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NEW YORK STATE MUSEUM
CHARLES C. ADAMS, *Director*

GEOLOGY OF THE CAPITAL DISTRICT
(ALBANY, COHOES, TROY AND SCHENECTADY QUADRANGLES)

BY RUDOLF RUEDEMANN Ph.D.
State Paleontologist, New York State Museum

WITH A CHAPTER ON GLACIAL GEOLOGY
BY JOHN H. COOK

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GEOLOGY OF THE CAPITAL DISTRICT

(ALBANY, COHOES, TROY AND SCHENECTADY QUADRANGLES)

By Rudolf Ruedemann Ph.D.

State Paleontologist, New York State Museum

WITH A CHAPTER ON GLACIAL GEOLOGY

By John H. Cook

PREFACE

The writer undertook the mapping of the capital district of New York for various reasons. For one, there had come requests for detailed geologic maps of the district both for economic use in connection with various engineering problems and for theoretical use by students, the capital district, with its expanse from the heights of the Rensselaer plateau to the summits of the Helderberg mountains being a favorite field for excursions by students of geology. Another reason that led the writer to the rather arduous task of mapping such a large area is that it comprises the entire series of shale formations of the so-called Shale Belt of eastern New York from the Lower Cambrian to the Indian Ladder beds of Middle Ordovician age, which the writer believes he is, from his long study of these formations, better prepared to distinguish than younger geologists would be. He therefore felt it his duty to perform this service.

In order to make the work as practical and as accessible to the greatest number of readers as possible, it has been written in popular language with the exception of a few chapters which deal with purely technical matters and have been denoted as technical chapters.

In order to show at once on the map where the rocks are near the surface or entirely hidden by glacial and river deposits, the demarcation of the areas of rock outcrops, shown on the map by the lack of overprint, has been carried out in great detail and with great care. This required more work than had been anticipated and

proved the cause of much delay in the final completion of the map, but it is confidently believed that the result justifies the greater work, the map showing at a glance where outcrops are to be expected and where not. It seems that altogether too many maps have been made in the glaciated areas of New York and other states as well, showing simply the outlines of the formations without any indications of the underlying evidence, sometimes boundaries being drawn across the map by sheer main strength. Professor Cushing used to draw in continuous lines boundaries directly observed, and in dotted lines those only inferred. This method gave a fair clue to the relative exactitude and positiveness of the boundaries drawn on the map. A detailed overprint carries this further and practically enters on the map all notes on observed outcrops.

The writer would like to say a final word on the correctness of the map. He is fully aware that there are errors in this map, for in areal mapping the geologist is always meeting local problems, structural and tectonic in kind, which have to be solved one way or another and the solutions entered on the map. There is often not sufficient evidence exposed at the time to reach a positive conclusion, yet the map requires a positive delimitation of the formations. Later new exposures may be created by road or dam building or other engineering works, which put another aspect on the local structure recorded in the map.

It may be added here that outcrops come and go. Human activities now often produce wonderful temporary outcrops and as often hide or destroy others. As an illuminating instance may be mentioned the bluestone quarries below Van Vranken avenue in Schenectady, which for many years were actively operated and also regularly visited by college professors and their classes (as by Professor Charles S. Prosser) and in which the writer obtained his principal collection of Ordovician eurypterids. These now have been filled in and built over, so that every trace of them has disappeared, or is disappearing. It is the same with sometimes highly illuminating outcrops in road ditches, foundations of houses, sewer trenches etc. There are thus recorded on our map by a star localities which have furnished fossils where today all opportunity for collecting has vanished. On the other hand, new exposures produced by man may at any time change boundary lines based only on inference without any reproach to the mapping geologist.

The author has enjoyed, while engaged in this work, the personal interest in the mapping of the capital district of the late Director,

Dr John M. Clarke, as well as of his successor, Dr Charles C. Adams. Active help was given him by Winifred Goldring, who for three months joined in the work of mapping the Helderbergs, being herself engaged on the Berne quadrangle, and of filling in hitherto unobserved areas on the Albany and Schenectady quadrangles. Clinton F. Kilfoyle and Walter J. Schoonmaker of the Museum staff also assisted in looking up outcrops on the Troy and Cohoes quadrangles and Mr Kilfoyle made most of the pen drawings. Edwin Stein took the photographs which accompany this paper with his usual care and artistic skill, and made some of the drawings.

While the writer was primarily interested in the rock geology of the region, the glacial geology has such a profound and unmistakable influence upon the secondary surface characters of the country, as well as upon the origin of the drainage, character of soil, and other important features, more or less directly shown on a geologic map, that he considers as a most valuable complement to the rock geology of the district the brief survey of the glacial geology of the capital district, written for this bulletin by Professor John H. Cook. The glacial geology of the Schenectady and Cohoes quadrangles has already been described by Professor James H. Stoller.

INTRODUCTION

The capital district of New York, comprising four quadrangles (Schenectady, Cohoes, Albany and Troy, in their order from northwest to southeast) covers an area of about 900 square miles (877.90 square miles to be exact). It is situated in the subtriangular inner lowland formed between the Adirondack mountains in the north, the Rensselaer plateau in the east and the Helderberg escarpment and plateau in the south. Its geographic center is formed by the confluence of the Mohawk and Hudson rivers, toward which point the greater part of the district can be said to slope and the drainage is directed.

The topography of the district, which can be seen best at one glance from the top of one of the towering buildings of Albany, as for instance the Telephone Building or State Capitol, is given its character by the straight north-south escarpment of the Rensselaer plateau in the east, with the Taconic and Green mountains in the farther distance, the distant peaks of the Adirondacks in the north, the Helderberg escarpment in the southwest, with the overtowering blue Catskill mountains in the far background and the trenches of the Hudson and Mohawk rivers in the middle of the plain that is inclosed on all sides by these mountains.

