and Green mountain region northward across the Gulf of St Lawrence and central Newfoundland; the Devonian or Acadian, "when the remainder of the Saint Lawrence geosyncline, the New Brunswick geanticline, the Acadian trough and the borderland Novascotis were folded almost wholly into permanent dry land" (*ref. cit.* p. 708); the Permian or Appalachian, which affected the Maritime Provinces and "refolded (crossed) the southwestern part of the Acadian geosyncline." The folding of the Appalachian Revolution, which affected eastern New England and eastern New York, extended in a northeast-southwest direction from Nova Scotia southward into Alabama and the Ouachita mountains of Arkansas. Schuchert's figure 4 shows the middle Hudson River region folded by only two orogenies, the Taconian and the Appalachian. There is no doubt about the presence of the Taconian orogeny in the Middle Hudson area, the classic area for it, and Clark in 1921, after a study of the literature on the subject, came to the conclusion that "the only orogenic movements at the close of the Ordovician of which we have any record were localized in eastern and southeastern New York State" (p. 163). He also suggests that much of the deformation beyond this region which has been "ascribed to the Taconic Revolution may have been due to the disturbance which characterized the Devonian in this area" (*ref. cit.*).

Schuchert who has recognized the influence of the Taconic orogeny as far north as Newfoundland, in the New Brunswick geanticline as well as in the two troughs (St Lawrence, Acadian), in this connection writes ('30, p. 710):

It is the main object of the present paper to show that the statements of Dana in his "Manual" and of Logan in his "Geology of Canada" are correct, and that the Taconic folding does continue far to the northeast. . . .

It has been maintained for years that the intense folding and sheet overthrusting (nappes) east of Lake Champlain in Vermont is not only of the Appalachian type but that this structure, including the Champlain-Saint Lawrence overthrust, was not made during the close of the Ordovician but was coincident with the Appalachian revolution during Permian time. The writer, however, holds with Dana, Logan, Dawson, Alcock and Ruedemann that all this deformation took place during the late Ordovician. Furthermore, the area of Taconian folding in the western and northern parts of the Saint Lawrence geosyncline from Albany, New York, through Vermont and southern Quebec, has not again been refolded, but in all probability was epeirogenically elevated and more or less normally faulted by the Devonian crustal disturbances. On the other hand, the southeastern part of the Saint Lawrence geosyncline and more especially the Acadian trough were refolded and greatly intruded by granites during the Acadian disturbance of Devonian time. Finally, the Appalachian revolution did decidedly refold the Acadian geosyncline from the Gut of Canso in Nova Scotia to eastern Massachusetts and Rhode Island and the eastern part of the Saint Lawrence geosyncline was more or less warped and strike faulted as far south as the Catskills of New York.

Through more recent work (Schuchert and Longwell, Billings and Williams, Longwell, Chadwick and Kay) the opinion has become prevalent that the Hudson Valley region was also affected by the Acadian Disturbance. Schuchert and Longwell ('32) from their study of Paleozoic deformations of this region, reaffirm the reality of the Taconian deformation there and the continuity of the belt of deformation "from southeastern Pennsylvania to eastern Newfoundland," and state that "in general the severity of the movement increased toward the northeast" (p. 323). They continue:

It is clear also that the rocks of the Hudson Valley were compressed again sometime after the Middle Devonian. Davis, Van Ingen, Ruedemann and others assumed that this later movement was contemporaneous with folding of the southern Appalachians, in the late Paleozoic. Perhaps this interpretation is correct; but we wish to emphasize that the direct evidence now available serves only to date the later folding as post-Middle Devonian. It is not inconsistent with the facts to postulate that the movement was part of the Acadian orogeny in southeastern Canada.

The authors (page 324) regard as insecure Keith's position in holding the view "that the intense deformation of Cambrian and Ordovician rocks in northwestern Vermont resulted during the Appalachian revolution (1923)," which would extend the late Paleozoic movement "much farther north than the Hudson valley"; but they add that "the possibility cannot be denied that both the Acadian and the Appalachian movements made some contribution to the folding and metamorphism in western New England and eastern New York." The suggestion of E. B. Bailey ('28, page 66ff) "that the deformation in western New England is of 'Caledonian' date, and that the front of the 'Hercynian' folded belt, swinging southwest from eastern Massachusetts, crosses the older belt in southeastern New York," is regarded as an interesting speculation and they present as two serious objections to the view: the much more prominent part played by the Taconian folding in "producing the structural features from the Hudson valley to the lower St Lawrence Valley" and the lack of "the slightest evidence, in trend lines or other structural features, that the later folding cuts across the earlier in southeastern New York." (*ref. cit.,* page 325).

Billings and Williams ('32) in a discussion of the Acadian folding in the Appalachian highlands write (page 25):

With the advent of the middle Devonian the Acadian Revolution began. The great land mass of Acadia began to migrate toward the northwest and for the second time during the Paleozoic the sedimentary rocks of New England were caught in the jaws of the great vise. . . . It is probable that the rocks of the whole New England-Maritime Province were folded at this time, but in many localities it is difficult to decide definitely whether the folds are products of the Acadian or the Appalachian Revolution. We can say with assurance that New Brunswick, Maine, Vermont, western New Hampshire and eastern New York were caught in the Acadian Revolution.

Longwell ('33) in his introduction to the geology of "Eastern New York and Western New England" discusses sedimentation and deformation in the Hudson valley. The latter is concisely summed up as follows (page 5):

Since Devonian time the region has been entirely emergent, so far as can be judged from sedimentary evidence. During the late Devonian western New England was uplifted strongly and shed large volumes of sediment to the west. Probably this uplift was part of the Acadian movement, which was especially severe in southeastern Canada.

The Appalachian movement near the end of the Paleozoic era deformed the Devonian strata in the southern part of the Hudson Valley, but farther north the results of this movement, if they exist, have not yet been differentiated from those of the older deformations.

Chadwick and Kay ('33, page 7) point out that there is evidence of at least two deformations in this region, the first definitely assigned to the Taconic disturbance.

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

Chadwick at various times, especially in the field (1938 and previous years), has discussed with the writer the age of the folding in the Hudson valley. He expressed the belief that north of the Kingston region the limestone belt east of the Catskills and Hamilton hills shows nothing more than miniature folds, accompanied by faulting and thrusting, which represent merely crumplings upon the toe of the rejuvenated Normanskill overthrusts, as suggested in his paper on the overthrust fault at Saugerties ('10, p. 160; *see* Davis, '83*a*, Van Ingen and Clark, '03). He has pointed out that the folds in the area of the Catskill and Coxsackie quadrangles fail to agree in direction with the Appalachian folds which extend in a northeasterly direction to the vicinity of Kingston, and also fail to agree in size. In connection with this view, he considers it noteworthy that, in the Helderberg mountains north of these areas, the folding ends where one of the major overthrusts in the underlying Ordovician beds, developed in connection with the Taconic folding (*see* above), emerges from beneath the Coeymans-Manlius escarpment (*see* Ruedemann, '30, geologic map and p. 151-57; Darton, 94*a*, p. 444-52).

COXSACKIE AREA

The area of the Coxsackie quadrangle may be regarded as divided into two belts, an eastern belt of Cambrian and Ordovician rocks, belonging to the eastern or Levis trough, and a western one of Silurian and Devonian rocks deposited in the western or Chazy trough. Due to the thrusting westward of the beds of the eastern trough the Silurian beds of the western trough rest upon the Ordovician Normanskill beds of the eastern trough. Features due to the Taconic Revolution may be studied in the eastern belt, while the western belt displays later folding and faulting belonging to the Acadian Disturbance or Appalachian Revolution (*see* figure 51 and discussion above).

Eastern Belt

Strike and dip. There is a general strike for the rocks of this belt of about N. 20° E. Due to the intense folding the rocks have variable dips, even nearly vertical. The Cambrian Schodack beds may be studied to advantage along the highway and along the New York Central railroad tracks for a distance of about a mile and a half north of Poolsburg (figures 14, 52), and in the cut for the railroad spur (Castleton cutoff), just north of School No. 6. The strike in the railroad cut is N. 36° E. and the beds dip at an angle of 30°. Farther south the strike is almost due north and the dip has increased to 40°. In a road cut on the east side of the state highway, one mile south of Stuyvesant, black Schodack slate alternating with thin limestone bands strikes N. 12° E. and dips at an angle of 62°. At the north end of Nutten hook the strike is N. 28° E. and both Nassau and Schodack beds stand nearly vertical, but at the north end of the south hill, near the spot where the old warehouse stood, the dip is N. 36° E. at an angle of 21° (figures 16, 17). The

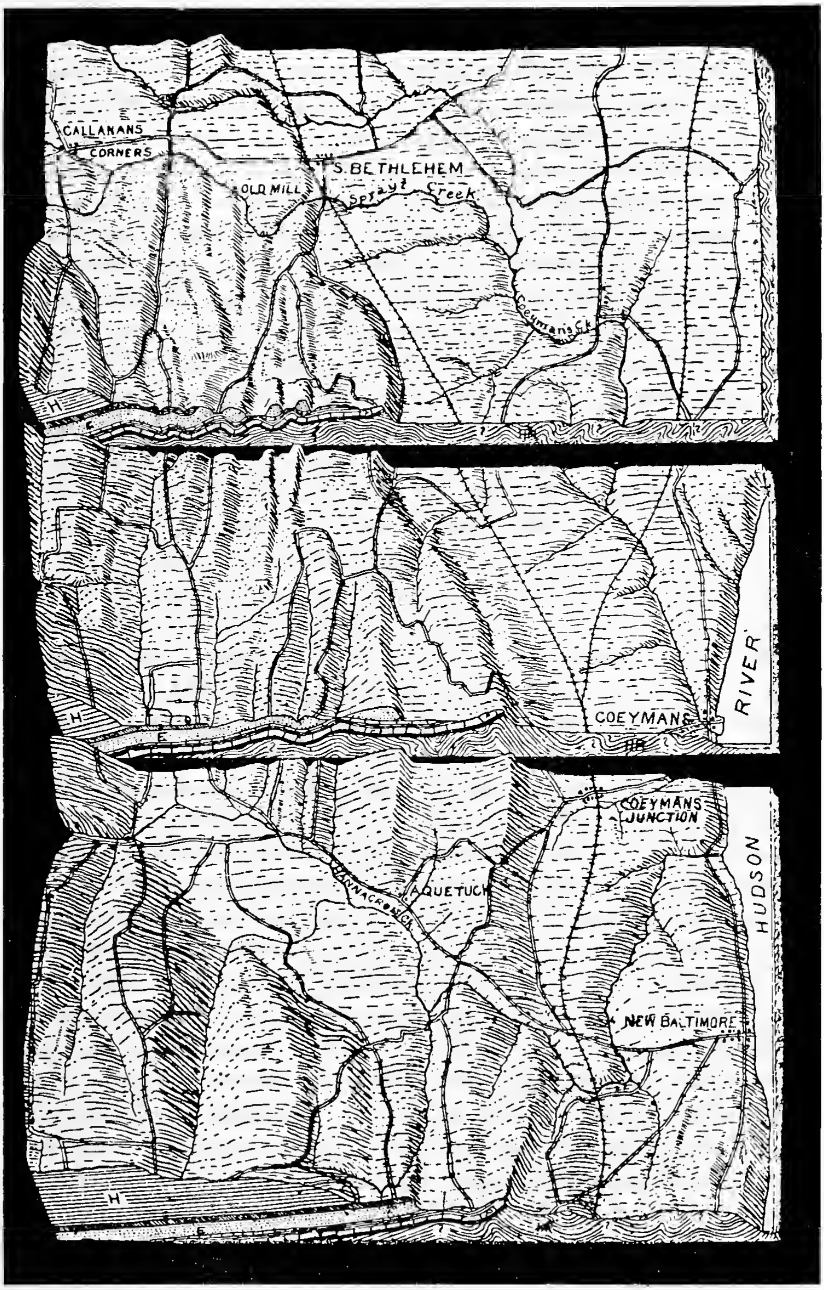

Figure 51 Stereogramic map and sections of the southwestern part of Albany county. Scale, one and three-tenths miles to one inch; vertical scale considerably enlarged. *HR*, Normanskill formation ("Hudson River" beds); *P*, Coeymans [Pentamerus] limestone, underlain by Manlius limestone and Rondout waterlime and overlain by New Scotland and Becraft limestones; *E*, Esopus shale and Oriskany sandstone; *O*, Onondaga limestone; *H*, Hamilton beds. (After Darton)

rocks of this area have been much faulted and, at the southern end, crumpled. The Nassau beds in the brook one-half mile east of Stockport station strike N. 13° E. and dip at an angle of 45°. There is an enormous thickness of Nassau beds of about a mile in the area north and east of Stockport station, but how much of this thickness is due to isoclinal folding has not been ascertained.

The general strike of the Normanskill (Ordovician) beds is indicated by the ridges developed on the grit (mainly) and chert beds, of which Flint Mine hill, striking N. 20° E., is a good example (figure 2). These ridges are due not only to the hardness of the beds but also to the steep angle at which they stand. The dip, however, is variable. A quarter of a mile north of the edge of our quadrangle a road turns west over the Helderberg escarpment from the South Bethlehem-Ravena road. About 115 feet above the road junction the Rondout waterlime rests upon Normanskill dipping in a southwesterly direction at such a low angle that at first glance the appearance given is that of a disconformity rather than an angular unconformity. Along the west side of the Ravena road, about one-eighth of a mile south of the northern border of the quadrangle Normanskill sandstones and shales dip N. 88° E. (strike N. 2° W.) at an angle of 42°. At the top of the Ravena hill (east side), along the road to Aquetuck, Normanskill beds dip S. 82° E. (strike N. 8° E.) at an angle of about 80° in the east arm of an anticline. Here the Manlius limestone, five feet above (aneroid), dips S. 38° W. at an angle of 12°. On the east side of the river along the Castleton cutoff, three-eighths of a mile south of the Rensselaer-Columbia county line, in the excellent section in grit, shale and chert, the strike was found to be N. 84° E. and the angle of dip 62°. The ridge of Normanskill just east of the domed hill north of Climax is formed by Normanskill grit which strikes N. 23° E. and dips at angles of 65° to 90°. One mile to the south of the Climax road in the east end of the ravine south of the road to Bronks lake the Manlius limestone and Normanskill grit are in unconformable contact, the Manlius dipping steeply eastward on the east arm of an anticline while the Normanskill dips in an easterly direction at a flatter angle. South of Stuyvesant railroad station, in the northern end of the Deepkill section, the strike was found to be N. 31° E. and the angle of dip 80°. The strike is changeable here due to crumpling and folding of the incompetent shales. At the north entrance into Athens on the west side of the state road Normanskill grit, with interbedded black shale, strikes roughly in a north-south direction and stands nearly vertical.

Folds, faults, inliers. The general northeast strike of the folding in the Cambrian-Ordovician belt has been discussed above. The overturned isoclinal folding, where greater thicknesses of shales occur, is further complicated by crumpling and miniature folds. Where competent beds occur, such as the grit and chert of the Normanskill and the quartzite beds of the Nassau, folds are more open. It is the intense isoclinal folding which has brought about the development of the ridges so characteristic of the Normanskill belt on the west side of the river, well-exemplified in Flint Mine hill (Minneberg) and the ridges to the west (Berg Stuyffsink) and the east (Spoorenberg). Flint Mine hill (figure 2) has been interpreted as an anticline. The chert, which underlies the grit, forms the core of the hill and has an easterly dip. Berg Stuyffsink, however, is formed by easterly dipping grit and probably is part of a syncline. Cross-folding is seen in the chert, just west of the first house, along the lane crossing Flint Mine hill. Such cross-folds occur, but usually escape notice. One may be seen, also, in the southern end of the Deepkill section on the west side of the river across from Priming hook. In both cases cross-folding is accompanied by crumpling and slickensides; in the second locality several small anticlines are exposed. An excellent place to study folding where the more competent grits predominate was found in the vicinity of Matthew point and northward along the west bank of the river south of New Baltimore. Here are a series of abandoned quarries. In the large one north of the bend in the lane to Matthew point there is a wall 100 feet high in grit which has been folded into an anticline and syncline. The quarry at the point, in grit (largely) and shale, shows an excellent exposure of a syncline and pitching anticline (figure 23). South of Coeymans, along the river road, an anticline in grit may be seen above and below the bridge across the Hannacrois creek. Along the tracks of the New York Central railroad a cliff of Normanskill shale and grit extends for five-eighths of a mile north of the Rensselaer-Columbia county line. These beds, folded, contorted and slickensided, show the effect of folding in incompetent beds.

For the Cambrian belt Nutten hook is an ideal locality for the study of folding and faulting on a minor scale. This rock island, consisting of a north and south hill, is joined to the mainland by alluvial deposits. In the southern end of the south hill is shown a fault (figure 10) striking northeast, associated with a syncline and broken anticline with east-west axis (*see* page 57). Two roughly parallel faults, striking south-southeast cut the north hill and a minor fault is seen at the northeast end. The condition found here, fully described above (pages 61, 75), has been interpreted as brought about by faulting of a recumbent anticline and syncline, perhaps at the time of the overthrusting, perhaps during the later folding.

Another interesting study locality is found in Barren island which is composed entirely of Nassau green shales with numerous thin bands of green quartzites, dipping steeply to the west at the north end and steeply to the east at the south end. In places there is much contortion. This island, now connected with the mainland at Coeymans, is interpreted as a *fold inlier,* the core of a pinched anticline.

The most striking feature of the eastern belt is the overthrust which is considered part of the southern extension of the overthrust line known as *Logans line* (*see* page 281). This thrust carried the Nassau and Schodack beds westward for an unknown distance over the Ordovician beds, but today, through erosion, Cambrian beds only appear on the east side of the river. At the north the older Schodack beds overlie the Normanskill, and the contact between the two may be studied in the cliff along the east side of the New York Central railroad tracks from a point about two miles south of the Schodack Landing station to Poolsburg. One of the best places for study will be found about one-quarter of a mile south of School No. 6, where the state road approaches the cliff and where it is possible to climb down from above. Here the Schodack limestone, dipping at an angle of 40°, rests upon dark Normanskill shales at an angle of 55° (figures 14, 52). In the vicinity of Stuyvesant the Schodack beds rest upon the Deepkill shales and just south of this the thrust plane passes under the river. North and east of Hudson the Nassau beds rest upon Normanskill beds and somewhere at the north end of North bay the thrust plane passes under the river. The thrust plane to pass over the Ordovician beds on the west side of the river would have to be bent upward abruptly. All the above conditions would, therefore, indicate an originally undulating thrust plane affected by the later folding.

Through this thrusting and subsequent erosion an interesting feature has been developed. This is a *fenster* of Normanskill (grit, chert and shale) within the Nassau belt, seen along the eastern border of the Coxsackie quadrangle, from a point just east of the Columbiaville bridge for a distance of about three and a half miles north, but occurring in large part on the Kinderhook quadrangle along, and east and west of, Kinderhook and Claverack creeks, from Sunnyside through Stuyvesant Falls, Rossman (Chittenden Falls) and Stockport to the vicinity of Stottville (map 2). This is an example of an *overthrust inlier.* Within this Normanskill fenster at Stuyvesant Falls,

Figure 52 Overthrust of the Lower Cambrian Schodack formation upon the Ordovician Normanskill shale as seen on the east side of the New York Central railroad tracks, about two miles south of Schodack Landing. The Schodack limestone, conglomerate and shale form the cliffs on top; the contact with the Normanskill is close to their base, covered by talus. See figure 14. (Courtesy of the New York Central Railroad)

Figure 53 South end of the "Canoe" looking north toward Black lake. This is a synclinal, faulted valley with steeply dipping beds at the right (east). In the spring or in times of heavy rainfall this valley is filled with water. (Photograph by E. J. Stein.)

under the bridge and downstream, Deepkill and Schodack beds in their normal position have been exposed by erosion and constitute an *erosion inlier.* A similar erosion inlier may be seen in Mill creek about two miles north-northeast of Stuyvesant where Nassau beds are exposed in the Schodack belt. The *fold inlier* of Nassau beds composing Barren island is cited above. For the various types of inliers the reader is referred to Ruedemann's paper on the subject ('09, p. 159-93).