The picture as seen from the top of one of the buildings is not only

wonderfully charming and picturesque, revealing on no less than three sides mountain ranges that reach above 4000 feet but it is hard to match in the State also for geologic interest, for these three mountain ranges seen in the blue distance reveal entirely different chapters in the geologic history of the State. The capital district is the very center where the three fundamental structures of the State approach each other so closely that they can be seen together. The Adirondacks represent the nucleus of the State, composed of granites and gneisses, the rocks that form the very foundation of the visible portion of the crust of the earth, and that date from the earliest era of our geologic history, the Precambrian era. They have been exposed through elevation of the whole region in relatively late time, the middle and later ages of earth's history, and the resulting erosion of the once overlying masses of younger rocks, mostly shales and limestones that were deposited over the plateau where it was submerged, wholly or partly, under the sea. The mountain chains in the east, as seen in the Rensselaer plateau, Taconic mountains and Green mountains, are on the other hand the last remains of the branches of the great Appalachian mountain system that parallels the east coast of the continent from Alabama to New Foundland. This gigantic mountain system, a series of folds of the crust produced by a pressure that came from the ocean side, arose toward the end of the Paleozoic era shortly after the great coal deposits of America had been formed from Pennsylvania to Kansas. These mountains consist along their highest axes, in the Green and Taconic mountains, also of rocks that are altered into the crystalline condition as those of the Adirondacks, and are, in parts at least, portions of the fundamental complex of the crust pushed up during the folding. The largest part of these ranges is, however, composed of much younger rocks of early Paleozoic age (Cambrian to Ordovician systems) that are now intensely folded, and through eons of weathering have been eroded to their very roots. We shall see that the history of this portion of the capital district is not only quite complicated but also full of dramatic interest, revealing gigantic movements of the earth crust.

It is entirely different with the Helderberg plateau and the Catskill mountains in the southwest. These beautiful mountain districts, while topographically fully as rugged and picturesque as the Taconic mountains in the east and the Adirondacks in the north, breathe placid peace throughout their entire geologic structure. They consist of shales, sandstone and limestone of younger age (Devonian

age) than those in the east and north, that on the whole are still nearly horizontal and very close to the position in which they were deposited in the ancient seas. The Helderberg plateau consists of the earlier Devonian rocks and the great mass of the Catskills resting on this plateau is composed of the latest Devonian rocks. All these rocks once extended over the plains of the capital district northward upon the Adirondack massif. They have been gradually eroded and the escarpment of the Helderbergs has slowly wandered away from the Adirondacks toward the southwest, getting higher at the same time.

The lowland that one sees from the tall buildings of Albany or from the Indian Ladder extending between these three bounding mountain systems has been formed in the eons of time since the sea receded from the surface of the entire region by the weathering away of the Helderberg and Catskill rocks and Rensselaer rocks (all of Devonian age) above it, the Helderberg and Catskill rocks receding southwestward, the Rensselaer rocks eastward.

The lowland of the capital district is technically known as an "inner lowland" in distinction to coastal and river plain lowlands, because it lies between a plateau of sedimentary rocks, the Helderbergs, and folded mountain masses, from which the plateau is backing away by weathering. The bed rock of this lowland is composed to unknown depths of shale and sandstone of early Paleozoic age (ancient era of earth) and the larger part of its area is more or less deeply buried under unconsolidated materials of glacial age, consisting of "boulder clay," gravel, sands and, at the lower levels, of stratified or layered clay deposited in a body of water which flooded the lowland at the end of the Glacial Period and which has been named Lake Albany. As a result, the bed rock of this lowland is exposed only in scattered places, as in the Cohoes gorge, the Normanskill gorge, at French's Mills etc., while the stream banks, especially of the Hudson, consist of clay. The exposures show two different structures. If we look at the shales and sandstones exposed in the western portion, as at French's Mills or, below Schenectady, at Rexford and Aqueduct, we see that they lie perfectly flat, as the Helderberg beds do, but, as we go eastward, they become more and more disturbed until, at the Cohoes gorge and at the Normanskill gorge at Albany, they are highly tilted (usually at angles of 70°) and intensely folded and crumpled. This condition continues and is intensified as we go eastward, and as a result the surface of the rock floor east of the river is very irregular and presents a restless appearance (figure 41). The cause of this is the presence of

numerous hummocks and hills, caused by harder beds, grit and sandstone, that are thrown into steep folds, and by those portions of the folds where these hard beds are present, having been protected from erosion. Rysedorph and Olcott's hills so well seen across the river when one goes down State street, Albany, are typical examples of such hummocks built up by protruding harder rocks.

The boundary line between the folded and unfolded regions of the shales of the lowlands can be quite accurately drawn. It is marked on the accompanying geologic map and passes near Ballston lake, below Rexford and between Albany and Voorheesville. The country east of it was all once highly folded and part of mountain ranges that now are worn down to their roots and buried deeply under glacial and postglacial deposits.

TOPOGRAPHY

Having obtained a general survey of the geologic structure of the capital district, we are now better able to describe its topography and drainage, its climatic, geographic and cultural features which are all dependent on its geology.

Of the three mountain systems that are bounding the district, and can be seen from the Capitol, only two actually extend into the district, namely the Rensselaer plateau in the east and the Helderberg mountains in the southwest.

The Rensselaer plateau rises from the lowland along a line extending east of Raymertown past Poestenkill, Averill Park, East Nassau to Brainard. The escarpment is everywhere distinct (figure 41) and mostly steep. The plateau itself, as seen best in the Grafton Center region and about Stephentown is a wooded region with subdued sculpture, the highest hills reaching just beyond the edge of the sheet near Cranberry pond 1800 feet above sea-level. Seen from a distance (figures 41 and 43) the top of the whole plateau is remarkably level, which means that uniform weathering has reduced the once highly mountainous region to a near-plane, a so-called peneplane. The entire district is underlain by a coarse sandstone, the Rensselaer grit, and intercalated red and green shales, which together produce an infertile and often acid soil full of grit boulders. The district has, therefore, been very lately settled (in the first half of the last century) and not being favorable to farming, has, after the lumbering operations ceased, again lost a large portion of its population and is, in large part, going back into woodland. It was once the home of the charcoal-burners for the district. The rather harsh beauty of the country, however, with its dark woods and scattered

small lakes and ponds, is beginning to attract people who are seeking summer homes not too far from the cities, and the future of the region seems to lie in that direction. There is little doubt that some of the finest woods in the district are now occupying the eastern uplands. There are luxuriant growths of white oaks intermixed with red, scarlet and dwarf chestnut oaks (*Quercus prinoides*) in spite of the open, thin, acid soil that supports large fields of blue huckleberries. Dale ('93, p. 325) gives the following vivid description of the plateau: "Outcrops on the plateau are generally confined to the hilltops or edges; great areas are covered with swamps, and the ponds are numerous," to which is added in a footnote: "Boulders are enormously abundant on the plateau, and these almost all grit, indicating a large amount of erosion in the northern part. The boulders are so numerous that some of the roads, although nearly level, are well-nigh impassable. The brook beds are full of them. Stone walls 10 feet thick, of boulders collected to clear the land, are frequent."