Western Belt

Strike and dip. The folding in this area is confined to the limestone belt and has a general northeast-southwest direction. In consequence of the folding and accompanying faulting the dips and strikes are variable. The escarpment, mainly formed by the Manlius and Coeymans limestones, strikes N. 8°-10° E. in the southern part of the quadrangle, N. 10° E. at High Rocks, N. 15° E. south of Climax, nearly north and south from Albrights to a point about a mile north of Ravena (figure 27) whence it turns westward. At the south, where the Athens-Leeds road crosses the escarpment, the dip is S. 10° W. at an angle of 8°; near the edge of the quadrangle only slightly west of south at an angle of 28°. Near School No. 4, along the road (south) to Greens lake the Manlius strikes N. 23° E. and dips at an angle of 70°. Where the Flint Mine Hill-Bronks Lake road climbs the escarpment the beds strike N. 30° E. and stand at an angle of 86°. East of Bronks lake, along the road past the reservoir, the Manlius strikes N. 28° E. at an angle of 35° (involved in an anticline). The beds continue to dip northwest along the escarpment to High Rocks, north of which they begin to dip to the southwest (strike northwest). At Albrights, in the road cut, the Manlius dips S. 58° W. at angles of 30° to 40°. With the same direction of dip and strike the Manlius at the top of Ravena hill dips at an angle of 12°. At Deans Mills, one mile south-southwest of this locality the angle of dip is only 3°, though the direction of dip and strike are the same. Near the northern border of the quadrangle the dip, taken on the Coeymans is S. 58° W. at an angle of 6°. West of the vicinity of the escarpment in the folded belt, the same variation in direction of dip and strike is found and the angle of dip varies from a few degrees to nearly vertical. A number of citations of dip and strike will be found under the discussion of the various formations. In general the direction of dip is westerly or northwesterly in the southern part of the quadrangle and southwesterly in the most northern portion.

The stress of the folding which so crumpled and faulted the limestone belt seems to have been taken up in the lower, softer thin-bedded strata of the Bakoven which wherever exposed are found to be much crumpled, contorted and slickensided. The more competent beds above in the Hamilton are unaffected. Dips as high as 24° have been found in these lower beds. In the beds above in the southern part of the quadrangle the dip is slightly north of west at an angle of 7°. The strike at the southern end of Potic mountain runs N. 15° E. Northward the dip turns more to the west, until east of Medway the dip is found to be N. 80° W. (strike N. 10° E.) at an angle of 7° (locally higher). Still farther north towards Coeymans Hollow and the Hannacrois valley the dip swings around to the south and the angle of dip (S. 5° W.) falls to 3° and even 2° going westward to the vicinity of Alcove, with a strike N. 85° W.

Folds, faults, cleavage, inliers. The folding of the limestone belt was accompanied by faults of various types and strongly developed cleavage.

Some of the localities where cleavage has been well developed are mentioned under the discussions of the various formations. It is found best developed in the Esopus and Schoharie formations (figures 38, 40, 55) and in the New Scotland beds, particularly the shaly limestone. An excellent and accessible area for the study of cleavage is found east and west of Aquetuck in the Schoharie and Esopus outcrops (*see* pages 208, 218) on the north side of the Coeymans Hollow-Ravena road. In the Schoharie the dip of the beds was found to be S. 63° W. at an angle of 36°, while the cleavage dips S. 23° W. at an angle of 62°. One mile almost due south of Aquetuck a cut in the Esopus along the east-west road shows nearly vertical cleavage, dipping N. 5° W., cutting across beds dipping almost due west (S. 83° W.) at an angle of 12°. Along the escarpment about a quarter of a mile south of the northern boundary strong cleavage has been developed in the Kalkberg limestone in connection with the faulting. East of the small fault south of Deans Mills cleavage in the Kalkberg at the top of the hill stands at an angle of 70°, dipping S. 23° W. Cleavage is well developed back of the escarpment in High Rocks, particularly in the New Scotland beds; also west and southwest of Roberts Hill in the same beds. Back of the escarpment from Climax southwestward cleavage is well developed and often stands at a nearly vertical angle. Accessible places for study are found along the Coxsackie-Bronks Lake road, where there is a good cut in the Esopus just north of the reservoir (figure 38); along the Flint Mine Hill-Urlton road at the escarpment; at the junction of the West Athens-Limestreet and Greens Lake roads and in the two southward trending ridges, notably in the New Scotland, Esopus and Schoharie; east of Black lake, particularly in the New Scotland shaly beds; south of Greens lake in Esopus cuts on both sides of the road and in quarries, and in Leeds gorge in the Esopus (figure 55) and Schoharie.

The folding on the Coxsackie area strikes north-northeast to roughly north-south. There are domed hills, small swells or anticlines, open anticlines and synclines, closely folded anticlines and synclines, pitching anticlines and so forth, all complicated by faulting and, through erosion, developing interesting physiographic features. Cross-folding is present, but is not often observed. A small fold of this type may be seen in the Manlius in the ravine just north of the first fault in the escarpment, about three-eighths of a mile south of the northern boundary. Cross-folding may also be studied in back of the escarpment, about three-eighths of a mile south of the four corners east of Limestreet.

The limestone belt north of the New Baltimore-Deans Mills-Stanton Hill road is characterized by a series of roughly north-south small anticlines and synclines. This is particularly striking in the Esopus-Schoharie belt where fingers of Schoharie, as also the roads, are seen extending northward along the crests of anticlines. The Esopus may cap some of the ridges, but also underlies synclinal depressions. To the west of the Schoharie stringers a small anticline forms a ridge of Onondaga limestone, with the Schoharie grit involved in the depressions to the east and west. The Onondaga of this northern area is characterized by numerous small anticlines or swells, shown on the map as small elliptical hills, trending roughly north-south. They may be studied along the two east-west roads crossing the Onondaga belt at the north, but are particularly well developed in the area traversed by the road turning south from the Coeymans Hollow road near School No. 16, especially south of the Greene County line. Between Deans Mills and Albrights there is a series of anticlines and synclines involving the New Scotland beds and to a certain extent the Becraft, the beds on the west side of the road having a general westerly dip and constituting part of the west arm of the anticlinal ridge just east of the road. The Onondaga belt, however, still shows a number of north-south trending swells.

Between the hill constituting the south end of High Rocks and the hill to the west, just north of Roberts Hill road corners, a glade is located in a depression or valley (figure 3). This feature has been developed through dissection along the axis of an anticline pitching northward. The Manlius and Coeymans limestones dip into the floor of the glade a short distance south of the right-angled bend in the lane; the hill at the west constitutes the left arm, the one at the east, complicated by folding, the right arm of the anticline. Northward this anticline dies out or is replaced by a series of small anticlines and synclines. Southwest of Roberts Hill through the Coxsackie reservoir area and westward to the road traversing the Onondaga occur the typical northeasterly trending series of miniature folds.

The Climax area affords an interesting region for study. Immediately north is a domed hill or domed southern end of an anticline, the eastern portion of which has been eroded away. North of the road and creek the strata show southwesterly dips on the west slopes which change through southerly to southeasterly dips on the east slopes. South of the creek occurs a smaller anticline domed at the north with a synclinal depression at the east. The depression or shallow syncline between the two domes has been complicated by a fault and the stream has developed a sink hole through the Kalkberg limestone (just west of the farm lane which turns south at the hotel) into which it disappears, reappearing from beneath the Manlius nearly a quarter of a mile downstream (*see* page 27). South of Climax the structures along the escarpment have been complicated by the faulting that accompanied the folding.

The cut in the Manlius, Coeymans and Kalkberg along the Coxsackie-Bronks Lake road, in the vicinity of the State reservoir, reveals the west arm of an anticline, both arms of which are exposed in the north bank of the ravine. It is broken by a roughly north-south trending fault and is cut off on the east by a northeasterly trending fault. The west arm of this anticline, steepened by a strike fault at the west and complicated by additional faulting, continues southwestward into an unbroken anticline well shown north of the Flint Mine Hill-Urlton road. The steeply dipping west arm passes into small gentle folds in the Onondaga on the west, the more gently dipping east arm passes into a shallow syncline, bottomed by the Oriskany sandstone and sharply separated by a strike fault from the nearly vertical beds forming the escarpment.

From the Limestreet-West Athens road southward the structure of the limestone belt is complicated but most interesting. An anticlinal ridge stretches southward from the four corners east of Limestreet. The west arm is very steep and the beds show angles of dip from 68° to nearly vertical. The dip varies from almost due west to nearly vertical with a southeast dip where the axis of the

Figure 54 Anticlinal fold in the Esopus shale, with accompanying westward thrust; south side of Leeds gorge. The Glenerie limestone is included at the base of the arch and with the Port Ewen limestone (right) forms the bed of the Catskill. Natural dam and falls in the distance (at the pool; see figure 4) are formed by the Schoharie and Onondaga limestones. View west. (Photograph by E. J. Stein)

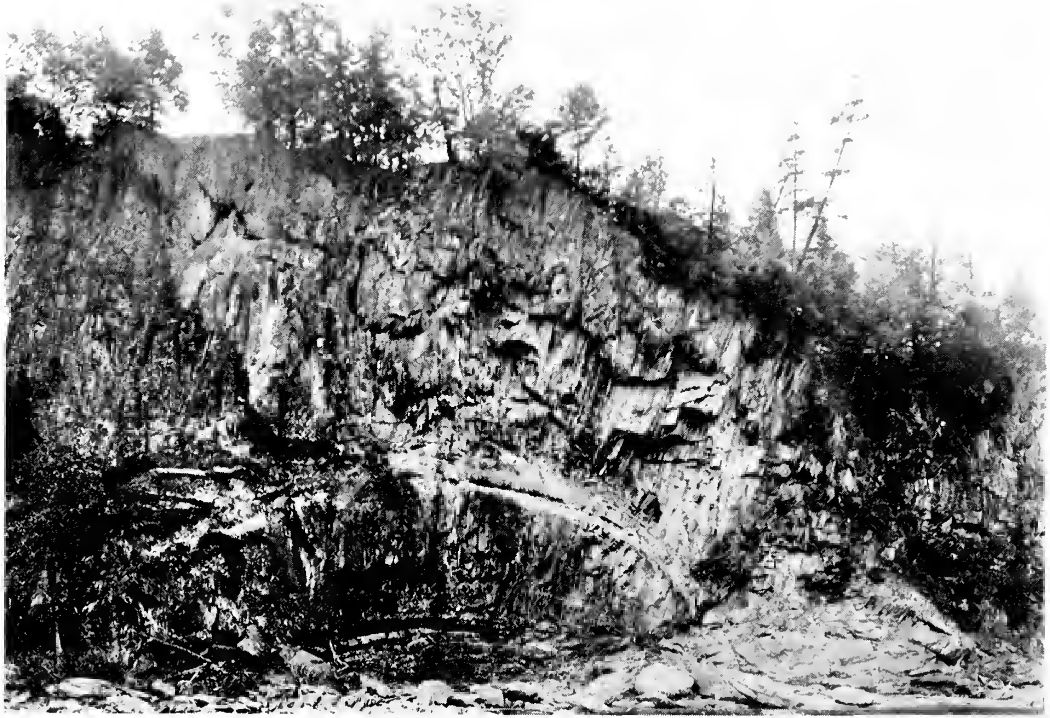

Figure 55 Near view of the Esopus anticline and overthrust shown in figure 54. The Glenerie limestone and Esopus shale are thrust westward over Esopus shale. The thrust, at stream level near the center of the arch is seen to rise above the bed of the stream at the right. Cleavage in the Esopus is well developed. (Photograph by E. J. Stein)

Figure 56 Doming of the Schoharie and Onondaga limestones just west of the millpond and "narrows" in Leeds gorge. The Schoharie forms the bed of the Catskill, the Onondaga, with numerous chert bands, constitutes the left bank and is seen in the middle distance crossing the stream. (Photograph by E. J. Stein)

fold is inclined westward. On the west the anticline is further complicated by faults seen along the road to Greens lake. The east arm of the anticline at the north shows a dip as low as 22°. The hill east-northeast of Greens lake is a continuation of this anticline. The strata on the west side dip into the hill (S. 58° E.) at an angle of 80°; on the east side they dip at a high angle to the northeast. The axis of the anticline here must have been inclined to the northwest and the anticline was faulted, giving a repetition of beds. The steeply dipping beds border the escarpment almost as far south as the Athens-Leeds road. Apparently an anticline on the east has been shoved and fractured against the anticlinal ridge, capped by the Becraft and Alsen limestones, which extends south from Black lake and was in turn fractured against the larger anticline to the west The hill north-northeast of Black lake, domed to the north and south, and to the east and west, has also been fractured on the west in the shove of the beds from the east.

South-southeast of Black lake is a narrow, canoe-shaped synclinal valley, known as the "Canoe" (figure 53). The Esopus on the west side dips N. 33° E. at an angle of 20° or less; the older beds on the east dip almost due west at an angle of 60°. The syncline certainly has been fractured and there is indication of a strike fault.

Southward from the vicinity of Limestreet a striking anticline extends through Greens lake and the Leeds gorge. Its axis is irregular, with the steeper arm at the west. This anticline pitches to the north and is domed at the south, a feature well displayed in the Leeds gorge in the cut made by the Catskill. A beautiful, and very regular, anticlinal fold is seen in the Esopus on the south side of the gorge (figures 54, 55). In the region of the millpond a pinched syncline involves the Onondaga limestone, while to the west of this occurs doming (figure 56) in the Onondaga and Schoharie beds (*see* pages 221, 235). The anticline has been dissected, exposing some portion of all formations beneath the Onondaga limestone down to and including the New Scotland beds.

There are no faults of any great magnitude on the Coxsackie quadrangle, and most of them are of the normal type. The strike faults are the most important and conspicuous. There has been little faulting in the northern half of the area. Two strike faults cross the Hannacrois valley west of Aquetuck, the one farther west with upthrow at the east has brought the Schoharie grit in contact with the Onondaga limestone. South of Deans Mills a similar fault has exposed, in a small cliff, an inlier of Coeymans limestone. The fault to the east of this has produced a cliff extending northward from the Deans Mills-New Baltimore road on the east side of the fault plane.

The escarpment near the northern boundary is broken by three small faults extending in a direction that roughly parallels the direction of one set of major joint planes and also the strike of the folding. They are associated with minor folding and have something of the nature of small block faults. In the fourth and most southerly summit (one mile south of the boundary), the beds have a southwesterly dip; in the first fault block north they dip almost due west, in the second block, south-southeast, indicating uplift with tilting. Similar small faults are seen in the escarpment at High Rocks, and east of Limestreet in the hill north of School No. 4. Some of the blocks have been tilted at a high angle. Greater tilting has been possible here because of the strike fault passing through the summit of the hill at the west. These escarpment faults are again seen just north of the Athens-Leeds road, but there they appear to be forkings from the main strike fault that trends south in back of the escarpment.

The small overthrust in the north-trending Onondaga limestone ridge seen along the northside of the road about one-quarter of a mile north of the Coeymans Hollow-Aquetuck road has been discussed under "folds" and in the chapter on the Onondaga limestone (page 231). An interesting, but also minor, overthrust in the Leeds gorge involving the Oriskany and Esopus formations (figures 54, 55) is described in the chapter on the Esopus (page 211).

Between Climax and Leeds the faulting which accompanied the folding has complicated the stratigraphy considerably. To the strike faults in back of the escarpment are due the high dips there and the structure is further complicated by cross-faults trending both northeast-southwest and northwest-southeast. Such faults are well developed about one-half mile south of Climax, along the Coxsackie-Bronks Lake road and three-quarters of a mile to the south (south of the State reservoir) where cross-faulting has resulted in a hill of Onondaga and Schoharie within the Esopus area. To the east a wedge-shaped segment has been uplifted at the north, developing there an east-west escarpment of the Coeymans and Manlius limestones. Cross-faults are also well developed in the anticlinal hill east of Limestreet. The effect of strike-faulting is well illustrated along the Flint Mine Hill-Urlton road. Here east of the anticline the Oriskany spreads out in a synclinal depression, on the east side of which this formation, with a dip of a few degrees, is in contact with Becraft standing nearly vertical. North of the road nearly horizontal Becraft is in contact with these vertical beds, first Becraft and then, farther north, New Scotland.

The faulting in the hill east of Greens lake has been discussed (page 303). A similar fault to the west continues southward along the east side of Black lake where the Becraft and Alsen dip nearly due west at angles up to 72° and form a high wall bordering the lake. The area occupied by Greens lake appears to have been a shallow east-west structural basin which has been broken by a southwesterly extension of one of the strike faults. South of Greens lake, at the east end, faulting has produced a long, narrow splinter of Onondaga standing nearly vertical (indicated by the numerous chert seams) and bounded on the east and west by moderately dipping beds. West of this the Onondaga dips westward at a low angle toward a minor fault with upthrow on the west which has produced a small cliff in the northeasterly dipping Schoharie. The fault bounding the east end of Greens lake continues southward probably through the "Canoe" (figure 53), then southwestward along the east side of the synclinal depression which crosses the Catskill-Leeds state road, thence along the steep west slope of the hill bordering the Catskill on the east. Where this strike fault crosses the state road there is well exposed on the north side Becraft limestone dipping S. 67° N. at an angle of 84° and showing slickensides and calcite veins. To the northeast at the four corners on the Leeds-Athens road the Becraft east of the junction dips N. 72° W. at an angle of 58°, while just a few feet east of this the New Scotland beds dip N. 87° W. at angles of 6° to 8°. This condition, found to the north of the road as well, indicates a break at the east as well as on the west, which dies out in the west arm of the anticline to the north. The fault drawn through the "Canoe" is clearly such to the north and the south, and the writer believes that it continues through the "Canoe" proper certainly as a fracture, probably as a true fault, as indicated by the presence of slickensides and calcite veins and, as might be expected in such a sharp syncline, with steeply dipping (60° and over) beds, including limestones, on the east and gently dipping beds (20°) on the west. The writer's associates, Dr Rudolf Ruedemann and Dr D. H. Newland, agree with this interpretation, the former after visiting critical localities in the field with the writer.

Two types of inliers were found (*see* Ruedemann, '09), *erosion inliers* and *fault inliers*. A small erosion inlier of Becraft was found capping a small dome or swell about one-half mile south of the northern boundary. The most striking erosion inlier occurs at Climax where the Manlius and Coeymans limestones are exposed in the midst of New Scotland beds. Several inliers were found along the irregular axis of the anticline extending north from Leeds through Greens lake, three showing New Scotland beds within the Becraft and Alsen area and the fourth, apparently a sink hole, Becraft and Alsen limestone within the Port Ewen belt, three-quarters of a mile south of Greens lake. A small inlier of New Scotland is exposed at the north end of the "Canoe" along the steeply dipping west arm of the anticline.

Fault inliers are not numerous and none is conspicuous. South of Deans Mills a normal fault, with upthrow on the east, has exposed a small cliff of Coeymans limestone. About one-half mile south of Climax two inliers of Becraft have been faulted into the New Scotland. South of the State reservoir and one-half mile south-southeast of Bronks lake Onondaga and Schoharie are found within the Esopus belt. South of Limestreet a strike fault trending south-southeast, accompanied by uplift at the east has resulted in a cliff of Esopus, with easterly dip, flanked on the west by Onondaga with a low dip to the east and pinching out to the north and south under the Schoharie. On the south side of the Leeds-Athens road, across from the Leeds Lumber Yard erosion of a small swell in the Port Ewen, accompanied by a minor break at the north end has exposed a knoll of Alsen limestone.