In the northeastern part of the district the southern extremities of the mountain ridges that extend east of the Hudson river through Schuylerville quadrangle and beyond, come just within the area north of the Hoosick river. These ridges are of little importance to the capital district and it may suffice to say that they are also portions of the Taconian fold system that are preserved because of harder rocks in them, mainly cherty beds and limestones.

The *Helderberg plateau,* popularly known as the "Helderberg mountains," while geologically quite different from the Rensselaer plateau is topographically very similar. Its most conspicuous feature is the escarpment, the "Helderberg cliff" that bounds it on the northeast. Behind this cliff, which is caused by a series of hard limestone beds with shale above and below, one sees from the lowland about Albany, long, fairly rounded, well-wooded hills, as for example Countryman's hill. These hills reach up to and beyond 1600 feet in height. (Countryman's hill is 1694 feet.) If one ascends one of these hills and looks back over the plateau, one recognizes at once that while the whole region is broken up by small valleys into a series of ridges and hills, the longest of which is the Helderberg mountain, just along the edge of the sheet, the tops of these ridges form a very distinct level sky line (figure 44), above which farther south the Catskill mountains rise to 4000 feet. It is easily seen that this sky line is the result of uniform weathering. It represents an approach to a peneplane, that is, a base-level plain due to continuous weathering down of a region composed of rocks of fairly uniform hardness.

The Catskill mountains again show a uniform level of their high peaks (figure 44). This interesting feature shows that there was once a much higher peneplane extending over the whole region, many eons or millions of years ago. This peneplane probably was continuous with that now seen on top of the Adirondacks and on the high mountains in the southwest of the State as, for example, in Allegany State Park. It is believed that this peneplane was formed when the area of the State had been reduced to near sea-level in the Cretaceous time, or geologically speaking, in the middle age of the earth and before the glacial period. Later in Tertiary time, there followed an elevation of the whole region which produced the main features of the topography and the principal stream valleys, as the Hudson and the lower Mohawk river valleys, leaving these old peneplanes behind as wonderful ruins of times that passed in the gray and distant past of the earth.

The Helderberg mountains, to come back to this most lovely region of the capital district, when seen from in front appear as a solid plateau, only breached by a few creeks, but offer an entirely different aspect when viewed from the interior of the region. The views here given from Cass hill (figure 45) and Copeland hill (figure 46) show that back of the Helderberg cliff the country mostly slopes downward toward the southwest. This is due to the fact that the beds all dip down in that southwesterly direction and that the weathering following the harder rock beds or strata will finally expose the surface of these sloping harder beds. Likewise the view from Cass hill shows a series of three hills (Copeland, Blodgett and Bennett hills) all of like form with the steep slopes on the northeast side, like the Helderberg cliff, and the gradual slopes on the other side. These hills are composed of the later shales and flags of Hamilton (Middle Devonian age), that have held out longer against weathering and that form all the interior hills of the Helderbergs. Such slopes that run with the dip of the rocks are known as "dip slopes."

The Helderberg region is more fertile than the Rensselaer plateau. This is due to the presence of limestones and more easily weathering shales or sandstones and besides there are broad and fertile valleys as that of the Oniskethau, breaching the ridges. The region was therefore early occupied by Dutch settlers, brought there by the patroons of Albany. Their descendants, who freed themselves from the onerous land rents that had been paid for centuries to the patroons, in the locally famous "Helderberg War" (1839) are still found in the valley farms of the region. Unfortunately the lure of

the cities has also extended to the rugged settlers of these regions, and many farms and whole sections are now deserted and the woods are reconquering large areas, once the homes of happy tillers of the soil. The Helderberg region with its stately hills, the tops of which offer magnificent panoramas, sweeping the country from the Catskills to the Adirondacks; its small, but mysterious lakes with hidden outlets and inlets; its fertile laughing valleys with attractive home-like villages, as Clarksville; its old-fashioned inhabitants, in part still with the customs and beliefs of the first settlers—all these features lend the region a charm, reminding one of parts of the Old World. The region is not nearly so well known to the city people of the capital district as it deserves, however, and there is no doubt that in time the deserted farms of the region (often still with fine, substantial houses standing), will be taken up by city dwellers looking for summer homes. It would be better yet if they were in the hands of immigrants from the hard-working farming people of northern Europe, who could again make the region as productive as similar ones still are in Scotland, Scandinavia and Germany.

The Helderberg plateau is gradually returning to the magnificent woods that once covered the whole region. The gorgeous fall coloring brings out the great variety of trees that cover the slopes, and vary from white pine to elm, oak, bass wood etc. The different belts of rocks, varying from the Helderberg limestones to the quartzose rocks of the Oriskany sandstone and shales of the Esopus and the Hamilton flags, also contribute to the variety of forest growths as well as of small plants.[1] Thus the limestone ledges support the cork or rock elm (*Ulmus Thomasi*), a special form of basswood (*Tilia neglecta*), large stands of snow berries (*Symphoricarpos albus*), as especially along the top of the Indian Ladder cliff, where also the June berry (*Amelanchier amabilis*), the purple virgin's-bower (*Clematis verticillaris*) and the hairy honeysuckle (*Lonicera hirsuta*) are found, while below the cliff one may find those mysterious and rare ferns that are the delight of nature lovers as, for instance, the "walking fern"[2] (*Camptosorus rhizophyllus*), brittle fern (*Cystopteris fragilis*), bladder fern (*C. bulbifera*), and smaller ferns as *Asplenium trichomanes, Cryptogramma Stelleri, Pellaea atropurpurea,* that grow only in the shady moist woods, often covering the fallen limestone blocks with a rich velvet blanket.

[1] I am indebted to the State Botanist, Dr Homer D. House, for the information on the distribution of the plants.

[2] The walking fern is very partial to the weathered surface of the Coeymans limestone. It is frequently found covering glacial erratics of this formation far south of the parent ledge while the bed rock on which the erratic lies, even when limestone, has not been invaded.

The belts of sandstone and gritty shales (as the Oriskany sandstone and Esopus grit, see below p. 56) are readily recognized by the prevailing cedar trees and the juniper bushes. Such a belt is distinctly seen between Callanan's quarry and South Bethlehem; and the banks of the gorges in the Esopus grit are covered with rich, dark green mats of the yew (*Taxus canadensis*).