No *outliers* of Silurian and Devonian formations have been found on the Coxsackie quadrangle. About one and a half miles south of the southern boundary of the quadrangle, south of the city of Hudson, formations from the Manlius to the Onondaga (inclusive) comprise Becraft mountain. North-northeast of Hudson, one mile east of the eastern boundary of the quadrangle, the Manlius waterlime and Coeymans limestone are found capping the Nassau beds in Mt Ida. These outliers, just outside of our boundaries, indicate that the Silurian and Devonian beds once extended much farther east.

HISTORICAL GEOLOGY

In preparing this bulletin the writer has thought it would be more effective to present some details of geological history as an introduction to the discussion of the stratigraphy of rocks of each system. Therefore, the historical geology will be set forth briefly here and the reader is referred for further details to those chapters. The historical geology of the Capital District and Mid-Hudson valley has been fully discussed previously by Ruedemann ('30, p. 162-81; Catskill bulletin, 42*b*, p. 171-88) and the writer ('35, p. 199-221).

PRECAMBRIAN HISTORY

No Precambrian rocks are exposed in the Mid-Hudson region. They are seen not much farther to the north in the gneisses and granites of the Adirondacks, which come down to the northern outskirts of Saratoga Springs, and in the southern Green Mountain range along the New York-Massachusetts boundary; not much farther south, in the Highlands. Under our region Precambrian rocks, which are the foundation rocks of the whole continent, would be found at a depth of 4000 to 5000 feet.

The Precambrian rocks were intensely folded, and, as shown by Ruedemann ('22), the folds have an orderly arrangement connected with the original form of the continent, "the folds having arranged themselves parallel to the outline of the continent, and the compressing force having acted from the heavier bottom of the nearest ocean" (*auth. cit.*, '30, p. 163). In the eastern half of the continent this folding is uniformly northeast. Long depressions or geosynclines existed (Schuchert, '23) in North America even in the last division of the Precambrian (Proterozoic time), one of which in eastern North America, the Appalachian geosyncline, extended inside the borderland from Newfoundland, or even beyond, to Alabama. The Capital District and Mid-Hudson valley constitute only a small segment of this great geosyncline. Such geosynclines, gradually filled with sediments from neighboring mountain ranges, became submerged, sank and were finally folded into long mountain ranges. As a result of Precambrian folding several long barriers or ridges were produced, separating the troughs or basins present in early Cambrian time. Two troughs were early distinguished by Ulrich and Schuchert ('02) and Ruedemann (*see* '30, p. 132) in the northern part of the Appalachian geosyncline, the eastern or Levis trough and the western or Chazy trough (*see* Structural Geology, page 279); and, more recently, Prindle and Knopf ('32) have distinguished in the Mt Greylock range a distinct "eastern sequence." Ruedemann, in his Catskill bulletin, points out that the two marginal troughs (Chazy and Prindle and Knopf's "eastern") correspond roughly in their sequences, the basal quartzite in each case being followed by a limestone and dolomite series. In the middle sequence, however, the Nassau and Schodack beds are followed by the series of graptolite shales. In his discussion he states ('42*b*, p. 173, 174):

> The view generally favored is that of the presence of barriers that separated the several troughs and thus produced the different sequences of rocks and the differences in the faunas. . . . There is no trace of the former barriers left in our geosyncline, nor could this

be expected as all three troughs have been shoved together and even partly pushed over each other by the general northwest compression of the geosyncline in the Taconian revolution. Also the varying presence and absence of formations in the different troughs . . . strongly indicates a considerable degree of independence of the troughs, hardly possible in a single basin.

However, there are certain facts which cannot be overlooked as indicating a certain unity of the whole geosyncline at certain periods. These are the presence of the great graptolite shale series in the middle basin, flanked on both sides (in the western trough farther north in the Chazy basin) by corresponding thick limestone and dolomite series. The graptolite series is to be considered as representing the deposits of the deeper middle regions of the geosyncline, the sandstones and limestones of the two marginal basins the littoral or at least nearer shore deposits. . . . It is suggestive of such temporary conditions and of the occasional submergence or entire disappearance of the barriers that at times typical beds of one trough encroach on the neighboring trough, as the Canajoharie shale appearing as thin intercalations in the Snake Hill beds (*see* Ruedemann, '30, p. 32) and the upper Normanskill shale as Wallumsac shale in the eastern trough.

There are those who would obliterate all barriers in the St Lawrence geosyncline and consider the three sequences merely as expressions of different facies in the same basin, a central oceanic planktonic facies and two littoral benthonic facies. It would seem that the varying conditions in the geosyncline allow the conclusion that both working hypotheses may be applied at certain times. . . .

CAMBRIAN HISTORY

During Lower and Middle Cambrian the sea was entirely drained from the western trough which remained dry until late Upper Cambrian time (lowest Ozarkian of authors) when the coarse quartzose sands and gravels constituting the Potsdam sandstone were laid down in a sea clearly advancing from the north, as the thickest beds occur at the north and the formation disappears southward. The Potsdam sandstone barely enters into the Capital District (Saratoga region). In the Saratoga region it is followed without sign of a break by two marine formations. The Potsdam sea extended around and over the Adirondack plateau in the north and the south, the bordering lands were lowered through erosion, less and less sand was brought down and dolomite began to be deposited, giving us the Theresa formation of alternating sandstones and dolomites. The Theresa beds grade up into the Little Falls dolomite (with basal Hoyt limestone as local phase), characterized by great reefs of the calcareous alga *Cryptozoön* which would seem to indicate a congenial climate.

In the Levis or middle trough were deposited in the Lower Cambrian the great thicknesses of the shales and quartzites of the Nassau beds and the limestone and shales of the Schodack formation (Georgia beds or Taconian series); in the eastern trough the Cheshire quartzite and Rutland dolomite. These troughs were emergent during Middle Cambrian time, though it has now been shown that the sea of that time invaded the geosyncline (eastern trough) at the north (Vermont) and possibly as far south as Stissing mountain where occurs the Stissing dolomite of Lower Cambrian and Middle (?) Cambrian age. In the eastern trough, also, occurs the Stockbridge limestone (Cambrian and Ordovician) the lower beds of which, as indicated by the fossils, were deposited by a sea contemporaneous with the late Cambrian sea of the western trough. In southeastern New York (Dutchess county) the Lower Cambrian Poughquag quartzite, representing the first sediment overlying the Precambrian basement, upon which it rests unconformably, belongs to this eastern trough, as also does the Wappinger limestone of Dutchess, Orange and Ulster counties, a terrane including the Hoyt dolomite of the late Cambrian, the Beekmantown (Rochdale and Copake limestones) of Canadian age and limestones of Ordovician age with Black River (Lowville) and early Trenton fossils (*see* Knopf, '27, p. 435-41). Ruedemann in a recent paper on Ordovician Plankton and Radiolarian Chert remarks that "all these formations are highly fossiliferous in their metamorphosed condition and they present in their faunas and lithology an amazing repetition of the Western or Chazy series, thereby suggesting the littoral series of the same basin" ('42*a*, p. 58).

Upper Cambrian deposition was followed by a mild uplift, through which the troughs were raised above sea level and the resultant land surface somewhat eroded. This period of uplift and erosion represents elapsed time of unknown length and marks the dividing line between the Upper Cambrian and the Canadian (Lower Ordovician of authors).

CANADIAN AND ORDOVICIAN HISTORY

During Canadian time the sea entered the Levis trough, spreading from the north as far as the Capital District and beyond into the present Mid-Hudson region. Here were deposited the thick masses of shales and grits which carry mainly graptolite faunas, but rarely stragglers from other classes. These deposits constitute the Schaghticoke shale of earliest Canadian age (*see* pages 47, 85) and the Deepkill shale (200 to 300 feet), equivalent in age to the Beekmantown limestones (Middle and Upper Canadian). The deposition in late

Beekmantown time of the Bald Mountain limestone, north of the Capital District, according to Ruedemann, indicates the appearance in this trough of congenial living conditions. The limestone formations of the "eastern sequence" have been touched upon above. Depression in the Chazy trough during Canadian time permitted its invasion by marine waters which bordered the Adirondacks on all four sides and in which were deposited the various dolomites and limestones of the Beekmantown group. These deposits, thickest and most complete in the Champlain region, do not continue as far south as the Saratoga region and Capital District either because the submergence fell short of covering this district or (barely possible) because the formation, thin here, was subsequently worn away (Ruedemann).

The marine invasions, bearing graptolites, continued in the Levis trough into the Lower Ordovician (Chazy time) during which time the uppermost Deepkill and Normanskill shales (over 1000 feet) were deposited. At this time the Levis trough undoubtedly extended the full length of the Appalachian geosyncline and the sea was permitted to sweep freely through it. Two shorter intervals of withdrawal have been noted (Ruedemann, '30, p. 168), as "between the Deepkill and Normanskill invasions and possibly between the lower and upper Normanskill invasions, the latter probably of Black River age" (lower Middle Ordovician). Ruedemann also believes (*ref. cit.*) that the Rysedorph conglomerate at the top of the Normanskill "indicates a period of great erosion or working up of various rock formations by an advancing sea with strong currents" which must have taken place in early Trenton (Middle Ordovician) time since the included pebbles represent Chazy and Black River (Lowville) formations. Then followed the Snake Hill invasion, which Ruedemann believes extended the full length of the Levis channel, with deposition of a great mass of shale and grit (3000 feet) characterized by a largely graptolite fauna but with another fauna of small mud-loving pelecypods. To allow this great accumulation of sediments the trough must have been sinking rapidly. No Snake Hill beds are found in the Catskill-Coxsackie area, but they occur to the north in the Capital District and reappear to the south in the Newburgh area (Holzwasser, '26). This would indicate that they existed in this area but were already eroded at the end of the Ordovician (Ruedemann). Of the Tackawasick limestone in the Capital District, Ruedemann remarks that it shows that "in this time . . . there were also places in the Levis channel where better conditions existed and calcareous Trenton beds could be formed," unless it has been "pushed over by overthrusting from a still more easterly basin" (*ref. cit.*). Indications are that the Levis trough was completely drained during Utica-Lorraine (Upper Ordovician) time.

The Chazy or Lower Ordovician invasion of the western or Chazy trough did not reach as far south as the Saratoga region, but in Black River (lower Middle Ordovician) time the invasion reached the Saratoga region (Amsterdam limestone) and, according to Ruedemann, "undoubtedly also extended into the Capital District" (p. 169). After a slight uplift, came further invasion by the Trenton (upper Middle Ordovician) sea and deposition first of the Glens Falls limestone, deeply buried under the Schenectady beds (over 2000 feet) of the Capital District, and then, with influx of mud, probably from the north, of the graptolite-bearing Canajoharie black shale (over 1000 feet thick), replaced westward by the Trenton limestone, indicating clear marine conditions. This sea extended through the whole Chazy channel and "also spread westward beyond the trough over the southern slopes of the Adirondack plateau" (*ref. cit.*). The Canajoharie shale grades upward into the Schenectady formation, with its persistent hundredfold alternation of shales and sandstones, a clastic shore formation deposited in a fast sinking basin that was rapidly filled with sediment. Though mainly of Trenton age, the "deposition may have continued even into early Utica time" (*ref. cit.*, p. 170). The last of the Ordovician formations of the western trough is found in the Indian Ladder beds (Upper Ordovician), consisting of alternating shales and thin sandstone slabs, calcareous in the lower part, of very local development and interpreted by Ruedemann as deposition "in a narrow trough that sagged rapidly in the middle and extended for an unknown distance from north to south" (*ref. cit.*).

There followed in the eastern and western basins an exceedingly long interval of emergence in which occurred the Taconic Revolution, placed at the close of the Ordovician era or in the Ordovician-Silurian interval of continental emergence. During this time were formed the Taconic mountains on the New York-Massachusetts boundary line. Folding was followed by extensive overthrusting and then a long interval of erosion (*see* Structural Geology, page 280*ff*).

SILURIAN HISTORY

As a result of the folding, overthrusting and erosion, Silurian and Devonian rocks are found resting partly on rocks of the western trough (Schenectady and Indian Ladder beds), partly on the rocks of the eastern trough (Snake Hill and Normanskill beds), as in the

Mid-Hudson valley. In the Coxsackie area the more or less disturbed Silurian and Devonian limestones rest very unconformably upon highly folded and tilted Normanskill beds. Eastern and western troughs, alike, had ceased entirely to function as depressions by the end of the Ordovician and the seas of Silurian and Devonian time extended more or less far east over them, as evidenced in the outliers in Becraft mountain and Mt Ida. "Still farther east, at the margin of the Capital District, the Upper Devonian Rensselaer grit rests directly upon Lower Cambrian rocks, thereby proving that either the Helderberg rocks never extended thus far, or that whatever thin sheets may have reached there had been eroded again before a new longitudinal trough was formed, in which the Rensselaer grit came to rest" (*ref. cit.*, p. 171).

During early Silurian time the sea claimed only central and western New York, but in late Silurian time practically all the State south and west of the Adirondacks was under water. The Salina sea, advancing from the southeast, was present in southeastern New York (High Falls shale, Binnewater sandstone, Wilbur limestone, Rosendale waterlime), but apparently did not reach north of the Kingston area in the Hudson valley, nor into the Capital District. If the Shawangunk grit, variously regarded, in the past, as a basal member of the Salina in the east (Clarke and Ruedemann, '07, '12; Hartnagel, '07), of Medina-Clinton age (Van Ingen, '11; Schuchert, '16; Swartz & Swartz, '30), of Medina-Clinton-Niagara age (Van Ingen, '11) is to be considered mainly or entirely of Clinton age or younger (Ulrich), the early Silurian sea also invaded southeastern New York (*see* Goldring, '31, p. 333, 342).

The pyritiferous Brayman shale present above the Ordovician beds in the Capital District and Schoharie region has been considered of Salina (Upper Silurian) age by Hartnagel, Clarke, Alling ('28, p. 97-102) and Grabau ('06, p. 104) and, more recently, by Ulrich and Ruedemann, independently, as a residual bed or soil of the Ordovician formed during the erosion interval and representing the hiatus between the Middle or Upper Ordovician and the Upper Silurian (Cobleskill limestone or Rondout waterlime).

It was not until late in the period that the sea encroached upon the Hudson valley to the western slopes of the Taconic mountains. The Rondout waterlime is considered to be "clearly a marine sediment, formed by chemical deposition in a shallow epicontinental sea" (Ruedemann, '30, p. 173) which extended westward from the Atlantic and also southward in a narrow embayment that reached into Virginia. South of our area in the Hudson valley (Catskill quadrangle). Chadwick has noted reef formation associated with the Rondout waterlime which may represent reef formation within the Rondout itself. The Manlius sea that followed occupied the southern part of the Appalachian trough and extended up into eastern New York and westward to the central part of the State. This sea had free connection with the ocean and carried a persistent marine fauna of corals, brachiopods, pelecypods, pteropods and trilobites. The Manlius sea in the Capital District and Mid-Hudson area was extremely shallow and the formation shows evidence of tide flat conditions (*see* page 135). This and the occurrence of *Stromatopora* beds near the top of the Manlius limestone "suggest that these limestones are principally lagoon deposits on tide flats, formed between and behind the coral reefs" (*ref. cit.*). To what extent the Silurian, and the Devonian, strata lapped up on the southern Adirondack area is not known, but they have weathered back over the broad inner lowland occupied by the Mohawk river and underlain by Ordovician rocks to the present escarpment of the Helderbergs, the "Helderberg Cliff."

No disturbance marked the close of the Silurian period and it is generally believed that deposition continued without a break, though there are local disconformities.

DEVONIAN HISTORY

The absence of the upper beds of the Manlius group in the Capital District and Mid-Hudson area indicates elevation of this region during the invasion of the late Manlius sea. A disconformable contact with the Manlius has been noted in the Helderbergs (Indian Ladder) and in the vicinity of the village of Catskill (page 136; *see* Goldring, '35, p. 88). In his discussion of the Coeymans sea Ruedemann writes (*ref. cit.,* page 173):

> The Coeymans sea was not greatly different in general outline from the Manlius. In New York it extended westward from the Helderbergs not quite so far as did the Manlius sea, and eastward it had about the same extent. The sea in the Helderberg portion of the Capital District was deeper than before and produced a fairly pure limestone, containing principally brachiopods. Farther west, in Herkimer county, plantations of crinoids and cystids are found, suggesting quiet waters.

The Helderbergian sea in the Hudson valley extended much farther eastward, into Massachusetts and perhaps into the Connecticut valley, as indicated by the Becraft mountain and Mt Ida outliers, and it also extended northward across the Mohawk Valley region and lapped up on the southern Adirondack area. The gradual transition from the Coeymans limestone into the lower New Scotland beds (Kalkberg limestone) indicates a gradual change in the conditions in the Helderbergian sea which in New Scotland time did not extend westward as far as the Manlius and Coeymans seas, but did extend southward into the Appalachian region and eastward across the Taconic region into New England and northward. This sea was characterized by a much greater influx of mud, producing the impure shaly limestone and calcareous shale of the New Scotland beds, and by a much richer fauna. The fauna is that of the littoral region and, especially in the lower beds (Kalkberg), includes a great variety and abundance of bryozoans, indicating deeper and quieter conditions. The parallel seams of chert, occurring through the uppermost New Scotland beds, but particularly characteristic of the Kalkberg, may represent secondary induration of the limestone or, possibly a siliceous mass or "gel" deposited on the bottom of the sea through the chemical action of bacteria on the marine waters.

Again, the change from the New Scotland sea to the Becraft sea was gradual with a consequent absence of a sharp contact between the two formations. Some change in conditions, possibly a shifting of barriers and currents produced the mud-free, clear sea in which was deposited a limestone largely composed of crinoid stems and plates and brachiopods. This sea extended westward, certainly as far as the vicinity of Cherry Valley, possibly into Onondaga county (*see*, page 176). In general it formed only "a narrow arm in New York, but it extended far down to Virginia and across the southern Taconic region into an eastern trough that led, as in New Scotland time, to the lower St Lawrence (Gaspé) country and Newfoundland" (*ref. cit.*).

At the end of the Helderbergian epoch the withdrawal of the sea from part of the Appalachian trough and subsequent erosion of much of the Helderberg deposits produced lime sediments which accumulated locally in depressions (Port Ewen beds). North of the southern portion of the Coxsackie quadrangle, a break between the Becraft and Oriskany formations represents these beds present farther south (Catskill area and southward, with best development in southeastern New York), indicating that the sea withdrew from the Capital District and, for the most part, from the country to the west of it (*see* Goldring, '35, p. 122, 209).

During this period of withdrawal of the sea, sand from various sources accumulated over the eroded land surface. As the waters flooded the Appalachian trough again, the advancing Oriskany sea reworked this material and deposited it as the Oriskany sandstone which is very fossiliferous in places and characterized by thick-shelled fossils. The fauna, which entered the sea from the northern Atlantic, shows European relations in contrast to the preceding faunas that showed southern Atlantic characters. At the type locality the Oriskany is a pure quartz rock, in the Capital District a calcareous sandrock, very flinty in places, but both represent shore deposits of a transgressing sea. From the southern portion of the Coxsackie area southward the Oriskany becomes more limy, continuing into southeastern New York as highly fossiliferous limestone beds (Glenerie limestone) with a basal pebble conglomerate (Connelly conglomerate). The deposits in southeastern New York (Port Jervis region) are considered as representing a deep-water or calcareous phase of the shallow-water, typical Oriskany sandstone, showing a persistence of Helderbergian species (Shimer, '05). The Oriskany sea which spread westward into Ontario, like the preceding seas, spread over the Taconic area into Massachusetts and thence northward into Canada (Gaspé country). At the end of Oriskany deposition the Appalachian trough was elevated in the Cumberland area, and in eastern New York we have only the coarse sands and grits of a mud delta constituting the Esopus formation (Oriskanian). At the close of Oriskanian time submergence became pronouncedly positive and continued to the maximum flooding of the continent in late Middle Devonian (Hamilton) time.