The topography of the plains of the capital district is fully as interesting and the landscape, if properly understood, as fascinating as that of the surrounding uplands. We must there distinguish between two regions, as set forth before, according to the underlying rock bottom. The western region, which extends within a few miles of the Hudson river, is marked by great level areas. This is the region where the rock bottom is not folded and hence probably relatively flat and undisturbed, and also worn down to greater depths and hence deeply covered by moraine and Albany lake clays. The eastern region is that where the rocks of the rock bottom are greatly folded, and the old rock surface is therefore very irregular, not so deeply worn down nor covered by glacial deposits and therefore sticks out all over in little hummocks, giving the region the appearance of a restless moderately choppy sea (figures 49 and 50).

The topography of the western plain is, owing to the deep burial of the rock bottoms, quite independent of that bottom, its structure being the result of glacial and postglacial agencies. These are fully discussed in the appended paper by Professor Cook; we will mention, therefore, only the most salient features of the district. The clay plains rise close to the Hudson river to various elevations: 200 feet at the southern border of the Albany quadrangle, 300 feet just west of Albany, 320 feet in the southern portion and 360 feet in the northern portion of the Cohoes quadrangle.

On this clay rest areas of *sand hills,* that were wandering sand dunes before vegetation recovered the desert left by the glaciers and Lake Albany. One such dune area, known locally as the "Pinebush," begins at the outskirts of Albany and extends northwest toward Schenectady and Guilderland, crossing the New York Central tracks and the state road for two miles just outside of Schenectady. Another large area of sand dunes and wind-blown sand extends north of the Mohawk from Crescent through Clifton Park to within two miles of Round Lake. Still another large area is found in the town of Stillwater extending from a mile north of Willow Glen to within a mile of Saratoga lake and continuing east of the lake. Other smaller areas of sand dunes are found north and west of Schaghticoke.

Figure 45 gives a characteristic view of such dunes. While the old lake bottom with its clay and loam beds makes very rich farm land, as in the area between Albany and Voorheesville, the sand dune regions are unproductive and mostly wooded. They carry a very characteristic stunted forest growth of pitch pines, gray birches, scrub oaks, alders, hazelnuts, poplars, a thick undergrowth of black huckleberry bushes (*Gaylussacia baccata*), and other light-loving plants. The open plains are covered with a new immigrant from the west, *Leptoloma cognatum,* the "diffuse crab grass," a most magnificently colored pinkish-brown grass, that I admired greatly in the Great Plains of Oklahoma and other states and that, as Dr Homer D. House, State Botanist, tells me, was not observed by him in the Albany region before 1919 (see House, '24 p. 70). These sandy regions, however, with their rounded wooded hills do by no means lack in charm, and they are decidedly beautiful in the fall, when the dark pines contrast with and form a background for the gorgeously colored deciduous trees. Truck farmers, mostly new immigrants, cultivate the scattered level stretches and add life to the otherwise lonesome country.

It is interesting to note that, as Doctor House has pointed out, these sandy dune regions once supported an entirely different and rich forest and ground flora. Dr James Eights, in a series of articles in the Albany Zodiac in 1835–36 (see also House, Report of the State Botanist for 1924, N. Y. State Museum, Bulletin 266, p. 11) reports that the old road to the fort at Schenectady led through a forest so high and dense (probably mostly white pine) that the trees closed above the road and shut out the sunlight. The ground was so swampy that much of the road was corduroyed. He also cites a number of plants as common that now have entirely disappeared from the region (see House, *op. cit.*). It appears that reckless cutting and still worse, series of forest fires, have destroyed the rich humus that once covered the sandy regions, and thus brought about chemical and especially also physical changes of the soil that have led to its deterioration and acidity. A small area, Doctor House states, north of Karners, in the midst of the sandy region, still retains its old soil and fine stand of oaks and white pines. Originally the sand dune regions were undoubtedly great gloomy forests of prevailing white pines and oaks with little undergrowth.

The Lake Albany clay deposits form the level, rich farm land extending on the west side of the Hudson to Albany and all the way up to Schuylerville and westward to South Bethlehem, Feura Bush, New Scotland, northward to the Normanskill, and up the

Normanskill to South Schenectady, thence up the Mohawk valley to Rotterdam Junction and northward on the Schenectady quadrangle to High Mills and east of the Clifton Park dune area beyond the sheet. This clay plain is the fertile farming land of the capital district. The fine homes, the sleek cattle and splendid orchards testify to the prosperous condition of this farming population, and the gigantic forests that once covered this rich land are still suggested by fine growths of scattering American elms in front of the farmhouses, by oaks, chestnuts, hickory and tulip trees and other stately and now altogether too rare survivals of the primeval woods in small patches of forests.

Between the broad smooth expanse of the Lake Albany clays and the cliff front of the Helderbergs extends a zone, three to four miles wide and well marked, between New Scotland and New Salem and thence north to Altamont, that is more hilly, the hills composed of glacial materials overlying a rock bench.

There are also two regions projecting from the lake deposits in the northwest corner of the district that are underlain by solid rock. One is the escarpment south of the Mohawk river, northwest of South Schenectady and the other the Glenville hill west of Town House Corner. In both of these areas the heavy sandstone beds intercalated in the Schenectady formation (see p. 33) have preserved these banks of preglacial drainage channels.

Farther west of the Hudson river there are two larger areas, where the bed rock appears at the surface producing an irregular topography. One of these is around the mouth of the Mohawk, extending from Waterford through Cohoes and over Peobles, Van Schaick and Green Islands to Watervliet. Here the much-tilted and contorted Normanskill shales and sandstones (see p. 96) are exposed in many small hillocks and ridges. These outcrops are below the level of the clay plain.

The other is an interesting rock area extending from Glenmont, south of Albany beyond Cedar hill (see map) and reaching a width of a mile and a half. This region rises west of Cedar hill, above the 200-foot contour and was therefore a prominent tract before the deposition of the Albany clays. It owes its prominent character, besides the intense folding of the rocks, to the indurated or hardened character of the shales and hard sandstone beds and really belongs topographically with the folded country on the east side of the river. The induration of the slates has given it a flinty character and a peculiar white weathering on the surface, readily seen on the surface rocks just below Glenmont, where the state road crosses the West

Shore Railroad. 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 (*Cerastium 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.*

Other plants that are found on these ledges and not on the surrounding clay and sand are: *Lonicera affine* var. *hypomaleucum* (L. *pubescens*), *Viola adunca* (*subvestita*), *Houstonia longifolia,* the two oaks, *Quercus ilicifolia* and *Q. prinoides,* that while common in the sandplains between Albany and Schenectady, are here confined to the outcrops of the ledge of chert; further, a small rose, *Rosa carolina* var. *glandulosa* Farwell (*R. serrulata* Raf.), a sedge-grass *Carex Bicknellii* Britton, and *Arenaria stricta,* Micheaux, the small white flowers of which are readily seen near the ground.