The open Onondaga sea, part of the great submergence of the Middle Devonian, was preceded by the short Schoharie grit episode. This formation is considered by Ruedemann and the writer as a sandy facies of the lower Onondaga limestone originating in a great influx of sandy material in the region from Albany county to Otsego county. Congenial conditions are indicated by the large fauna, suggesting the rich life of the zone below tides. Southward through the Hudson valley into southeastern New York, this impure, siliceous limestone gives way to or is replaced by more shaly, less fossiliferous beds indicating a change in conditions of deposition (*see* page 223*ff*). The great interior sea was again established in Onondaga time and in it was accumulated the limestone which by its wealth of corals and brachiopods indicates a warm clear sea of long duration, bordered by lowlands. Extensive coral reefs, seen on a smaller scale in western New York and to a certain extent in the Capital District and Mid-Hudson valley, characterize this formation which in New York stretches from the Hudson river across the State, continuing into Canada.

The Hamilton sea spread "from its entrance at the St Lawrence and New Jersey regions across the continent with arms extending to the Gulf of Mexico and north through the Mackensie region to the Arctic ocean" (Ruedemann, *ref. cit.,* p. 175). As Middle Devonian time continued the northeastern part of the continent was elevated, resulting in the rejuvenation of the streams which brought into the sea large quantities of mud and silt (Hamilton sandstones and shales). The deposition of limestone was checked, though in central and western New York thin limestone beds occur at intervals in the thick mass of Hamilton shales, several thousand feet thick in eastern New York. The Hamilton sea was teeming with life adapted to the muddy sediments, especially brachiopods and pelecypods. In the east the faunas have an Atlantic aspect, farther west Arctic and Pacific faunas are found. Toward the close of Middle Devonian time there was a further shrinking of the seas, coincident with further shrinking of Appalachia, and the rejuvenated streams built great deltas in the northern part of the Appalachian trough. In eastern New York such deposits were laid down in a broad bay (Caster's Penn-York embayment) widely open to the west with the source of the sediments to the north and east (*see* Mencher, '39). As enormous quantities of materials were deposited the bay was gradually filled landward and became narrower and shorter. Nonmarine deposits such as the Ashokan shales and flags and the Kiskatom red beds (2300+ feet thick) of Hamilton age, equivalent in time to marine beds farther west, therefore, would encroach upon previous marine deposits in the east.

During Upper Devonian time the continental seas were gradually withdrawn. In New York the embayment (Clarke's Albany Bay) continued to exist in the northeast corner of the sea, but as time went on became more sharply separated from it. A thick mass of nonmarine sandstones and shales, the "Catskill" red beds (over 3000 feet thick) were deposited here (*see* Barrell, '13, '14) while the Naples and Ithaca faunas ("Portage") and, later, the Chemung fauna flourished in the seas of western New York. The Upper Devonian beds in western New York are, therefore, marine, while those in the east are mainly nonmarine and in between intermediate conditions are seen. These nonmarine beds contain plant remains and at some horizons fresh or brackish water clams which would indicate that heavy drainage from the land had changed the bay into a large fresh water or brackish lagoon or estuary. The deposition of the nonmarine "red" beds continued through Upper Devonian post-Chemung time ("Hampshire" red beds according to Chadwick, '36, p. 96) even into early Mississippian time in southwestern New York and Pennsylvania (*see* Willard, '33, '36, '39).

Middle and Upper Devonian deposits in the eastern belt of New York must once have extended much farther north to the southern slopes of the Adirondacks. On the Coxsackie quadrangle and in the Capital District area to the north all beds above the Hamilton and some of the upper Hamilton beds have been entirely eroded away. The Rensselaer grit along the eastern margin of the Capital District, believed by Ruedemann ('30, p. 127ff.) and the writer to be possibly of Upper Devonian age (may prove to be Middle Devonian), is regarded as the deposit of a great river, coming from the north into the Albany estuary, "along the edge of the Capital District in a sinking trough at the same time that farther down in the bay the Catskill beds were formed" (*ref. cit.* p. 177).

At the end of the Devonian there was a practically complete emergence of North America. The *Acadian Disturbance* which is believed by some to have affected the Hudson Valley region of New York (*see* page 286) started in the Middle Devonian and continued even to the end of Devonian time.

POST-DEVONIAN HISTORY

The Devonian marked the end of marine deposition in this part of the State. In later invasions of marine waters during the **Mississippian** and **Pennsylvanian periods** (Carboniferous) were deposited the great series of formations seen in Pennsylvania but sparingly represented in southwestern New York where outlying masses of oldest Mississippian are unconformably overlain by oldest Pennsylvanian. The extent of these seas over southern New York is not known. It is believed possible that a large portion of the formation that furnished the rich coal beds of Pennsylvania once extended into our region and that the luxuriant swamp forests that furnished the coal beds once flourished here.

The close of the Paleozoic is marked by an almost worldwide mountain-making disturbance, beginning with late Mississippian, which culminated at the end of the Permian (late Carboniferous), when the deposits of the Appalachian geosyncline were elevated into the Appalachian mountains (Appalachian Revolution; *see* pages 283*ff*). In the period of erosion that followed a mile and a half, possibly as much as two miles, of rock was removed from the Capital District and Mid-Hudson Valley region, furnishing a section from the Lower Cambrian to the Upper Devonian. East of the Hudson river outliers of beds younger than the Ordovician, indicating a once greater eastern extension, are seen in Becraft mountain south of Hudson, Mt Ida just to the northeast and the Rensselaer grit plateau along the eastern border of the Capital District. North of the Helderberg escarpment to the southern slopes of the Adirondacks all rocks of Silurian and Devonian age have been removed and in back of the escarpment here and in the Hudson valley (the Kalkberg) the higher beds extending into the tops of the Catskills have already been worn away.

During the **Mesozoic era** most of eastern United States was undergoing erosion with the result that this region was reduced to a more or less perfect peneplain, known as the Cretaceous peneplain because it was best developed in that period. In Triassic time the coast line was farther east and the lands were undergoing erosion, therefore no Triassic marine sediments have been found in eastern North America. Continental deposits, such as the Newark series of New York and New Jersey, however, accumulated in troughlike depressions developed along the eastern margin of the Appalachian region. No rocks of Jurassic age occur in New York State. The wide erosion along the Atlantic slope continued through this period of time. The Lower Cretaceous or Comanchean is not represented by any marine deposits, but deposits of gravel and clay, which extend from Martha's Vineyard, Mass., to Georgia, were laid down as deltas and flood plains or in marshes or shallow lakes. Nonmarine Lower Cretaceous beds in New York are found only along the northwest border of Long Island. Great subsidence occurred during the Upper Cretaceous and the sea spread over the Atlantic coastal plain. This subsidence included most of Long and Staten Islands where, alone, in New York marine deposits of this period are found.

The Mid-Hudson and Capital District region was land throughout the entire era. It is reasonable to suppose that the Cretaceous peneplain continued into our area, though according to the views of Ashley ('35, p. 1398ff.) the concordant tops of the Catskill mountains would not represent the original peneplain surface, but have been lowered hundreds of feet through the millions of years that have elapsed since the close of Cretaceous time. In reconstructing the events of this era Ruedemann (*ref. it.*, p. 180) calls our thoughts to "the strange world that . . . existed at the beginning perhaps two miles above the present site and level of Albany; . . . the strange and gigantic reptiles, the tracks of which are still found in continental deposits of the Connecticut valley, that once wandered about in equally weird forests and swamps high above our present city." The region was again uplifted at the close of the Mesozoic era, 1500 feet or more in the Adirondack area. Rapid erosion of the surface was initiated and the stream valleys were cut down and broadened. According to Ruedemann and Cushing ('14, p. 144, 145), the faults of the Champlain basin and the Saratoga region were renewed as a phase of this uplift.

The close of Jurassic time in western United States is characterized by a period of mountain building (notably the Sierra Nevadas). The closing stages of the Upper Cretaceous were likewise marked by large-scale crustal disturbances which resulted in mountain building from Alaska to the southern end of South America. It was at this time that the Rocky Mountains were elevated. North America became practically dry land and extended farther out in the Atlantic and Pacific oceans than in Tertiary time following.

Deposits of the **Cenozoic era** in New York State are mainly Quaternary. The earliest Tertiary deposits do not occur on Long or Staten Islands, but Middle or Tertiary deposits are found there. The history of this era has been summarized by the writer in an earlier report ('35, p. 218):

Marine Tertiary deposits occur along the Atlantic and Gulf coasts from Martha's Vineyard island into Texas. Toward the end of Tertiary time there was a period of widespread elevation (Pliocene) and the eastern coast of North America became practically the same as today. North of New York the coast extended farther out than at present and the greater part of Florida was under water. During the Tertiary there were periods of mountain building (Coast and Cascade ranges, reelevation of Sierra Nevadas and Rockies) and igneous activity (Oregon, Washington, Idaho and Pacific ranges in California). Late Tertiary and early Quaternary was a time of elevation. The continents stood higher than now and there were broad land connections permitting migrations of the animals between the continents. Later, elevation ceased and with subsidence these land connections were broken. The cooling of the climate of Tertiary time culminated in the Pleistocene or Glacial Period, during which time vast ice sheets spread over much of northern North America and Europe.

New York State has a variety of glacial deposits (continental), but there are also marine and brackish water deposits of gravel, sand and clay found in the St Lawrence, Champlain and Hudson valleys. These deposits contain fossil shells of animals that live in the sea today. During the Pleistocene there was a great subsidence of the northeastern Atlantic coast and marine waters spread over the St Lawrence valley and Lake Ontario area and through the Lake Champlain and Hudson valleys. It was during the period of the Champlain subsidence that the sea coast acquired nearly its present position. Following the subsidence was the very recent gradual elevation which expelled the Champlain sea. Marine and brackish waters also disappeared from the St Lawrence and Hudson valleys, leaving New York as it is today.

There were minor oscillations of level in eastern New York during the early part of the Cenozoic era, the Tertiary; but according to Ruedemann ('30, p. 181) "we lack precise knowledge of just when and what they were. Later in Tertiary time an additional uplift took place, not improbably with renewed faulting." In the Capital District area and southward in the Hudson valley an early Tertiary peneplain has been recognized in the top of the Hamilton hills and possibly a late Tertiary, incipient, peneplain in the lowland occupied by the Mohawk and Hudson River valleys (*ref. cit.*, p. 19-21).

The final chapter in the geological history of our area is the invasion by the ice sheets of the Glacial Period. The Pleistocene or glacial geology is described in the following chapter by my colleague, John H. Cook, who has written similar chapters for the Capital District (Ruedemann) and the Berne (Goldring) and Catskill (Ruedemann) quadrangles.

GLACIAL GEOLOGY OF THE COXSACKIE QUADRANGLE

By John H. Cook

Before it was discovered that in the long history of our planet, Ice Ages have been of not infrequent occurrence, the Pleistocene division of geologic chronology was believed to be a unique chapter of that history. During the period, valley glaciers crept farther down their valleys; existing ice sheets were larger; continental glaciers covered northern North America and northwestern Europe; everywhere the snowlines came lower. It was a time of cold relative to the present and it was early named the Glacial Period.

But the glacial phenomena of the period are now known to have been localized expressions of a condition which obtained over all the earth, a worldwide lowering of temperature. The simplest and most reasonable theory to account for a cooling of the whole atmosphere is to attribute it to a weakening in the intensity of solar radiation. For we are called upon to explain not only other "glacial periods" but also the disappearance of conditions which favor accumulation of land ice, not refrigerations alone but also incalescences. For changes in world-temperature no local or even terrestrial cause would appear to be adequate.

On this hypothesis a change in the character of solar radiation acts as the precipitating cause for changes on the earth, of which the most obvious is the atmosphere's response to variations in its supply of heat, namely, expansion or contraction. Differences in the volume of the atmosphere according to its thermal condition are to be inferred from the general physical principle of the relation between temperature and volume; but the rising and falling of snowlines provides us with a more definite conception: that of the snow-ceiling, the upper limit of the body of air in which water vapor condenses into water. At and above this limit, water-vapor crystallizes out as a solid (ice spicules or flakes of snow). One characterizing difference between the regions is this: Water vapor condensing in the region beneath the ceiling returns to the air exactly the same amount of heat as it took from the air in the process of evaporation, but water vapor turning solid gives up *in addition* the "latent heat" of water, its energy of molecular freedom. This difference is important.

The ceiling is highest over the torrid zone, declines outside the tropics and, at the present time, comes to sea level before reaching the poles. Ideally the two intersections with sea level would be, at any given time, parallels of latitude beyond which the circumpolar areas lie wholly above the ceiling. Actually they are irregular. Represented in section, the arc is that of a spheroid slightly more oblate than the solid earth and in a diagram its constant movement with the seasons must of necessity be ignored.

If, now, we assume that the snow-ceiling has been stabilized at some position (as A A A, figure 57) it is evident that, as long as the

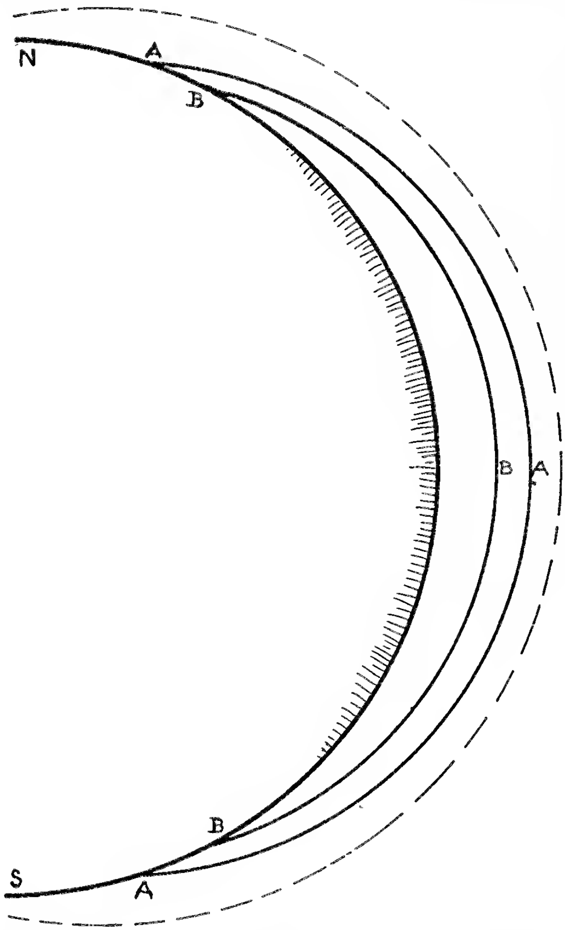

Figure 57 The volume of air in which temperatures above freezing can be maintained varies with the thermal condition of the atmosphere; and the position of the snow-ceiling (the upper limit at which water vapor condenses into water) is altered by changes in the volume of the air beneath it. When the latter is expanded, less of the polar areas are above the ceiling; when it is contracted, the ceiling intersects the solid earth in lower latitudes and at lower altitudes. Secular refrigerations are probably brought about by diminution of the intensity of solar radiation. (J. H. Cook)

thermal condition of the air beneath remains unchanged, this position will be maintained. But should the rate at which heat is being generated fall off, the amount of air which could be kept at temperatures above freezing would be less, the ceiling would be brought lower (B B B); mountain snowlines would descend; the intersections of the ceiling with sea level would move farther from the poles, and the circumpolar areas of preserved snowfall become of greater size. Around the new margins of these areas land ice would accumulate wherever the conditions necessary for precipitation were fulfilled and in process of time the thicker parts of the ice would become continental glaciers.

Of the great Pleistocene ice sheets which have disappeared, the one which engages our attention in this chapter had its geographic center southeast of James bay in the Province of Quebec; it is usually referred to as the Laurentian or Laurentide continental glacier. It invaded the region which we now know as the State of New York not once but several times, the invasions being separated by warmer intervals, "interglacial epochs," during each of which the southern marginal ice *certainly* and the whole body of ice *possibly* was melted off. Since thaw conditions passed over the ice sheet in a general way from south to north, it is quite within the range of possibility that some part of the northern limb was never melted until the end of Wisconsin time. But whether the successive glacierizations preceding the Wisconsin were followed by complete removals of the Laurentian land ice or not, the several dissipations and renewals of the southward-moving ice indicate that, during the Pleistocene, there was a notable alternation of decreasing and increasing solar radiation.

In the region which has been most intensively studied, the northern United States and southern Canada, the thaw-freeze line must have swung back and forth over the marginal ice many times during each period of general advance, retreat or stagnation of the periphery. The changes thus brought about, might last for hours or centuries and the effects produced might be insignificant or important enough to demand recognition. West of New York State moraines of readvance have made it necessary to subdivide Wisconsin time into early, middle and late; over New York and New England, where the marginal ice appears to have stagnated, recognition of these stages is not easy, for later stages may have been superposed upon unmelted portions of the earlier ice.

Glacial ice, if it is being continuously pressure-fed from snowfall, maintains a definite though shifting terminus along the line of frontal melting. But, if the snowfall is not great enough to supply the required pressure, the ice lies stagnant and melts away *in situ*. The failure of snowfall to increase proportionately as the periphery of an ice sheet enlarges is sufficient cause for the stagnation of some sectors. But of more immediate interest, in connection with the present study, is stagnation caused by a lessening of snowfall, either a lessening of the total precipitation over the isblink (central ice dome) or the change of a part of it to rain. Whatever may have been the cause, the southeastern quadrant of the Wisconsin glacier stagnated. All of the pressure-head developed by the reduced snowfall found relief farther to the west along those avenues of movement marked by the great western lobes.

While this condition of affairs lasted the New England ice cover suffered surface ablation (downwastage) to a marked degree. It seems reasonable to believe that this was more rapid during the intervals between advances of the western lobes, and also that during those advances, the downwastage may have been stopped altogether; but we have no direct evidence of the changes which took place in the ice here until the time of its final removal, and most of this evidence has to do with the very latest stages of the removal. From the courses of eskers, however, it seems allowable to infer that the ice remaining when final melting began was still thick enough to overwhelm the land topography. An esker is a long, narrow ridge of glacial materials (much of it washed gravel) formerly believed to be the partial filling of a subglacial tunnel. But eskers are *discontinuous,* and the lines which they follow seem to proclaim a *superposed drainage system,* one let down onto the land from above. They are probably, therefore, incidental accumulations in old ice-canyons which had been excavated in the clean upper ice by superglacial streams, deposits which could have been made only after some dirty basal ice had been exposed.

We gain, then, from the trend of esker systems, a picture of dead ice still thick enough to bury much of the land topography, and sloping somewhat east of south to the Atlantic seaboard. The eskers are most abundant in Maine, southeastern New Hampshire and eastern Massachusetts; they thin out westward and the cross-country type disappears. In spite of the lack of such evidence, we must postulate for eastern New York a condition at the beginning of final melting not greatly different from that inferred for New England, for the later stages of dissipation in the Hudson valley are essentially contemporaneous and have left the same types of drift accumulation, predominantly those associated with the downwastage of dead ice.

The conditions under which deposits were made during downwastage are illustrated by figure 58, which represents the cross section of a meridianal valley having the form of the Hudson valley, and stages of ice evacuation. The surface of the glacier at the time when it first ceased to move (A) is imagined as sloping so that superglacial streams are carried over the eastern divide. Ice canyons cut at this stage would trend across the rock ridges and deposits made in them, in situations where they could be preserved, would now be recognized as cross country eskers. When the ice has so far melted that the divides rise above it (B), drainage can not escape from between the valley walls; it may follow against them (one bank of each stream being of ice) or it may excavate a canyon (for a series of canyons) far out from the land slopes. When a tongue of *active* ice is pushing through a depression it is highest along the axial line; but the form of such a tongue is maintained principally by its movement and there is no reason to believe that the surface of a stagnant ice tongue could long remain convex even supposing it to have been so at the beginning. The débris-laden basal ice follows the relief of the underlying basement (hardpan and rock) and, because of the contained material, it does not melt so readily as the comparatively clean upper ice. Stagnant ice, therefore, tends to disappear through stages having profiles somewhat like B′ in the diagram, to a final stage (C, C) consisting of partly or wholly buried remnants in the lowest parts of the valleys. Certain extraordinarily deep places in the Hudson estuary known as "deeps" were formerly bridged by such masses of residual ice.

Since so much of the flow of meltwater was directed away from the valley walls rather than along them, it is not surprising that hillside terraces are, as a rule, too insignificant and too widely separated (both horizontally and vertically) to serve as clues to the main lines of contemporary drainage and that the deposits which reveal unequivocally the character of the ice evacuation and the meltwater flow are, if not confined to, at least most conspicuously developed on the valley bottoms.

Of the easily recognized forms into which sediments were cast by intimate association with the remains of the decaying glacier six are pictured in figure 59. Ice still nearly fills the inner valley, a steep-sided gorge, creating a series of dams. Behind these dams are ponds in which clays have accumulated (horizontally ruled areas). Above the clay-beds are various amassments of streamlaid sands and gravels whose flat tops are indicative of a higher (and now abandoned) water level. At the left (A A) is a shelf which ties into the hillslope

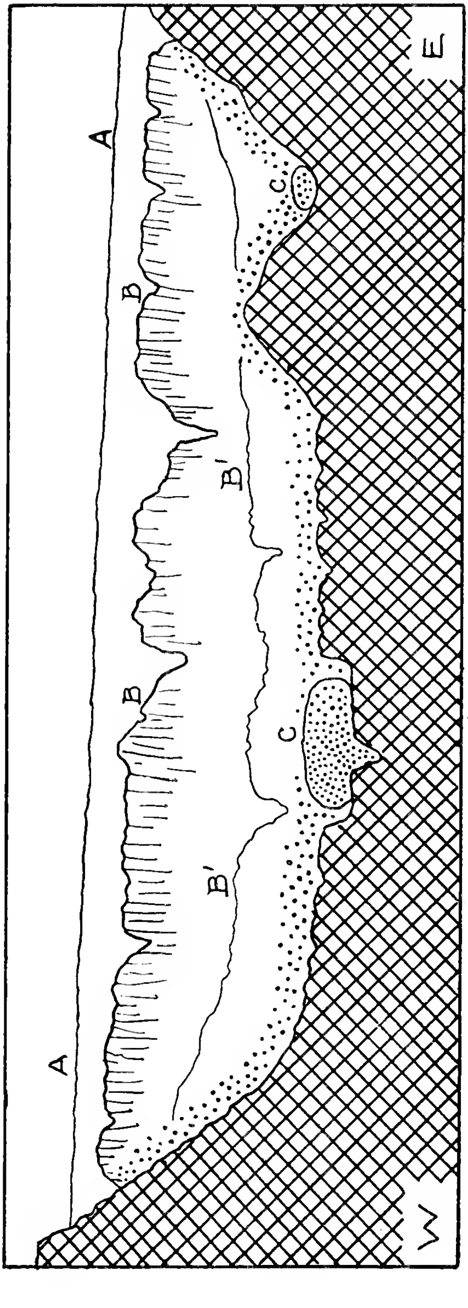

Figure 58 Cross section of a valley of the form of the Hudson valley and stages in the downwastage and dissection of a stagnant glacial ice tongue. A-A: original surface of glacier at beginning of final melting; drainage independent of rock topography. Stipple indicates basal ice heavily charged with rock débris. C-C: very late stage when residual ice is mostly confined to the deepest part of the valley, the gorge. B-B and B'-B' intermediate stages. Drainage lines do not necessarily lie against the valley walls. Deep canyons are apt to develop where the ice is thick and clean. (J. H. Cook)

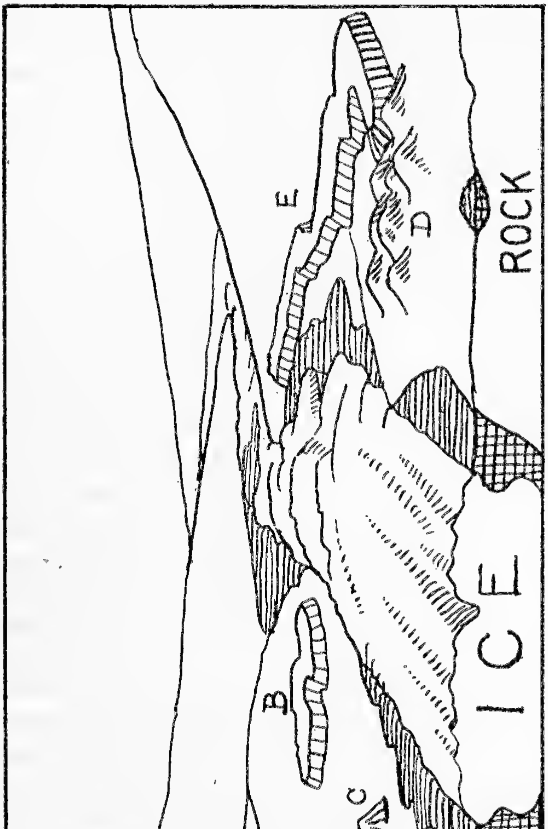

Figure 59 Typical forms of deposit made in association with masses of stagnant ice. A: a marginal terrace; B: a platform; C: a single kame; D: a group of kames; E: a crevasse filling. All but the kames retain the detail of slopes where they were in contact with ice. (J. H. Cook)

(dotted line) but terminates toward the valley's axis in a steep embankment recognizable as the line of former contact with ice. The surface plain is pitted with "kettles," basins marking the former sites of ice-blocks. A part of the deposit is separated from the terrace; it is called a platform (B). The conical hill (C) is an isolated kame and a group of kames appears at D. This term (kame) does not lend itself to definition, inasmuch as it denotes little more than a mound of glacial materials, and mounds either singly or in groups may be formed in a variety of ways and under varying conditions. Kames are associated with active ice as well as with melting stagnant ice. Employed as a purely descriptive term devoid of precise meaning the word is useful but must be understood to carry no implication concerning the manner of origin. Many kames appear on the Coxsackie quadrangle the significance of which for interpretation of the glacial history has thus far quite eluded the writer. An elongate platform which might be mistaken for an esker (E) has been named a "crevasse filling," a designation which requires that we enlarge the concept crevasse to include linear cavities appearing in thin stagnant ice and produced otherwise than by movement. There is, however, no accepted term for these long, narrow platforms; and "crevasse filling" serves the necessary purpose of calling attention to the fact that they are *not* eskers.

The internal structure of the single kame would probably show that originally (when supported by ice-walls) it had been rudely columnar, and excavations made among the grouped kames might reveal that the knob-and-hollow topography had also resulted from slumping when underlying or confining ice melted out.

The several units designated by letters constitute one glacial formation, a mass of stream-borne sand and gravel washed into and filling up a single curiously irregular and apparently discontinuous basin. Such basins were peculiar to areas where thin stagnant ice was decaying; and an understanding of their origin and development is invaluable for carrying on detailed studies of the deposits made in them. When a thaw sets in, meltwater is produced which not only runs off but also *soaks into the ice*. Shallow pools standing here and there on the surface penetrate into their porous bottoms, honeycombing and breaking them up into sludge which is replaced from below as it melts at the top. By this process the basins are deepened and enlarged laterally.

How important the action of absorbed water may have been in the disintegration of the stagnant Wisconsin glacier is a matter for conjecture for evidence of the former existence of fusion basins is determinate only where the subjacent rock was uncovered. That its surface was pitted by standing water is not improbable; there are kames, platforms and crown-terraces of monumental proportions which call for recognition of *preexisting basins,* and the forms which have been given to deposits left on plateaus, rock benches and broad valley floors often warrant the inference that the thin ice with which they were originally associated had been perforated. The manner in which a residual tongue of ice in the last-named situation may be supposed to have decayed is illustrated by figure 60. The first panel shows a part of the (imagined) tongue at the beginning of a thaw period; the others show successive stages by which it is conceived to have been diminished. Basins bottomed by bedrock (solid black) hold water, the ponds becoming larger as the ice melts. If no other process intervenes, eradication of the ice will be effected and no record left of the steps leading to its disappearance. But during a period of thaw the meltwater may be moving quantities of gravel, sand and rock-flour and from each available source for such materials the pools are being obliterated progressively downstream by sediments washed into them. In this way the fusing water is displaced and no further enlargement of the basins occurs. Let us assume, that, in the time which it has taken to fill depressions farther up the valley, the section of our hypothetic ice tongue pictured in the figure has wasted to the condition shown by the last panel and that, then, a considerable body of rock fragments has been swept into and across the area. The basins will be quickly filled, the stream bed graded, and the ice protected except where its upper surface may have escaped being covered. When the thaw period comes to an end, the water impregnating the sediments deposited in the basins freezes, if not to the bottom, at least to a considerable depth and makes a conglomerate which does not melt readily and which resists erosion. In consequence it retains its form (frequently even to the details of contact slopes) while the next thaw period is removing less heavily charged ice and lowering the level of the stream bed. The glacial formation pictured in figure 59 was, first, a set of cavity fillings in the bed of a meltwater stream running over ice at the level A-A, later a frozen terrace and a group of frozen islands standing somewhat above the wasted ice which still occupied the spaces between them and finally a group of gravel beds no longer in contact with ice.

Glacial deposits originating in the manner described above appear along the courses of Cob and Grapeville creeks and the other (smaller, unnamed) streams contributary to Potic creek. For the

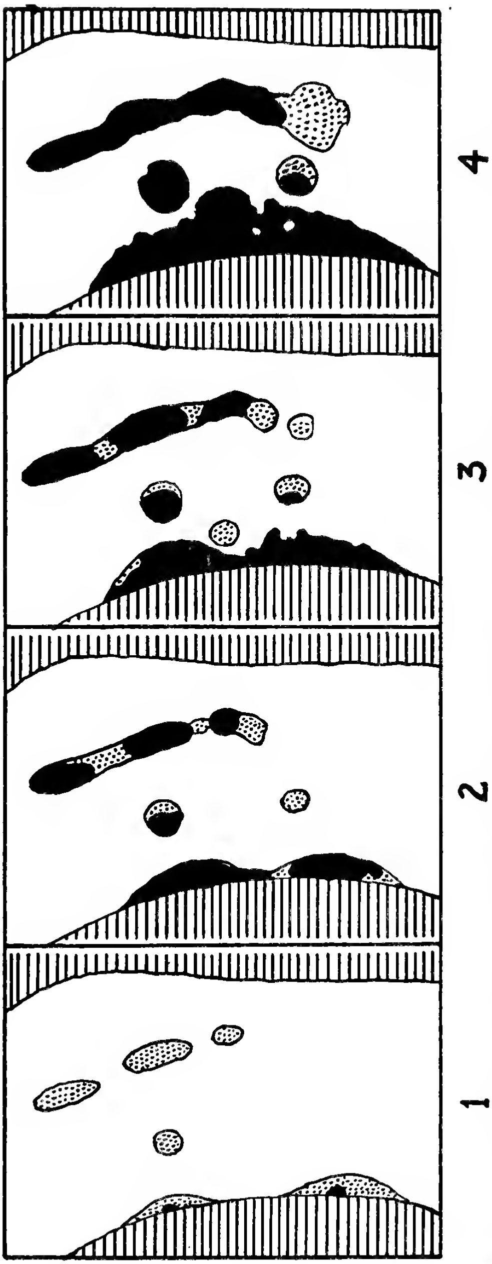

Figure 60 Theoretic development of fusion basins in thin stagnant ice. Water-soaked ice is stippled. Uncovered basement in black. Enlargement of the perforations might be stopped at any stage by the incursion of sediments. If the cavities are not filled until stage 4, the resulting formation will resemble that pictured in figure 59. (J. H. Cook)

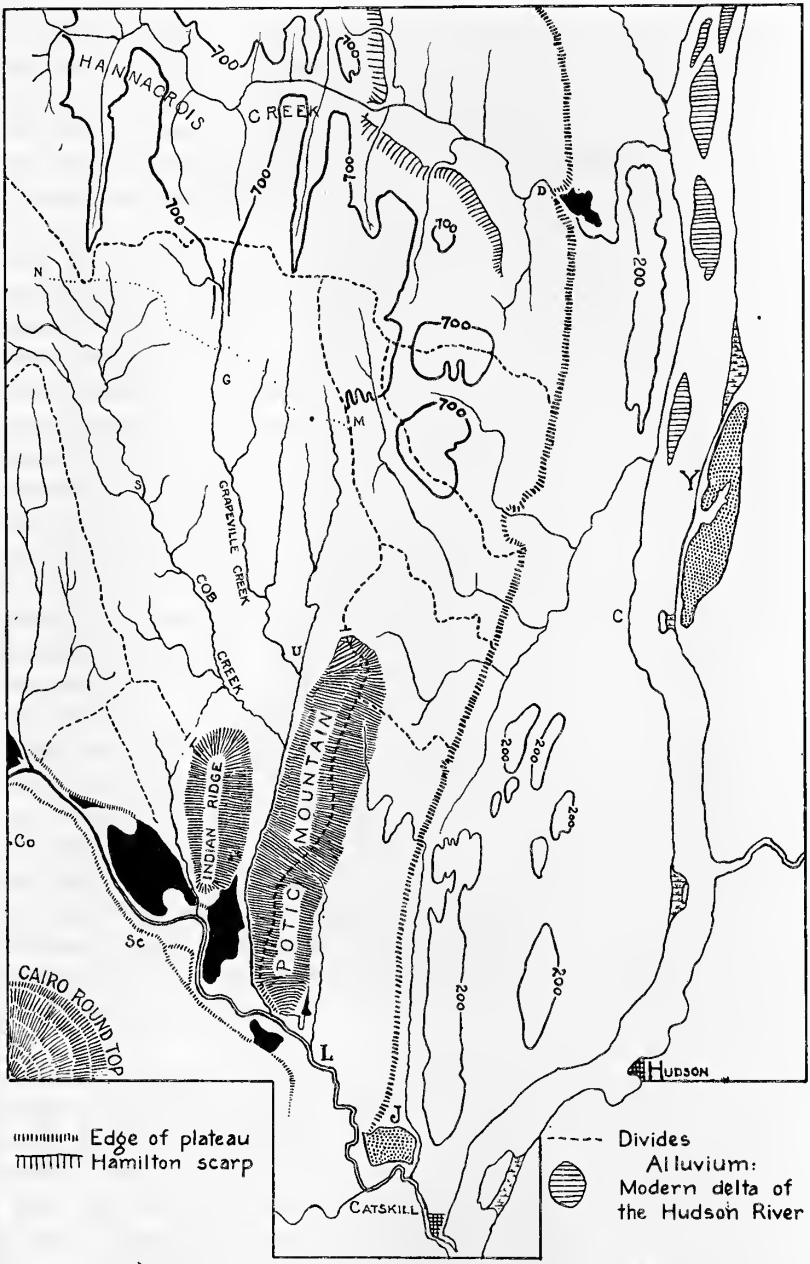

Figure 61 Sketch map of the Coxsackie quadrangle showing distribution of the more important glacial features. Deposits above the highest clay beds in black; deposits below that level in stipple. N, Newrys; G, Grapeville; M, Medway; C, Coxsackie; U, Earlton (Urlton of the topographic sheet); Y, Stuyvesant; L, Leeds; J, Jefferson Heights; Co, Cairo; Sc, South Cairo. N........M = approximate northern limit of the Potic Basin kame field. (J. H. Cook)

greater part of its length each of these streams wanders through a succession of swampy or postglacially aggraded flats which are the sites of the final remnants of the glacier in its valley. Along the sides of these bottom lands rise the ice contact slopes of variously shaped cavity-fillings, the predominant form being that of the simple, more or less conical pile, though the larger, compound mass is well represented. True terraces (lateral to the bodies of ice) are rare; but in a few places the accordant levels of neighboring platforms indicate control by a common water surface. Perhaps the heaviest concentration of massive kames is found between Grapeville and West Medway creeks; one mass has crowded the latter well up onto the eastern hillside about a mile and a quarter above the marshy confluence, as may be read from the topographic map. Another cluster having considerable significance occurs from one to two miles north of Urlton, a view of some of the more northerly mounds of which is given in figure 64. Cavity fillings are not confined to the bottoms of the valleys: they cover the slopes and, in places, the crests of intervening ridges over a large part of the basin north of the highway from Gayhead to Potic Mountain. The kame area is bounded roughly by Cob creek, the eastern watershed and the road from Newrys to Medway. Taken as a whole, it presents a type of glacial topography which, if not unique, is certainly far from common. The multitude of little subconical hills (see figure 62) indicates that the associated ice was thin and much pitted, and that, although many of the pits became vertical shafts in which the basement was exposed, comparatively few escaped being filled in before they could develop into sizable basins. This argues that the materials for filling cavities were present on the surface of the ice before the latter was perforated and the large number of angular boulders studding the deposits (figure 63) (mostly from the Hamilton sandstone beds) suggests that those materials were derived from a superglacial moraine.

At Surprise, north of the tributary which there enters Cob creek, is a smooth sandy plain traversed by weak channels. It blends northward into a gravelly terrace with kettles and across the creek there are several irregular cavity fillings with flat tops at the same elevation. A local waterlevel is indicated at about 610 feet and meltwaters escaping southward from the pool can not be traced. This is interpreted to mean that the bed of the outlet was, for an unknown but probably considerable distance, on the ice.