East of the Hudson river the clay plain of Lake Albany forms but a narrow strip, that in its widest part near the northern margin of the capital district is but two and one-half miles wide and often not more than a quarter of a mile wide. Beyond this extends the rocky country, described before, covered by a mostly thin mantle of moraine or till formed by the ice of the glacial period (figures 41 and 49). This hilly moraine, till and rock country forms a belt, six and more miles wide, between the clay plain in the west and the Rensselaer plateau and the mountains of the Cambridge district. The hills have as a rule a rock core, formed by small pitching anticlines of heavy sandstone or indurated flinty shale. Their axes all run about N. 20° E. with the prevailing strike of the folded rocks. The northern end of the hills often shows more or less smoothed rock exposures. It was the "stoss-side" of the protruding ledge. Behind it often a ridge of moraine material has been heaped up by the glacier. Between these sharply projecting rock hills one sees the evenly rounded glacial hills, either kames or drumlins, that is, hills that were formed at the end of the glacier or under it, and also small sand dunes. These rounded glacial hills are usually farmed, often plowed, but mostly used for pasturage, while the rocky hummocks are left wooded.

This rocky belt rises gradually eastward from the 300-foot contour to the 600-foot contour at the foot of the Rensselaer plateau. It is therefore in reality a westward sloping upland, from which

the Rensselaer plateau rises abruptly to 1300, and in some places to 1400 feet along the escarpment.

There are several larger hills protruding in this belt, that are topographical landmarks and as such deserve special notice. The northernmost are Rice Mountain near Grant Hollow and Mount Rafinesque (popularly known as Bald Mountain) east of Lansingburg, Rice mountain rising 500 feet above the plain to 925 feet and Mount Rafinesque nearly 900 feet to 1197 feet. This latter picturesque mountain stock (figure 42) so well seen from the State Education Building and other high buildings of Albany to rise as a fine wooded mountain chain just northeast of Troy, owes its origin to several causes, the most important of which seems to be that hard and competent rocks form here a cross-fold, extending east and west (see below under Structural Geology). Farther south three prominent hills are plainly seen as one goes down State street in Albany to rise from the horizon just across the river. These are Olcott's hill and Rysedorph hill (popularly known also as Bald mountain and Pinnacle hill) a triangulation station of the United States Geological Survey and south of it Catamount hill (not named on map). This hill, I was told by an old settler of the neighborhood, has received its name from a cantonment of troops in the war of 1812, the word "cantonment" having been perverted into "catamount." These hills owe their prominence to the hard sandstone or grit, characteristic of a geologic formation (the Normanskill shale) outcropping upon them, and Rysedorph hill to the conglomerate bed that has received its name from the hill.

South of Catamount hill runs a fine ridge north and south, extending south from the Rensselaer-East Greenbush road and known as Teller hill and Grandview hill. This ridge also contains the indurated, flinty beds of the Normanskill shale, forming there an anticline. Finally, in the southeast corner of the capital district, just west of Tackawasick pond, there rises from the plain a wooded ridge, Curtis mountain, known to local hunters as an excellent hunting ground. This ridge is also a large syncline or fold that has withstood weathering longer on account of the hard quartzite beds it contains in folded condition.

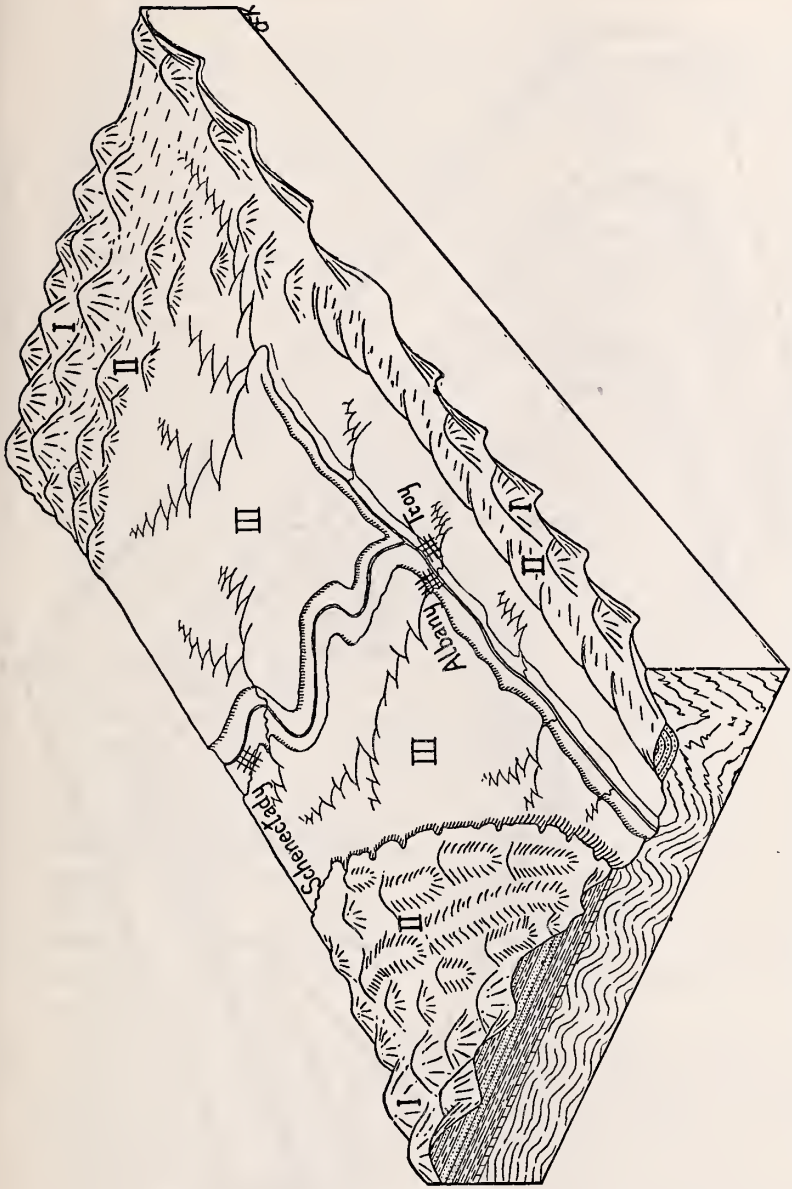


Figure 1 Block diagram of capital district, to show the three peneplanes of the area. *I-I* Cretaceous peneplane. *II-II* Tertiary peneplane. *III-III* Incipient recent or Albany peneplane (inner lowland)

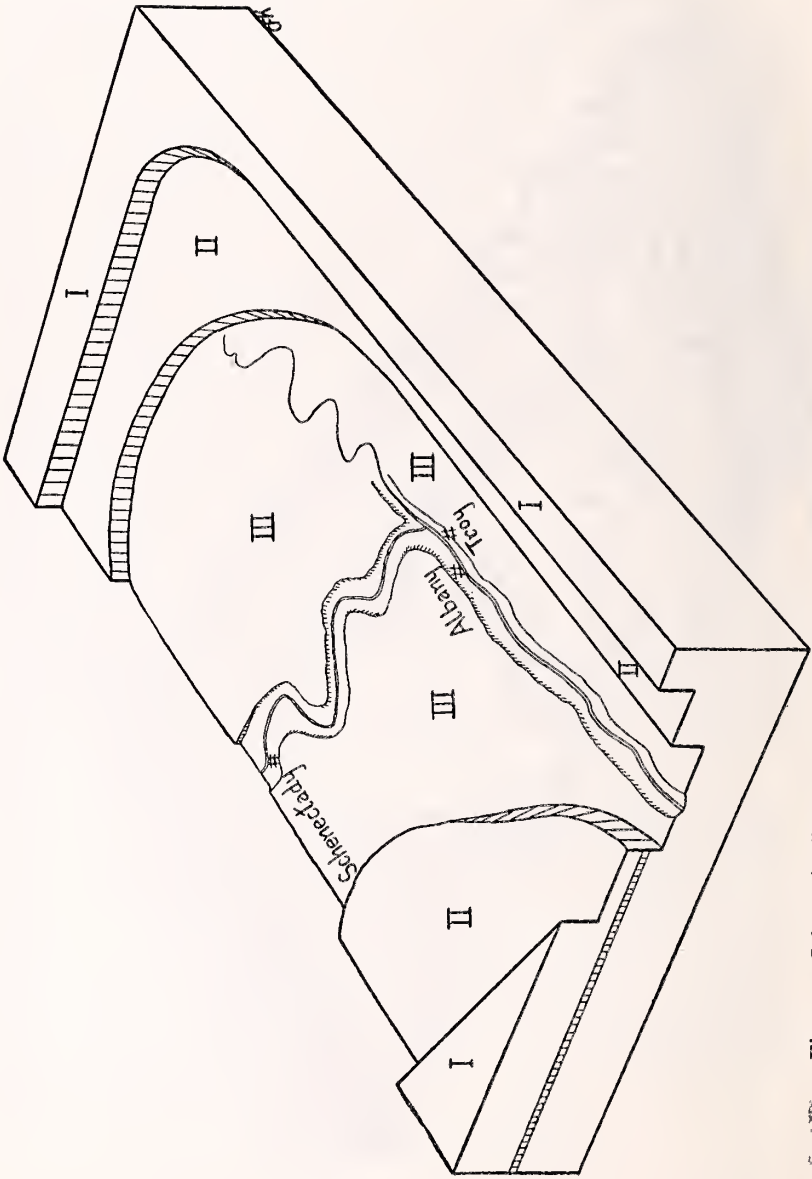


Figure 2 Schematic diagram to show the three peneplanes undissected, indicated in figure 1

THREE PENEPLANES OF CAPITAL DISTRICT

(Figures 1 and 2)

We have mentioned in the preceding pages the peneplanes of the Helderbergs and of the Catskills. The peneplanes of the capital district are such prominent and important features of the topography that they require separate description.

If one looks out from the windows of the Capitol or any other of the public buildings on Capitol hill, one can not fail to see, rising beyond the houses of the city, a broad plain stretching south and west to the Helderbergs, north to the Adirondacks and east to the Rensselaer plateau. Into this plain (figures 41 and 43) the deep valleys of the Hudson and Mohawk rivers are sunk. The plain is about 200 feet above sea-level at Albany; it rises westward slowly to 300 feet and eastward to about 600 feet at the foot of the Rensselaer plateau. This "inner lowland" of the Helderberg plateau has distinctly the character of an incipient peneplane or erosion plane, for it is cut across folded and unfolded beds alike, almost without regard to the rock structure, as the appended sections B-B and C-C clearly show.

Still there project above the plain numerous hillocks, especially east of the river, that owe their prominence to the existence of harder rocks (mostly grit beds or chert beds) that are brought up by small folds. Teller hill, Grandview hill, Rysedorph hill, all three south of Rensselaer, are such projecting rock hills. Mount Rafinesque and Rice mountain, north of Lansingburg, are larger mountains, projecting to 1300 feet and also caused by folded and harder beds, mostly chert and grit beds of Normanskill age. These projecting hills and mountains, composed of harder rocks, partake of the nature of the so-called "monadnocks," that is, of mountains that, like Mount Monadnock in New Hampshire, owe their existence to their composition of harder rocks, and are erosion remnants. There are also numerous other more gently rounded hills of glacial origin scattered over the plain.

This lowest or Albany peneplane, as we may call it, is the youngest of the region. It existed at the end of the Tertiary period, when the glaciers advancing from the north buried the country under ice. It originated from the uplift of the country in Tertiary time when the rivers established new grade.

The Albany peneplane was not so smooth and level before glacial time as it appears now. It was more dissected and irregular, because of the great differences in rock structure and hardness, but the

mantle of drift that was deposited by the glaciers and still more the mantle of laminated clay, laid down in the group of lakes known to geologists as Lake Albany, have smoothed out and hidden many irregularities of the former surface, while, on the other hand, some new irregularities of the plain, in the form of sand dunes and drumlins, were formed. Considered as a whole, however, the inner lowland was distinctly a "near-plane" in the wider sense, or a new level that was being formed below the Helderberg peneplane, when the glacial epoch began. While it may not be a peneplane in the strict sense, it is undoubtedly an incipient peneplane that in the course of time, if no new elevation occurs, will extend down the river and spread in all directions.