The deposits in the Potic Creek basin are probably the best and most characteristic examples of those topographic forms produced

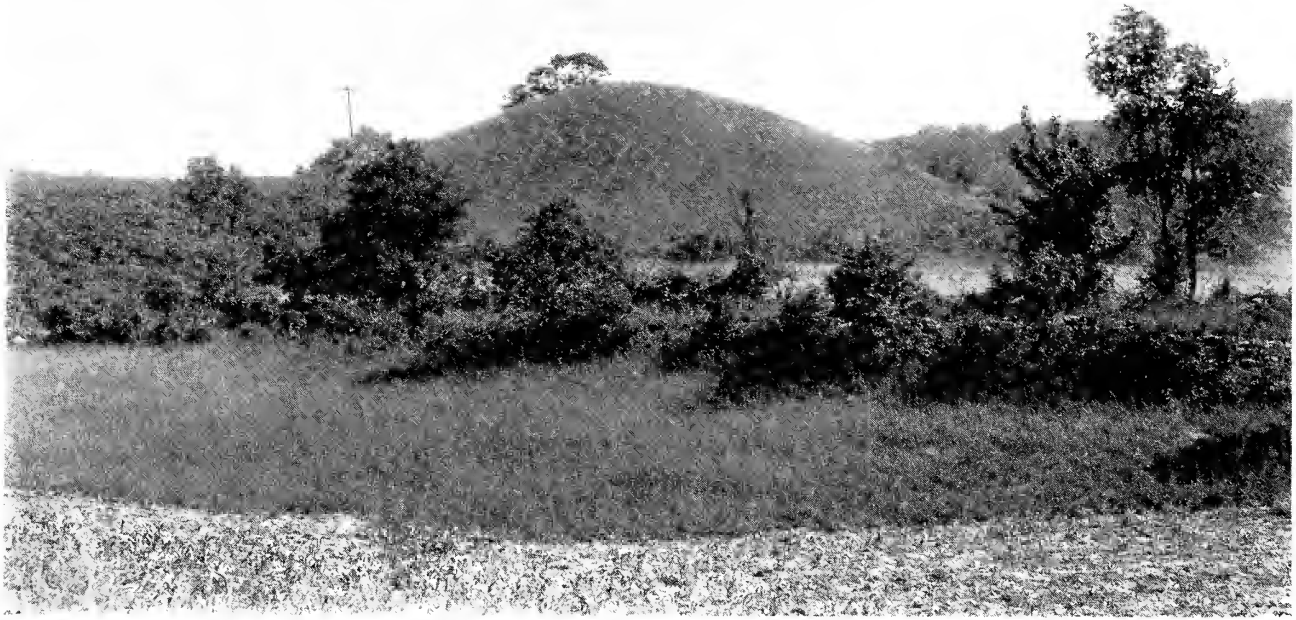

Figure 62 Typical isolated "kame." Two miles northwest of Urlton, view looking south. (Photograph by E. J. Stein)

Figure 63 "Kame" with boulders. About one-quarter of a mile north of Surprise, view looking southwest across Cob creek from the road. (Photograph by E. J. Stein) in association with the melting off of stagnant ice to be found on the Coxsackie quadrangle. Their position affords an excellent opportunity for testing the adequacy of the conception of a "front" of active ice (retreating up the slope from Catskill creek to the Hannacrois divide) to elucidate the sequence of events as recorded on the ground. Any attempt at restoration of ice-evacuation stages must take into account embarrassments to the free runoff of meltwater from a basin sloping southward. The general problem of south-sloping basins (including that of the Hudson) is well exemplified by the little lake above Surprise and its solution is there indicated with unmistakable clearness for no barrier across the valley can be imagined in this locality other than that formed by residual ice.

At the northern end of Indian ridge the meltwater following down the Cob Creek valley, was prevented from taking an eastward course and caused to cross the divide west of the ridge at an elevation of approximately 475 feet (A. T.). Neither the col nor the valley running south from it was cleared of rotting ice while used by this stream and a considerable amount of sediment appears to have been trapped in the ice. For this reason it is not possible to establish a relation between forced drainage and the broad, terraced plain at the foot of the slope opposite South Cairo.

This deposit (Sandy Plain of the topographic map) was regarded by Chadwick ('10) as having been made by "drainage from the north," an opinion seemingly justified by the position of the plain at the lower end of a side valley. But all its surface features indicate the action of meltwater passing down the Catskill valley. At the upstream (northwestern) end of the 263-foot level coarse material and small boulders have been swept into place directly from abutting ice and a weak channel heads at the eastern end of the S-shaped contact. It may be believed, however, that the ice-cavity in which the sediments came to rest was made in part by drainage from the north. Ice is easily basined by eddying currents at the bottom of a steep grade and the abrasive action of rock fragments is not essential for the production of such plunge basins; they are often made by streams of comparatively clean water.

Sandy plain extends eastward to the southwest base of Indian ridge and there is nothing to suggest that it was met by contemporary drainage from the north. We may be confident, therefore, that before sediments came to fill the cavity, the ice which lay over the lower courses of Cob and Grapeville creeks had weakened and opened a way to the defile west of Potic mountain. The earlier stages of flow through this straight and narrow groove are obscure but they must have been over ice at elevations above 250 feet. The stream finally entrenched itself along the east flank of Indian ridge, the bottom and east side of the valley remaining under ice. Here also the Catskill Valley ice was basined and the basin was completely filled with sediments. There can be no question concerning the origin of this deposit: as noted by Chadwick (*op. cit.*) it was built by the glacial stream coming from the north. Although Catskill creek has made a narrow cut across its southern end and has washed its western margin, it still preserves in all essential details the outlines of the cavity which contained it. The eastern edge is a continuous ice-contact which for a considerable distance upstream parallels the course of Potic creek. Modern alluvium now floors the ice-occupied area.

The glacial deposits along that part of Catskill creek appearing on the Coxsackie sheet were first described by Davis ('92) who interpreted them as remnants of the formerly continuous mass of a delta. This interpretation must be set aside as inadmissible even from the point of view of the physiographer; the deposits were never appreciably larger than they are now and those sections of the valley between them having a superficial resemblance to excavations were not made by stream erosion, but came into being when the ice which had occupied them melted away.

The elevation of the meltwater stream in the Catskill valley is indicated by the levels of the pools along its course. There is a well-developed terrace on the Durham quadrangle whose eastern end appears on our sheet; it so nearly blocks the valley that the present creek is thrown against the rock wall of the southern side. The bridge a mile north of Cairo spans what at first sight might be taken for a postglacial gorge (figure 65); the left bank is, however, not of rock but of glacial material. Below the bridge the terrace as it approaches Jan de Bakker's kill shows a well-defined ice-contact and it is probable that the bounding slope west of the bridge (now undercut by the stream) was originally a continuation of this contact. The top of the deposit lies between the 300 and the 320-foot contours. In a shallow excavation near the eastern margin (figure 66) there are boulders dropped from contemporary ice. From this terrace to the cavity-filling opposite Indian ridge the glacial stream appears to have kept close to the northeast side of the valley, its course being marked by narrow shelves of drift and the higher levels of Sandy plain; the lowest elevation to which it can be traced with certainty is that of the surface of the Potic creek deposit at about 235 feet. Any considerable flow of meltwater past this obstruction must have been by

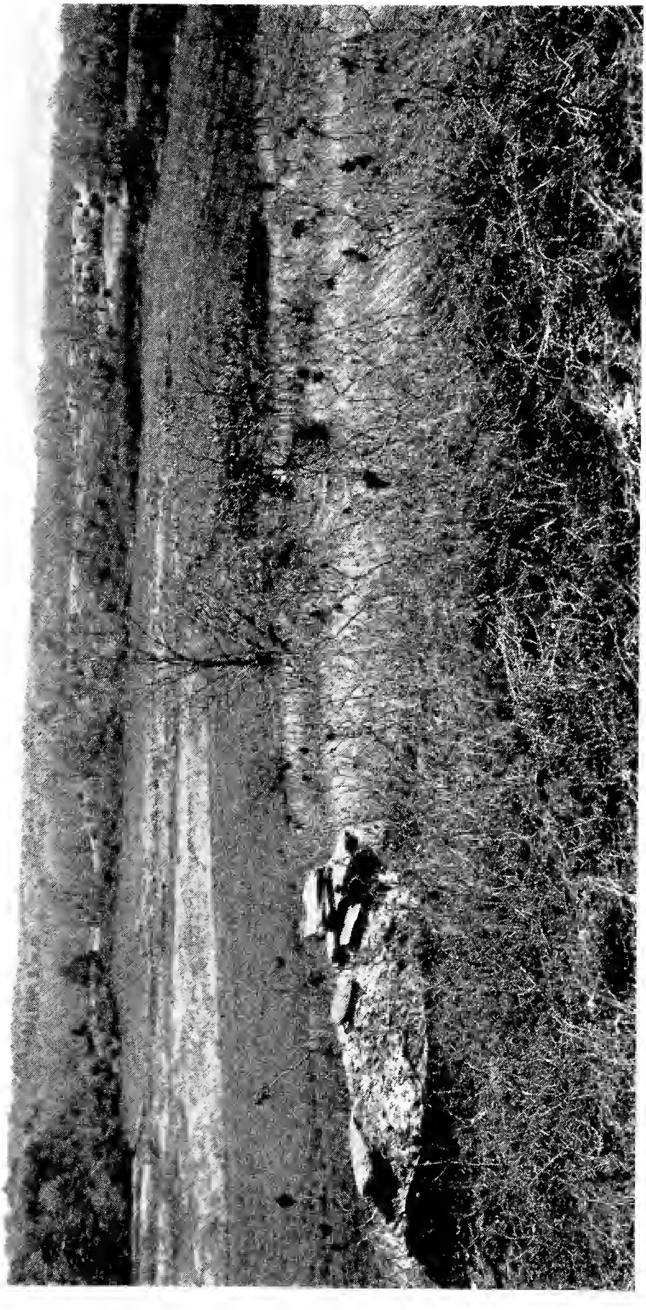

Figure 64 Cluster of "kames," about one and three-quarters miles north of Urlton. View east-southeast. (Photograph by E. J. Stein)

Figure 65 Catskill creek north of Cairo, looking downstream. A heavy glacial terrace (left bank) has crowded the stream against the south side of the valley undercutting the Kiskatom beds. Part of the glacial terrace has been washed downstream; boulders too heavy to be moved appear here and there above the bridge. View northeast. (Photograph by E. J. Stein)

Figure 66 Surficial gravels exposed in borrow pit on the top of the terrace shown in figure 65: just west of the Jan de Bakker's Kill confluence. Boulders such as the one shown here are reliable evidence of the presence of contemporary ice. When the 300-foot terrace at the edge of the sheet was built, stagnant ice lay in Jan de Bakker's Kill valley below the confluence. View looking north-northeast. (Photograph by J. H. Cook)

way of a channel at the southern end, which channel was later found and deepened by the present-day creek. Farther downstream beds of laminated clay are banked in terraces against the south slope. They rise to a little over 200 feet; but the bodies of standing water which they proclaim may have developed locally between the land and residual ice and at a later time. The hypothesis that the valley between Indian ridge and the beginning of Austin glen was once filled with lacustrine clays and sands to (or nearly to) the level of these highest beds is open to several serious objections; and it seems probable that this section of the valley was occupied by ice even after Potic basin ceased to contribute meltwater. By discontinuance of this affluent the volume of glacial Catskill creek appears to have been notably reduced, and the evidence of its later stages indicates gentle, low-grade currents having no great carrying power. Beyond the limits of the Coxsackie quadrangle there are flats of fine sand below the level of the highest clays (south of Austin glen, at Jefferson Heights and at West Catskill) which seem to preclude the possibility of any explanation other than that of a feeble flow close to the level of standing water.

It is to be presumed that dissection of the stagnant ice-plateau went on *pari passu* with a general lowering of its surface, and that the changing topography (progressively less of ice sheet and more of uncovered basement) always presented drainage patterns which were partly independent of the relief of the bedrock since some of that relief remained under ice. Canyons would be worn into the free edge of the glacier and work back into the interior most readily where deep valleys were in line with the direction taken by the runoff of meltwater. Elsewhere their development would be governed by the thickness of ice overlying the rock divides beneath them and onto which they must eventually be let down.

Meltwaters were moving southward across this part of the plateau before the northern divide of the Potic basin was uncovered. As the divide came through the thinning ice, diffuse drainage became more and more concentrated into definite streams which gradually worked down into the passes. Whether the pass at the head of West Medway creek was used could not be satisfactorily determined, nor was it found possible to recognize in a miniature gorge running south from the col, the work of a glacial stream contemporary with the great kame-field. The passes between Gulf and Cob creeks and between Elder and Grapeville creeks carried meltwaters coming from the ice-filled Hannacrois basin, but in both cases the flow ceased before the passes were fully cleared and while the Potic basin still held a large amount of ice. The present elevation of the former is a little more than 700 feet above sea level, that of the latter about 650 feet; but a group of kames rising above the marsh at this level indicates that the final waterplane was associated with residual ice and was some 20 feet higher. The subsequent course of glacial waters diverted from these points was governed by the bedrock topography and that part of the 700-foot contour which has been introduced into the sketch map, figure 61, furnishes the key to the topographic control. It shows that such waters could have escaped only by way of the Hannacrois valley either over a narrow belt of ice in its deepest part or against the steep hillsides eastward from Alcove. Nothing was found to proclaim the action of flowing water either along these slopes or southward from the county boundary to Potic mountain. It is probable, therefore, that the diverted drainage became wholly superglacial. It doubtless had a long course over ice to confluence with the contemporary master stream of the Hudson valley, then located along the outer edge of the rock terrace east of the river. The plain west of Kinderhook lake (Kinderhook quadrangle) is believed to be in the line of the master stream and its nearest point is more than 10 miles from Alcove. If the present elevation of this plain could be accepted as that of the confluence, no part of the floor of a canyon made by the meltwater-Hannacrois could lie below 313 feet; and for a considerable distance back from its mouth (at least to the Onondaga surface above Aquetuck) the basement would not be exposed in it. The old ice-valley in which the master stream ran was, however, greatly modified during later stages of the glacier's disintegration and sections of the depression must have been notably aggraded by vast quantities of sand and gravel brought in by contributaries from the east and northeast. Farther south (on the Catskill quadrangle) terraces which appear to be for the most part free from subsequent deposits occur along the main drainage line at 250 feet, and, if the waters coming over ice from the Hannacrois basin did not join the trunk stream until they had reached (or passed) the latitude of these terraces, the lowest elevation at which they might expose the basement would not have been so high as that of the plain west of Kinderhook lake. These considerations are pertinent because it is necessary to account for a curiously shaped cavity-filling at the end of the short gorge through which the Hannacrois flows below Deans Mills. The deposit is partly of till dropped from confining walls of ice and its form suggests that

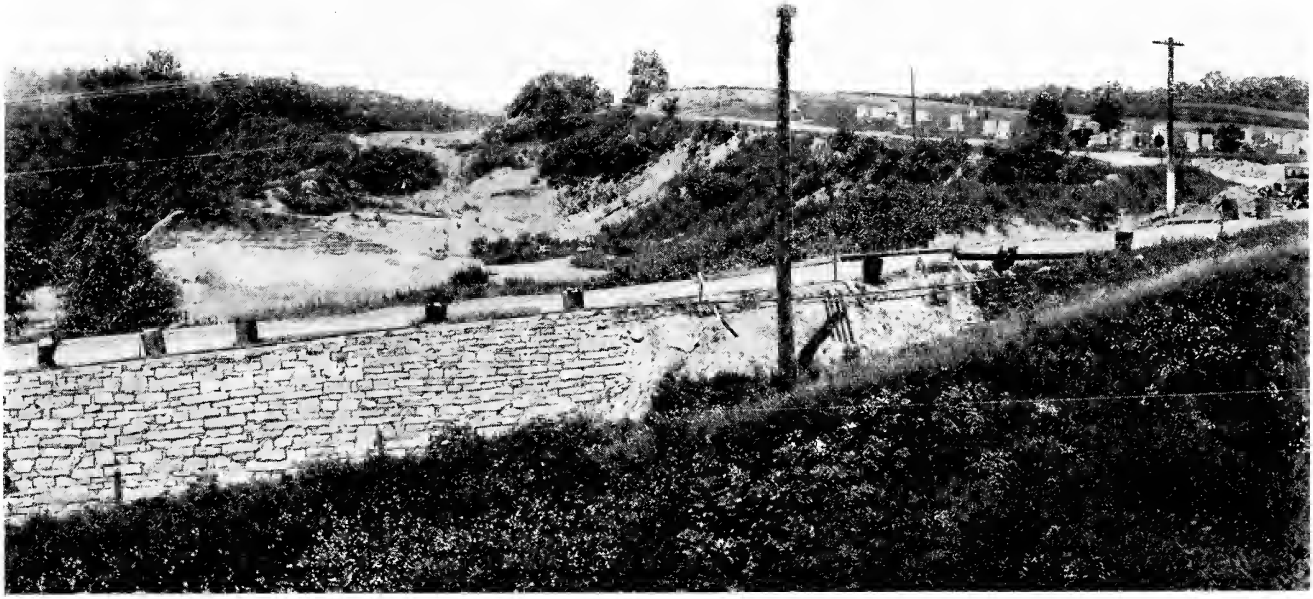

Figure 67 New Baltimore glacial delta, looking west. Excavations expose the sand beds. At the right the cemetery is on the slope which runs down to the ice contact shown in figure 68. View west-northwest from the West Shore Railroad bridge. (Photograph by E. J. Stein)

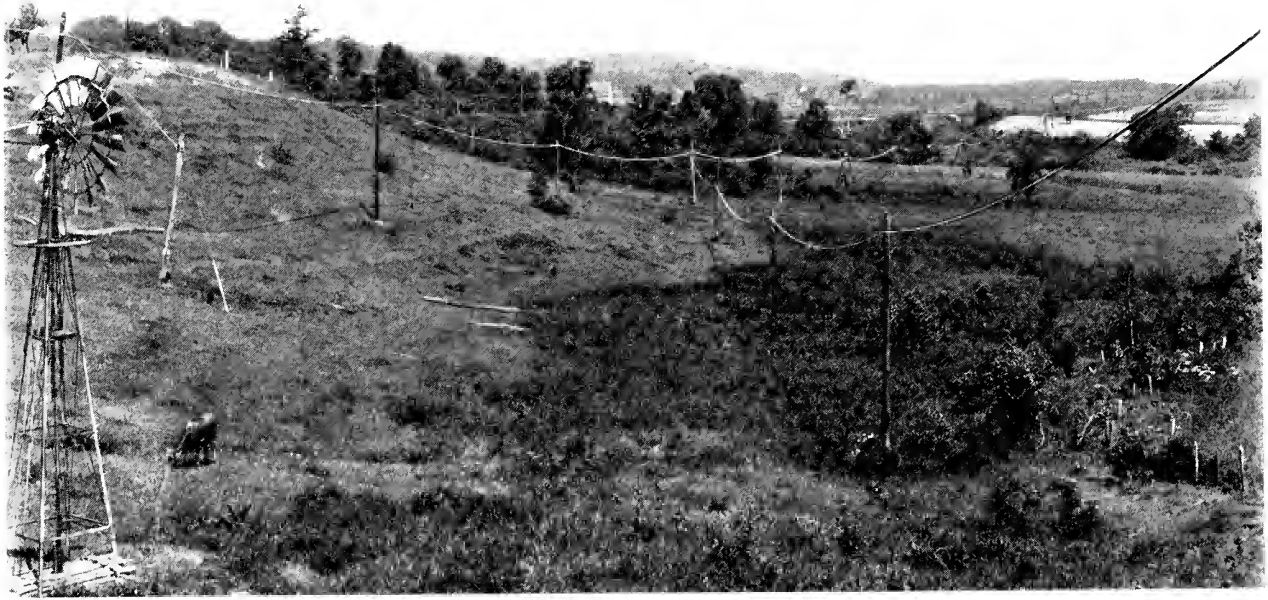

Figure 68 Ice contact face of New Baltimore glacial delta (at left). A part of the 200-foot clay plain may be seen in the middle distance at right (*see* page 347). View north-northwest from the road east of the New Baltimore cemetery. (Photograph by E. J. Stein)

it accumulated in an ice canyon. The northern ice contact face is shown in figure 68. Fine water-laid sands may be seen in an excavation south of the road leading up the valley (figure 67), the indicated water plane for which appears to have been a little less than 280 feet A. T.

The possibility that this cavity-filling was not made in contemporaneity with the heavy glacial terraces across the river must not be overlooked. Icebound deposits occur in many, though not all, of the alcoves where preglacial valleys open onto the western rock terrace (of the Hudson valley), and from South Bethlehem (on the Albany quadrangle) to the southern limit of the Catskill sheet these are *consistently lower* than the levels to be expected, if the streams, which built them, were contributaries to the glacial river flowing over the eastern rock terrace. The fact favors a supposition that westside deposits were not made during the time of strong southward flow shown by the eastside terraces, but later. There was no marginal drainage along the western wall of the Hudson valley from South Bethlehem to the Catskill and the waters produced by the melting of ice which was thick enough to block the gap at the north end of Potic mountain have left no evidence by which they may be traced.