The next higher peneplane can be distinctly recognized when one looks from the Helderberg mountains backward toward the Catskills (figures 44 and 46). The top of the Helderberg ridges appears then as a level, more or less dissected plateau, that once must have been a continuous plain. If one looks across the Albany peneplane towards the Rensselaer grit plateau (popularly known as the Grafton and Stephentown hills) one will see at once that these mountains again form a distinctively level plateau (figures 41 and 43) which extends north-south, and is of about the same height as the Helderbergs. The Helderberg mountains rise to 1600 feet on Countryman hill, near New Salem, and this level of 1600 to 1700 feet is maintained over the plateau. The average height of the Rensselaer plateau is likewise 1600 to 1800 feet, the plateau rising eastward from 1400 feet at the western margin to 2000 feet above the Little Hoosick valley, with most of the plateau at about 1600 feet. It is therefore legitimate to conclude that the Helderberg and Rensselaer plateaus belong to the same, or are remnants of the same peneplane, that once extended above the Albany peneplane across the Hudson river valley. By comparison with the peneplanes known south of New York the Helderberg peneplane can be correlated with the peneplane that was uplifted in early Tertiary (Eocene) time, and that is known as the Harrisburg peneplane.

The last and highest peneplane is the one we see represented by the even tops of the Catskill mountains as seen from higher altitudes, as for instance, the tops of the Helderbergs (figure 44). This peneplane lies now at an elevation of about 4000 feet. It was once a low plain that extended all over the district, in fact, far and wide over the East. It was elevated in early Cretaceous time and is known as the Kittatinny peneplane. The tops of the Adirondack mountains

and the level stretches of the Taconic and Green mountains also appear to be remnants of this ancient peneplane.

Summarizing, we can picture to ourselves the capital district as composed of three stories of rock formation that once rose into the sky above the district, and that were successively eroded away, leaving only remnants. These are, from top to bottom, the Cretaceous peneplane, 4000 feet high and extending from the top of the Catskills to that of the Adirondacks; the early Tertiary peneplane, extending from the top of the Helderbergs to that of the Rensselaer plateau, about 1600 feet high; and the Albany or late Tertiary peneplane, about 100 to 600 feet high and extending from the foot of the Helderbergs to that of the Rensselaer plateau and of the Adirondacks.

DRAINAGE

The drainage system of the capital district is in its major features entirely controlled by the general geologic structure, finding expression in the physiography just described; and on the other hand, the minor physiographic features of the region are in their part largely controlled by the drainage and by erosion in general.

The trunk stream of the district is the Hudson river, which crosses the district in south-southwest direction from the northeastern margin to the approximate center of the southern margin. The river is sunk now in a valley, about 200 feet below the lowest terrace of the clay plain and about a mile wide. The stream channel is one-fourth to one-half of a mile wide. The head of the navigation is at Troy and the tide reaches to the Troy dam, where the river is only 3.8 feet above sea level.

The principal tributary of the Hudson river and the other principal stream of the district is the Mohawk river, which rising to the west of the Adirondack plateau flows around it in the south and reaches the Hudson river valley at Cohoes. The next important tributary of the Hudson river in the district is the Hoosick river, which rises east of the Taconic mountains and breaking through the Appalachian ranges in southern Vermont reaches the Hudson river from the east two miles above Mechanicville. An interesting southern tributary of the Hoosick river in New York is the Tomhannock creek, rising near the north end of the Rensselaer plateau and flowing through an old lake bottom that has been revived as a lake in the Tomhannock reservoir of the Troy water works. At Mechanicville empties the Anthony kill which flows out of Ballston lake in a northeast direction, then at East Line bends sharply southeast and flowing through Round

lake reaches the Hudson river at Mechanicville. The small creek flows through a valley out of proportion to its size, and, as we shall see presently, it has a most interesting geologic history which explains that disproportion. The larger Mourning kill comes within a mile of the Anthony kill near East Line, but then turns northward toward Ballston, where it joins the Kayaderosseras creek, that in its turn empties into Saratoga lake, located astride the north margin of the district. Saratoga lake is drained by Fish kill that flows at Schuylerville into the Hudson river.

The only noteworthy tributaries of the Mohawk are the Alplaus kill on the north and the Lisha kill on the south. The Alplaus kill (Alplaus is a perversion of the German "Aalplatz," meaning a place to catch eels, at the mouth of the creek) drains the country east of the Glenville ridge.

Other tributaries on the west side of the Hudson river that we shall have occasion to mention are the Patroons creek, emptying just north of Albany; the Normanskill, emptying in the southern outskirts of Albany, with its branch the Vly creek (Vly creek is a tautology, since vley is Dutch for a swampy creek), that drains the New Salem region; the Vlauman kill, reaching the Hudson river at Cedar hill; the Oniskethau and Sprayt kill, which drain the Helderberg area of the capital district and uniting form Coeymans creek, that empties at Coeymans.

On the east side should be mentioned south of the Hoosick river, the Deep kill, that arises in Mount Rafinesque and forms a gorge above Grant Hollow, in which was discovered a series of fossiliferous shales (Deep kill graptolite shales) that received their name from that creek; the Poestenkill coming from the Rensselaer plateau and emptying at Troy; the Wynantskill, which drains a whole series of lakes at the foot of the Rensselaer plateau, in the eastern rocky plains: namely Burden lake, Crooked lake, Glass lake, Sand lake (now Crystal lake), Reichard pond and Aries lake (popularly known as Snyders lake).[1] It empties within two miles of the Poestenkill. The Moordener kill empties at Castleton and the Valatie kill, flowing through Nassau pond, empties beyond the capital district into Kinderhook creek, which just cuts the southeast corner of the district, receiving the Tackawasick creek, flowing through the Tackawasick pond, as a northern tributary.

There are also extinct lakes and rivers which existed when the ice of the glacial period was receding and thereafter during unknown intervals of time, until the lakes became filled up or drained. They

[1] Some of these artificially enlarged by dams.

are found especially in the eastern hill region where they form excellent green agricultural oases between the rocky hills. The largest is the old Tomhannock lake, already mentioned, now revived by a dam. Another large lake bottom is seen west of the village of Poestenkill and half a dozen small lake basins now filled in are recognizable in the region south of West Sand Lake. They are marked on the map as alluvial bottoms. Others are seen west and east of Nassau pond. An exceedingly well marked extinct lake or valley extends south from Raymertown near the foot of the Rensselaer plateau past Clums corners into the Quaken kill valley and the extinct Poestenkill lake.