At the stage represented by the highest (and presumably earliest) of the Potic Basin kames we may picture the remnant of the glacier in this district as filling the broad Hudson trench up to at least the 800-foot contour. The canyons which had developed in it have a north-south alignment and the most important one lies east of the valley axis. The drainage passing across the buried basin of Hannacrois creek comes to occupy at least two cols of the southern rim, crosses the Potic basin and leaves it (480 feet) west of Indian ridge. The drainage is then diverted eastward. A new picture suddenly replaces that of the canyoned ice tongue. The bed of the master stream has been abandoned and so much of the glacier has disappeared that, except in the still ice-filled gorge, clays are being deposited in bodies of quiet water the highest of which is little more than 200 feet above tidewater.

One of the most perplexing problems presented by the Pleistocene formations of the upper Hudson valley is how the very considerable body of ice present when the last conspicuous gravel beds were completed could have been removed without leaving a more complete record of the successive stages of its dissipation. With the exception of a few kames in the little valley east of Medway, nothing to suggest glacial drainage could be discovered along the eastern face of the plateau south of the Hannacrois. More than a score of small rock-basins occur in the belt of folded strata immediately west of the clay-covered ground. Some are filled by lakelets or swamps, but at least a dozen are represented on the topographic map by depression contours. A few are solution basins but the majority have been gouged out of the rock by the overriding glacier. Except for two which are just within the northern boundary of the sheet they lie south of Roberts hill, the most southerly (and the deepest of all) being located one and three-quarters miles northeast from Leeds. That none of these rock-basins received glacial sediments argues that the belt in which they occur was not traversed by any important line of meltwater drainage.

As noted above (page 341) shelves of laminated clay which rise above the 200-foot contour occur along the right bank of the Catskill below the cavity-filling at the mouth of Potic creek. Although it is not improbable that the modern stream has undercut these deposits, the recent alluvium and the evidence of associated meandering are much below the level of the glacial clays and there is no good reason to suppose that the latter were once continuous to the opposite side of the valley. Farther south (on the Catskill quadrangle) the same water plane appears to be indicated by flat-topped ice-confined delta terraces in the courses of the Beaver and Platte kills, while east of the Hudson there are ice-confined plains at this elevation about Rhinebeck and Red Hook and from the Roeliff Jansen kill to Claverack creek sedimentary beds of the same series were laid down in the presence of contemporary ice.

The quiet waters necessary for accumulation of such fine sediments as are found at all of these localities (except in the Beaver Kill terrace) and at Kingston and Esopus must have been retained by ice plugging the gorge between Kingston and New Hamburg and for an unknown distance southward. It will be recalled that the "deep" opposite the rock terrace at West Point (where the depth of water is more than 200 feet) was bridged by ice throughout the time of clay deposition in the upper valley. That much residual ice persisted throughout all the lacustrine stages is shown by alcoves and basins which otherwise would have been obliterated by sediments. Low level alcoves due to ice remaining in the gorge appear at Hudson (North and South bays) and south of Catskill (Duck Cove and the Imbocht), while from Stuyvesant to a point opposite Newton hook (Coxsackie quadrangle) is an amassment of washed sands and till below the summit level of the lake. This was deposited against a tongue of ice or, more probably, in an ice canyon.

The considerable amount of ice still in place at the end of the lake stage justifies the belief that much more ice was present at the beginning of that stage, that the earliest "lake," following upon establishment of the 200-foot (plus) water level, consisted of a series of pools marginal to the ice tongue. Where the tongue was several miles wide, the high level lacustrine deposits are well back from the river (as those near Leeds). Where the tongue was narrow, such deposits occur close to the brink of the gorge as the sandy plain east of Schodack Landing. How far lacustrine beds rising to the same elevation may be of contemporary origin it is impossible to say, but, in view of the irregular manner in which decay of the glacier may be assumed to have uncovered the lake bottom, it is hardly probable that concordant elevation can always be regarded as a reliable basis for correlation.

Lacustrine clays rise above the 200-foot contour west of Hannacrois creek where it flows north from the sharp bend west of New Baltimore (figure 68). The course of this postglacial stream was determined by the slopes of the old lake bottom and the ground along the east margin of the clay plain must have been lower than the sedimentary surface between the sharp bend and the head of Sickle's creek. This suggests that the creek follows a depression left on the melting out of ice which was present when the 200-foot plain was made.

Determination of the water levels throughout the Hudson valley is an undertaking beset with difficulties which are more easily appreciated than surmounted. Two facts of late glacial climate militated against the production of an easily decipherable record: the prevalence of strong northerly to northwesterly winds and the lack of precipitation. Because of the latter, valleys did not carry meteoric runoff and true deltas were built into the pools and lakes only at points where they were entered by meltwater streams. And because of a thick covering of aeolian sand the structure of the clay beds is often masked in critical localities. How complex this structure may be becomes evident only when details are studied attentively, but some idea of the kind of problem presented may be gained even from a casual inspection of the accessible surfaces and exposures. The thickness of the deposit and the elevation to which it has been built up often vary considerably within short distances, frequently without any ascertainable reason, and the break between higher and lower levels is occasionally almost precipitous. It is believed that many of the areas where the clay surface is low were long occupied by ice while most of the higher flats represent the earliest open water. When, then, in the postglacial period the climate altered and rain again fell over the region, the old lake bottom was traversed for the first time by streams of meteoric water. Across the clays with their topping of sand these streams followed consequent courses determined in large measure by location of the lower (and at least in part presumably later made) deposits. Clearly defined ice-basins from which lake sediments were excluded altogether occur a short distance beyond the limits of our sheet along the course of Kinderhook creek. The road leading eastward from Stuyvesant (see topographic map) leaves the Coxsackie quadrangle on a dissected clay plain at the divide between northward (Mill creek) and southward slopes. Within a mile (Kinderhook quadrangle) it rises 100 feet to a flat sandy glacial plain whose elevation at the junction with U. S. Highway 9 is given as 224 feet. East of the junction is one of the large ice block basins which determined the course of postglacial Kinderhook creek below Valatie. (The drowned mouth of this stream appears on the Coxsackie quadrangle as Stockport creek.) It seems reasonable to suppose that residual ice lay over the Stockport Creek section longer than it did north of Columbiaville, that the eventual melting of this ice left a basin which was subsequently filled with clay but not to the level of the earlier deposit. Kinderhook creek was induced to follow a path east of the 170-foot plain north of Columbiaville and Claverack creek was induced to use a long northward path leading to the same low point whence both joined the Hudson.

On the west side of the river a large part of the lake bottom south of the latitude of Stuyvesant is less than 140 feet above tidewater and, for purposes of this discussion, it may be referred to as a low level area. It appears to correspond in point of origin with a similarly low level tract which for several miles south of Catskill creek borders the Hudson. The elevation of the clays in the southern end of the Hans Vosen valley (see topographic map) and of the sandy plain at West Catskill (Catskill quadrangle) is not much more than 100 feet A. T., but there are intervening clay beds in the northern part of Catskill village and under the sands of the Jefferson Heights delta (J in figure 61) which are at least 40 feet higher. The absence of lacustrine clays from the defile which is followed by the railroad northward from Catskill onto the Coxsackie sheet is taken as evidence that the higher deposits were made in pools surrounded by residual ice.

Figure 69 Sloping clay surface north of West Coxsackie, looking west of south. From Lampman's hill northward (opposite the Stuyvesant moraine) the clay surface slants westward away from the river. (Photograph by E. J. Stein)

Drainage basins making up the low level area are, at the south, those of the Hans Vosen kill, Corlear kill and Murderer's creek and, at the north, that of Coxsackie creek. A mile south of West Coxsackie the divide between the two last-named basins is less than 120 feet A. T. From the railroad embankment which crosses the depression the sedimentary surface rises steadily eastward and northeastward to the brink of a bluff overlooking the river where it has a summit elevation of 155 feet. The outline of the mass of clay sloping westward from the bluff is sufficiently well indicated by the 140-foot contour; its form is that of the underwater fringe of a delta built from the east and into open water. The surface slope is noticeable from Lampman's hill and from the road entering Coxsackie from the north (figure 69). That the stream or lake current which supplied the rock flour crossed residual ice in the gorge would seem to be evident. Not only does the deposit lie opposite the southern end of the Stuyvesant cavity-filling (Y in figure 61), but, had it extended solidly to the east side of the river, the present course of the Hudson would be through the low ground west of the obstruction and thence down the trough of Murderer's creek.

Other instances of discordant levels having no relation to the rock topography or the preglacial valleys might be cited, but the foregoing will serve, it is hoped, to justify the contentions that the clay beds were laid down *pari passu* with the irregular removal of basal ice; and that the chronological order of their deposition does not lend itself to interpretation in accordance with any simple and easily applied formula. Decay of the glacier to the basement may well have begun where it was attacked by the flow of meltwaters coming down the Mohawk, Hoosick and other valleys to the north while the partial clearing of the Hudson valley in this more southerly region, where a still horizontal water plane appears to be indicated, may be a late extension of the "lake."

The absence of unequivocal wave-wrought features may be accounted for in part by the persistence of residual ice, but in many places materials fine enough to be moved by even weak wave action lie just above the underwater deposits; yet they show no sign of such action. Now and again one comes upon a sandy slope of beachlike evenness but it is to be doubted that true beaches or bars exist in the Hudson valley or in the Champlain valley south of Crown Point. Lack of strand-lines makes it necessary to attempt the determination of water levels from the series of ice-confined "deltas," deltalike alcove accumulations and high level lake beds. (In addition to the local deposits which have been mentioned earlier as suggesting the former existence of a water plane between 200 and 220 feet A. T., there is a terrace of uncertain significance northwest of West Coxsackie south of the small stream called, on the old (1894) topographic sheet, the Diep kill.) Taken all in all, the evidence from Rhinebeck to the Albany quadrangle does not support the hypothesis of postglacial tilting. We may recognize that the land has risen some 200 feet in the latitude of Crown Point since the time when the sea was in the basin of Lake Champlain without assuming that, as a result of postglacial uplift, the horizontal planes of Pleistocene time are now warped or tilted everywhere between Crown Point and New York bay. Whatever may be the case north of the Coxsackie quadrangle or south of Rhinebeck, nothing within these limits has been found which supports the hypothesis of a dislocation of the late glacial water levels.

Geologists are in general agreement that the weight of the Laurentian ice sheet was great enough to depress the earth's crust (lithosphere) beneath it creating a broad basin deepest in the central area in Quebec. Just when this movement began, how long it continued and when the reverse movement set in are questions the answers to which are still to be worked out. It seems probable, however, that during the period represented by the lacustrine deposits which we have been considering, the sea entered the St Lawrence and Champlain valleys wherever it found passage through or under the decaying stagnant glacier, and that, had it not been excluded by ice, it would have extended southward to Whitehall or beyond.

The northern end of the Champlain basin seems to have been occupied by an open arm of the sea before the remains of the ice sheet disappeared from the southern end, and the static waters held up behind (south of) this ice are not separable from the static waters in the Hudson valley; the lake was continuous from one basin to the other and its surface was more than 150 feet higher than the low col north of Fort Edward. In view of these relationships the possibility of a northern outlet should not be overlooked.

The great glacial terrace system just east of the Coxsackie quadrangle appears to have been built by meltwaters coming down side valleys *from the northeast* at a time when the deeper part of the valley and the western rock terrace were still under ice. The glacial terrace antedates the lake stage and, though a few exposures of the lower gravels show that the drainage was southward when they were deposited, the upper beds and the aeolian sand covering the surface give no indication that meltwaters contributed by the Mohawk valley (assumed to be a copious flood) was sweeping over them.

Search for traces of this flood between the 310-foot level of the terrace and the river revealed a small "crown" with kettles at Muitziskill (one mile off our sheet) and the interesting accumulation within the gorge north and south of Stuyvesant (Y of the sketch map, figure 61), neither of which gives evidence of the flow of any extraordinary volume of water.

For some distance northward from the railway station at Stuyvesant the New York Central tracks run at the base of a slope almost destitute of vegetation. It rises more than 100 feet and, because of its steepness, could not be satisfactorily examined. Although some indications of the presence of glaciofluvial beds were noted, the material, so far as could be ascertained, is almost wholly till. The deposit is highest at the brink overlooking the river and the top declines gently eastward. The precipitous western face, though somewhat modified, is the northern end of an ice-contact which margins the Hudson for more than three miles. Cross-bedded sands and gravels appear in excavations back of Newton hook and in the village of Stuyvesant and a natural exposure of fine black sand (comminuted shale) occurs along the east-west road, three-quarters of a mile below the latter place.

Through part of its length the formation is bounded by a ridge of bedrock between which and ice in the gorge the glacial materials accumulated. But a deep valley east of the rock ridge is filled with later clays and must have been occupied by ice at all earlier stages. The Stuyvesant deposit is to be regarded, therefore, as a cavity-filling rather than a lateral terrace and the complexity of its structure (shown by differences of texture and elevation in close juxtaposition) indicates that it was not built up as a unit but a section at a time. Opposite Coxsackie island there is a small area which is more than 200 feet above the river. Whether it is underlain by till or coarse gravel could not be determined. Three ice-block basins at Stuyvesant are represented by depression contours on the topographic map; they are associated with a platform outlined by the 180-foot contour and on which the triangulation station symbol appears. Eastward is a deeply dissected plain underlain by beds of coarse sand which dip to the southwest. (Its elevation, approximately 170 feet A. T., is the same as that of a secondary delta of Catskill creek, the Jefferson Heights delta, which fact suggests that the deposits were controlled by a common water level while there was still much residual ice in this part of the Hudson valley.) In the opinion of the writer these graded sediments lying between the platform (and kettles) on the west and the ridge of bedrock on the east were laid down contemporaneously with the sloping clays at Coxsackie (figure 69).

Thus far attention has been directed to the accumulations of drift associated with the downwastage and fragmentation of the Wisconsin ice sheet after it had stagnated. Taken as a whole the stagnation drift may be said to form a discontinuous mantle only partly concealing the surface over which the continental glacier had moved. Where this mantle is absent or thin or has been removed the basement is open to inspection.

Exposures of bedrock frequently show the familiar scratches (striae) engraved by hard rock fragments dragged along at the bottom of the glacier, fragments either held in the ice itself or incorporated in a mass of till being ground between the rock and the glacier's bottom, the ground moraine. True ground moraine is subjected to great pressure which, if long continued, will convert clayey material into compact beds popularly known as "hardpan." Till which has lodged against a cliff or steep slope normal to the direction of ice movement may be built into a ramp of hardpan up which later ice will slide with a minimum of friction.

None of the striae found over the Coxsackie quadrangle are at all spectacular. They are abundant on the harder strata of the Hamilton formation and in general have a north-south alignment showing that here the Hudson Valley lowland was being used as one of the principal avenues for relief of pressure. In the northwestern corner of the sheet, however, as about Newrys (figure 70), the striae point as much as 17° to the west of south. This is the eastern edge of a sector of the glacier which appears to have pushed forward against the rather formidable barrier presented by the northern escarpment of the Catskill mountains.

It will be observed that, in the belt of folded strata forming the eastern edge of the plateau region, many of the contours on the map make a series of closely crowded elliptic curves against slopes which are either ascending or descending southward. Although the trend of the ridges of bedrock here very nearly coincides with the direction of the last ice movement down the valley, the regularity with which the axes of the ridges are aligned in parallelism is largely due to the action of the overriding glacier. Hills having the same more or less elliptic ground plan and with smoothly curved profiles but composed wholly (or almost so) of till were also given shape by the overriding ice: they are known as drumlins. The best exhibit of drumlins on the quadrangle lies between Jan de Bakker's kill and the Cob Creek watershed where they are associated with drumlinized bedrock. Of the many others scattered over the sheet two prominent examples call for notice because of their typical symmetrical form.

Figure 70 Typical high level glaciated bed rock showing striae. Near Newrys, looking north. (Photograph by E. J. Stein)

Figure 71 Wooded drumlins facing the Catskill mountains, as seen from Sanford's Corners, looking southwest on the Durham quadrangle. (Photograph by E. J. Stein)

One lies north of Medway and its summit is outlined by the 800-foot contour. The road leading northward from Urlton passes longitudinally over the crest of the other. Slightly curved drumlins occur south of Gayhead; they indicate a local streaming of the basal ice out of line with the main current. The cause of the deflection is, in the present case, not obvious. Drumlins pictured in figure 71 lie just beyond the western limits of our sheet.

The streams which enter the Hudson estuary have been "drowned"; the tides now extend up each stream-cut valley for some distance above its former mouth. The tidal inlet named Stockport creek is the largest of the local examples but the smaller inlets of Murderer's, Coxsackie, Hannacrois and Coeymans creeks are equally instructive. The valleys were necessarily excavated while above sea level and the drowning of the lower sections has resulted from a positive subsidence of the earth's crust in postglacial time. Indeed, this crustal movement is probably the latest geological event of importance in the district; it would appear to be complementary to the uplift evidenced by raised marine beaches in the Champlain basin. The order of magnitude of differential change between the marine beach northeast of Crown Point (200 feet A. T.) and the preexisting shore line at the Atlantic end appears to be about 400 feet. The submarine canyon continuing the Hudson valley beyond New York bay is interrupted by a flat area some 34 fathoms under the water which may be the sea level delta contemporary with the cutting of the postglacial tributary valleys. Certainly the large amount of material removed by streams must have resulted in a sedimentary deposit at the Hudson's mouth now lowered beneath the sea out beyond Sandy hook.

The alluvial islands in the present estuary are the sea level delta of the river at the present stand of the land.

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ECONOMIC GEOLOGY AND INDUSTRIES

There is little to write relative to the economic geology of the Coxsackie quadrangle. The *flagstone* ("bluestone") industry was once important and flourishing in the area, as attested to by the numerous abandoned quarries in the upper Mount Marion and Ashokan belts. Some of the refuse on the abandoned dumps, such as those along the Alcove-Newry road south of the Alcove reservoir, is now being crushed for use in road building. Throughout the area covered by the "red" beds the red and green sandy shales are quarried for *road metal.* Similar quarries are found on the east side of the river, particularly in the Nassau beds. The abandoned quarries in the Normanskill grit, along the west shore of the river once supplied material for building railroad beds in the old days and for ballast.

Only one *crushed stone* company is at present working in the area. This is the Hotaling Quarry Company, located along the west side of the state road about three-quarters of a mile south of Ravena. The quarry here is located in the Manlius limestone. About two miles north of our northern boundary, at South Bethlehem, the Callanan Road Improvement Company uses both Coeymans and Manlius for the manufacture of crushed stone. This company has another plant at Feura Bush and while the World's Fair was underway opened a subsidiary plant in the Kingston area, since it was cheaper to ship by water.

The Racex Lime Corporation is working with the Onondaga limestone. The limestone is pulverized to make *agricultural lime.* The plant is located on the east side of the road, about three-quarters of a mile north of the west end of Greens lake.

No *cement quarries* are being worked in our area, but there are several located a few miles south of our quadrangle, on both sides of the river. Two companies are quarrying Manlius, Coeymans and Becraft in Becraft mountain, south of Hudson (the Lone Star Cement Corporation and the Universal Atlas Cement Company). A few miles south of Catskill, on the west side of the river, the North American Cement Corporation (Acme Plant) is located at Alsen and the Alpha Portland Cement Company south of there at Cementon. The Manlius and all the Helderbergian limestones are quarried, but the Becraft limestone, with its high content of calcium carbonate (90 per cent or over) and its low magnesia content, is considered the best material.

Moulding sand has been taken from this area in small quantities. One locality noted is along the road to Selkirk, north of Coeymans; another was found in the hill above the west bank of the river (north side of the lane), directly opposite Judson point. Compared with the Capital District which ranks as the most important area in the East, the production in our area is negligible.

Marl occurs in a number of places in small ponds, often dry. The one south of Greens lake may be seen from the road, on the east side. Another fairly accessible one occurs on the east side of the road about three-quarters of a mile south of Deans Mills. The muck found on the marl here has been taken out for use in the mushroom industry, according to the Rev. Delber W. Clark of Coxsackie. Still another lies in the depression one-quarter of a mile south-southwest of the hotel at Climax. They are all insignificant and easily passed over, and, so far as the writer could ascertain, the marl is only used locally by the farmers as a fertilizer.

Two industries are outstanding on the Coxsackie quadrangle, brickmaking and mushroom growing. The *brickmaking industry* is dependent upon the clay found so abundantly in the Hudson valley in the terraces on both sides of the river. These clays, deposited in the bodies of water that, at various levels, occupied the Hudson valley in the closing stages of the Ice Age (late Pleistocene), contain a considerable percentage of the fluxing ingredients, such as lime, iron, magnesia etc., but, according to the former State Geologist, D. H. Newland, are as a rule suited only for the manufacture of the commoner kinds of building bricks. Numerous brickyards may be seen on both sides of the river, but a large number have not been in operation during recent years. On the Coxsackie quadrangle three companies are now working in the vicinity of Coeymans (Powell and Minnock Company, Roah Hook Brick Company and Sutton and Suderly Brick Company), and some of the "workings" may be seen north of the outskirts of Coeymans along the road from Selkirk. The largest brickyards are located in the vicinity of Little Nutten hook (the Carey Brick Company, Stuyvesant Works, to the north; the Empire Brick and Supply Company, Stockport Works, to the south) and north of Hudson (Greenport Brick Corporation).

Mushroom growing, the most interesting and apparently also the most flourishing industry in the Coxsackie region has no connection with the geology of the region. The industry was started in the old, abandoned icehouses along the river and flourishes not only in the Coxsackie region but in the regions to the south on both sides of the river. The icehouses have been supplemented by other buildings and, also, the caves created by quarrying the Rondout waterlime in the Rondout region have been adapted to mushroom growing. The industry at Coxsackie is controlled by Knaust Brothers. They have used the icehouses along the river on the south outskirts of Coxsackie and in 1937 increased their plant by a $250,000 building in the western part of the village, which has a floor space of more than three acres. A spur of the West Shore railroad permits fertilizer to be unloaded within the building.

This addition, according to information in the Coxsackie Union News (August 27, 1937), makes this the most modern mushroom plant in existence with the world's largest output a day. The new plant was expected to increase the production to about 1500 complete trays a day, each tray equalling about six three-pound baskets of mushrooms (July 30, 1937). In the spring of 1938 the minimum daily production was estimated at 3500 baskets and the maximum at 6500 (facts obtained for the writer by the Rev. Delber W. Clark of Coxsackie). The new building contains 20 germinating rooms and one room is planted each day. The germinating trays, when ready, are taken to the icehouses, where they are arranged in tiers on both sides of the aisles in dark rooms with controlled temperature and where they remain until all the mushrooms have been picked. It takes six weeks from the time the germinating tray is prepared until the mushrooms can be picked and another six weeks until the tray has yielded all it can. The owners figure on keeping 200,000 baskets in circulation, with an estimated loss of about 5000 baskets out of this total. They market as many mushrooms as possible in baskets, with Chicago as about the limit in shipping distance. The surplus is canned in a factory belonging to the concern. Another side line is mushroom spawn, in the growth of which brewer's grain is used. It has been estimated that the Knaust Brothers control 85 per cent of the mushroom industry in the United States (55 per cent to 60 per cent in the summer). In 1938 this plant employed 500 persons. Visitors are permitted in all parts of the plant.

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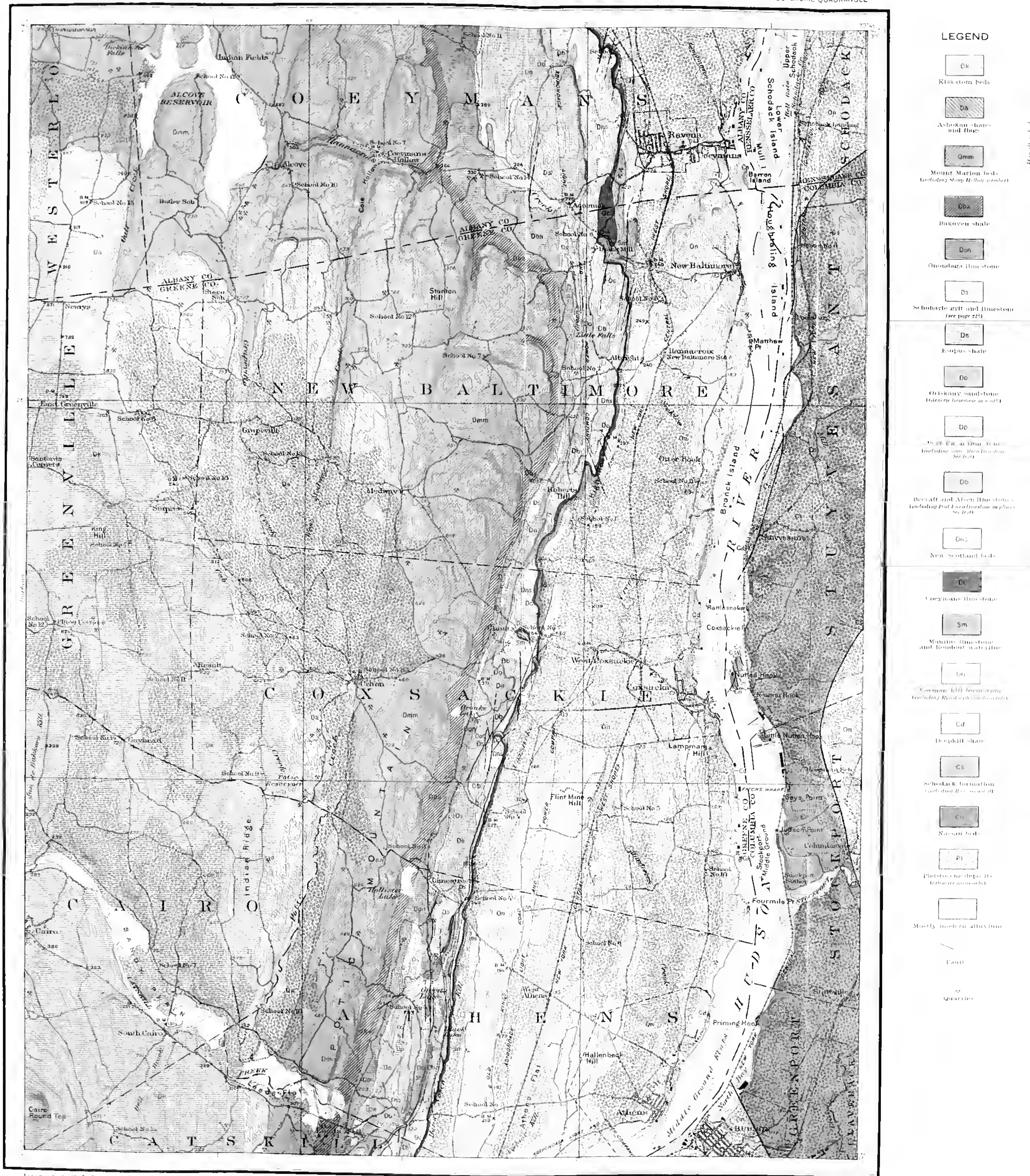
INDEX

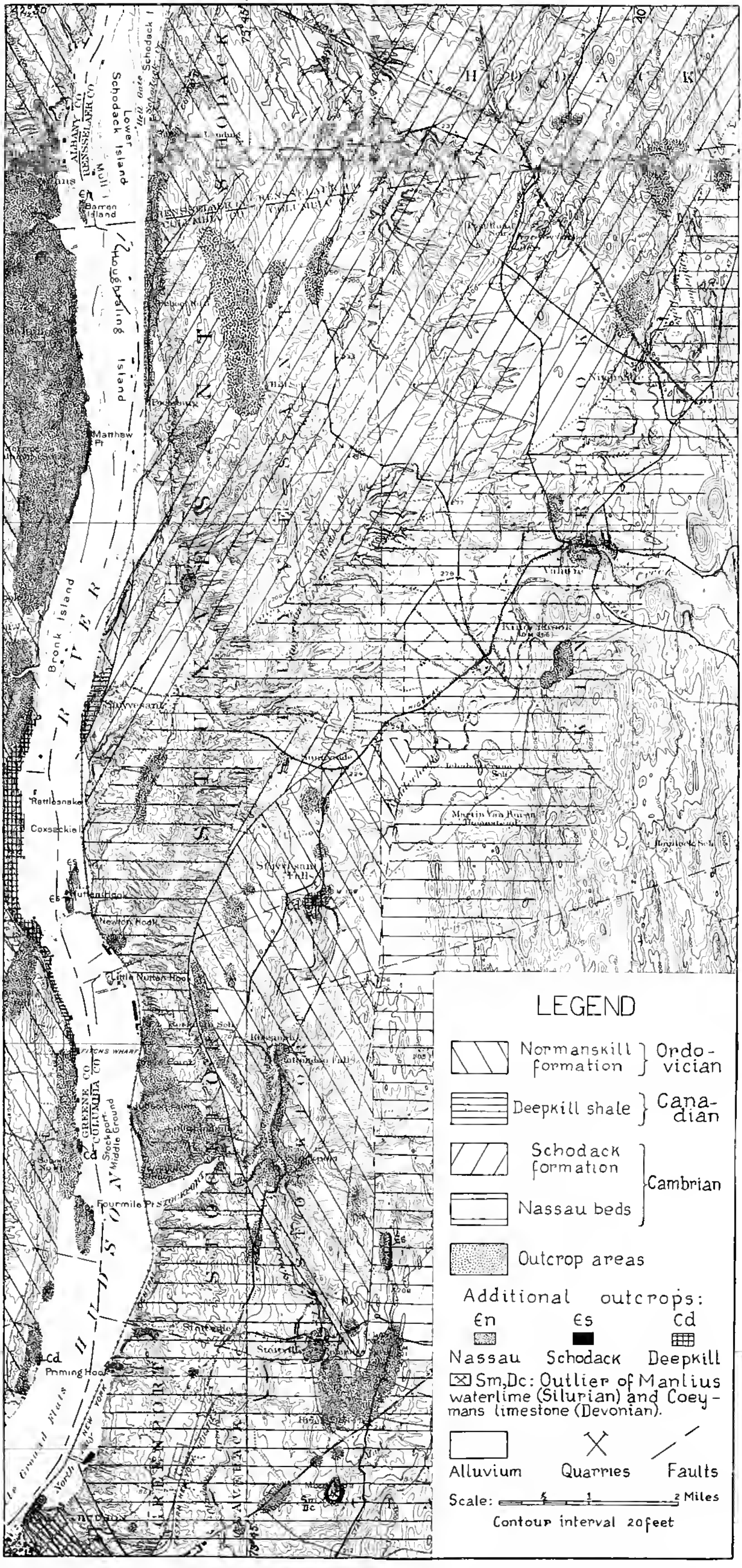


Topography by U. S. Geological Survey and the State of New York 1926 (revised)

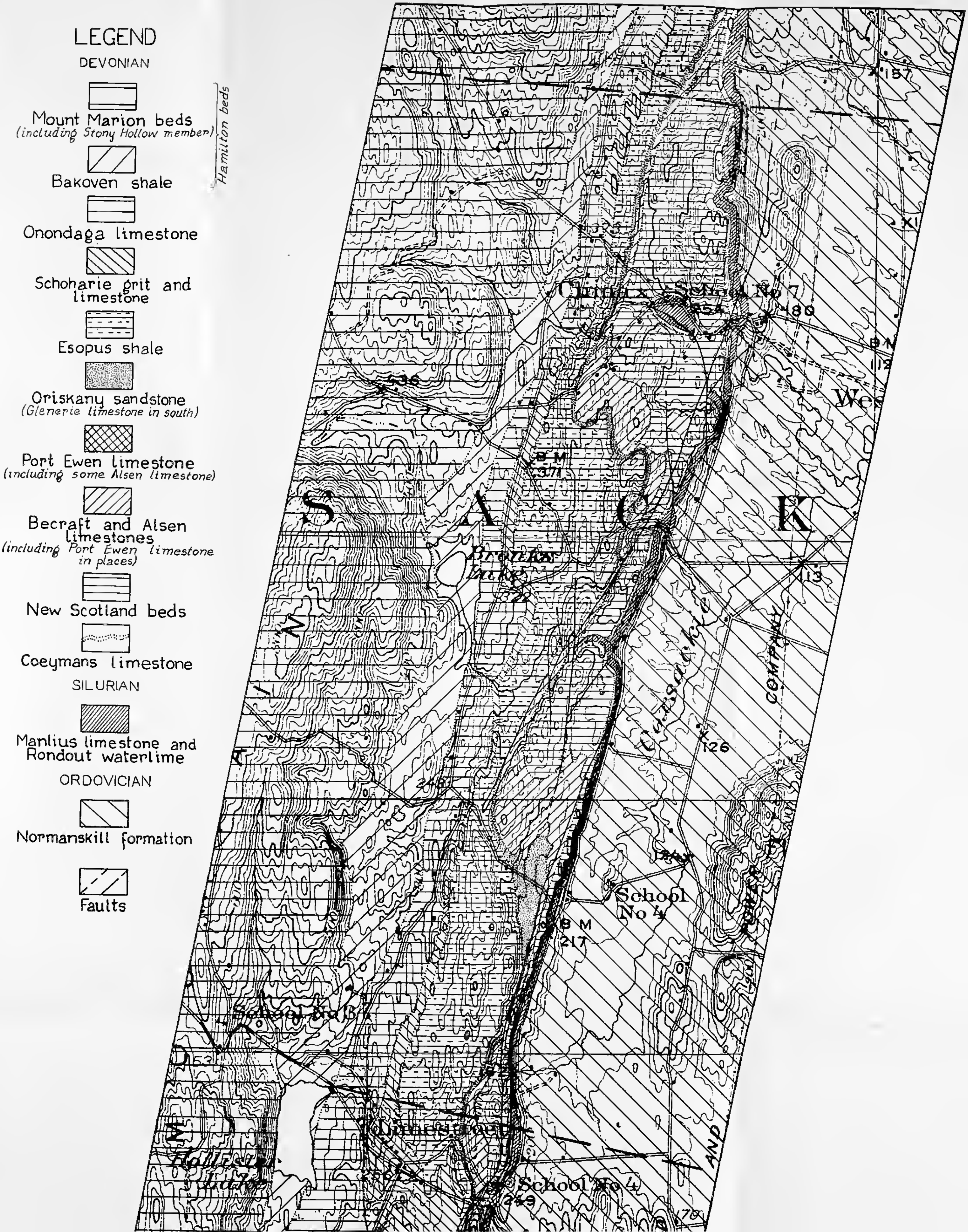
GEOLOGIC MAP OF THE COXSACKIE QUADRANGLE

Geology by Winifred Goldring, 1934-1937

Contour interval 20 feet
Datum is mean sea level



Map 2. Eastern portion of the Coxsackie quadrangle and western portion of the Kinderhook quadrangle showing the relation of the outcrop areas.


LEGEND
DEVONIAN
Mount Marion beds
(including Stony Hollow member)
Hamilton beds
Bakoven shale
Onondaga limestone
Schoharie grit and limestone
Esopus shale
Oriskany sandstone
(Glenerie limestone in south)
Port Ewen limestone
(including some Alsen limestone)
Becraft and Alsen limestones
(including Port Ewen limestone in places)
New Scotland beds
Coeymans limestone
SILURIAN
Manlius limestone and Rondout waterlime
ORDOVICIAN
Normanskill formation
Faults
S
A
C
K
B M
371
B M
217
School No 4
126
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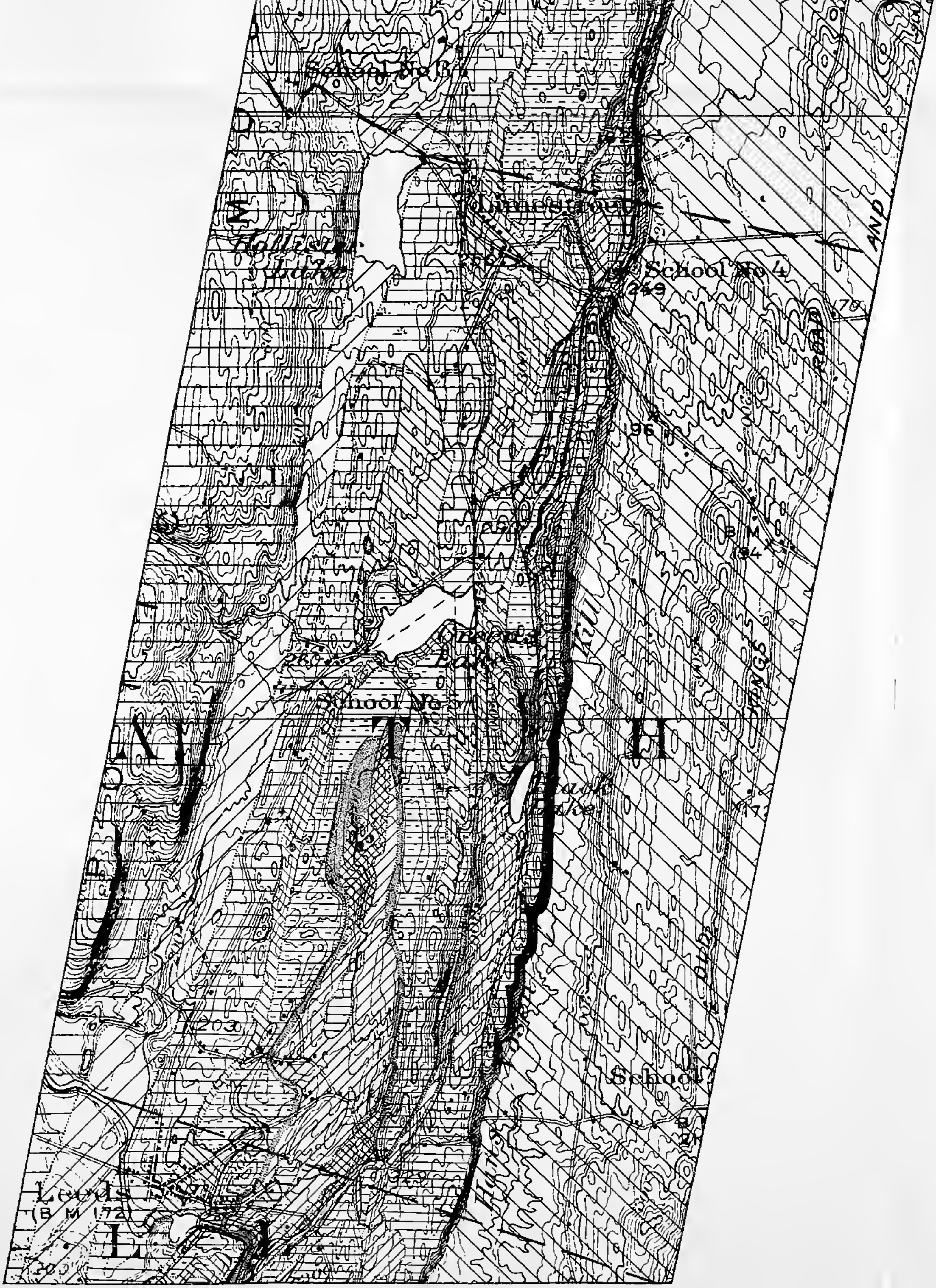
COMPANY
AND
249
School No 4
170



Map 3. Geology of the limestone belt from the vicinity of Climax south, enlarged three times. Contour interval 20 feet. Scale: three inches to one mile.