A drainage feature which deserves special mention in the capital district is the great number of small brooks which have eroded deep ravines in the several hundred feet of soft sands and clays of the Albany lake on both sides of the Hudson valley. Many of them can be seen well on both sides of the train from Waterford to Mechanicville or between Rensselaer and South Troy, as also north of Stillwater, and about Castleton. The Normanskill valley above the Kenwood rapids is also a deep erosion valley in the Albany clays. These numerous deep ravines on both sides of the river constitute a characteristic physiographic feature of that particular region.

In some places the ravines have reached rock bottom, as south of Troy and between Rensselaer and Castleton. In such cases they give valuable information as to the composition of the rocks of the immediate neighborhood of the river as well as to the former river courses.

While it is readily seen that the courses of the smaller brooks and creeks are of postglacial origin and no longer connected with the drainage that existed before the glaciers overran the country, the master streams, notably the Hudson and Hoosic rivers, have in general returned to their old valleys. The creeks have but for short distances reached rock bottom and then by always accidentally striking irregularities of the old rock bottom; for the most part they are in the glacial moraine material and the postglacial clays and sands of Lake Albany, following the surface irregularities in the rather unsystematic fashion of a new drainage.

The present valley of the Hudson, as here considered, is the broad depression on the bottom of which the river flows in a more or less winding course and the sides of which are the steep clay banks which rise 100 feet or more above the valley bottom. The present valley lies within the old rock gorge, its bottom being coincident with

the middle portion of the floor of the latter. The present channel of the river, however, in the greater part of its extent, is cut into the floor of the old gorge, forming a shallow rock gorge representing the erosive work of the river in the recent period. The present valley bottom, threaded by the channel, has a width varying from three-fourths of a mile to one and one-half miles.

The result of the fact that the Hudson river flows in the inner gorge of a broader valley with rocky banks is that the tributaries, all of which were not able to erode their beds to grade or to the level of the Hudson river on account of their smaller eroding power, form now so-called "hanging valleys," that is, their valleys hang so far above that of the Hudson river that they form waterfalls where they descend from the upper level of the rocky banks of the river. The writer has already pointed out in the description of the Schuylerville quadrangle what important influence these hanging valleys had through the water power that they furnish in the development of the settlements. In the capital district the hanging valleys of the Anthony kill (Mechanicville), Mohawk (Cohoes), Normanskill (Normansville and Kenwood), Vlauman kill (Cedar Hill), Hoosick river (Schaghticoke), Poestenkill (Troy), Wynantskill (South Troy), Mill creek (Rensselaer), Moordener kill (Castleton), either still furnish power to mills or did so formerly, thereby starting most of the settlements mentioned.

To this must be added the fact that the Hudson river itself had lost its channel in various places and thereby is induced to form rapids, which have become valuable sources of power, as at Stillwater, Mechanicville and Troy, and thereby have made these places centers of industry. Troy and Waterford further owe their location to the end of navigation in the river at this place, the river proper entering here its estuary or its lower stretch, which lies so low that it is made to feel the influence of the tides. Albany itself marks the site where the old Indian trail that followed the Mohawk down to Schenectady cut across, using the Normanskill valley to the broad expanse of the Hudson, thus avoiding the turbulent and circuitous course of the Mohawk from Schenectady to Cohoes. The old corduroy road from Albany to Schenectady, whence first the Mohawk river and later the canal were used for transportation, was one of the chief highways of America opening the West, a fact that the "Gateway bridge" at Schenectady is intended to memorialize. Both Albany and Schenectady owe their origin to this close approach of the navigable portion of the Mohawk to the navigable portion of the Hudson river.

DESCRIPTIVE GEOLOGY

(Technical chapter)

The rocks of Precambrian age, or of the fundamental crust of the earth, where complete metamorphism of the strata has taken place, are not exposed in the capital district and have not been reached in wells, although they extend in the north, on the Saratoga quadrangle, within six and one-half miles of our map.

The overlying rocks are all sedimentary in origin, that is, were formed under water, mostly marine.

The exposed rocks of the four quadrangles are of Cambrian, Ordovician, Silurian and Devonian age, together with the unconsolidated deposits of Quaternary age.

There are 27 geologic formations recognizable in the capital district. These extend from the lowest Cambrian to the uppermost Devonian. They are the following in ascending order:

A Lower Cambrian (Taconian) system
- 1 Nassau beds
- 2 Bomoseen grit
- 3 Diamond Rock quartzite
- 4 Troy shales and limestones
- 5 Schodack shales and limestones

B Ordovician system
- 6 Schaghticoke shale
- 7 Deep Kill shale
- 8 Normanskill shale
- 9 Tackawasick limestone and shale
- 10 Rysedorph Hill conglomerate
- 11 Snake Hill shale
- 12 Canajoharie shale
- 13 Schenectady beds
- 14 Indian Ladder beds

C Silurian system
- 15 Brayman shale
- 16 Rondout waterlime
- 17 Manlius limestone

D Devonian system
- 18 Coeymans limestone
- 19 New Scotland beds
- 20 Becraft limestone
- 21 Oriskany sandstone

22 Esopus grit
23 Schoharie grit
24 Onondaga limestone
25 Marcellus shale
26 Hamilton shale and flags
27 Rensselaer grit

In looking at the map we see these formations so distributed that the youngest formation, the Rensselaer grit of Upper Devonian age, occupies the eastern highland, the Rensselaer plateau; the remainder of the Devonian, together with the thin Silurian beds, forms the Helderberg plateau. Between these two highlands the formations are arranged in broad belts that in general run nearly north-south, or more correctly, north-northeast to south-southwest. They are so arranged that the oldest, the Lower Cambrian rocks, are in the east, and the lower division of these, the Nassau beds, directly under the youngest of the series, the Rensselaer grit, a fact of considerable significance for the tectonic history of the region, that will be discussed in the chapter on tectonic geology.

The next belt is the upper division of the Lower Cambrian, the Troy shales and limestone and associated formations. Then follows the belt of Normanskill shale, that crosses the Hudson river, with small patches of Deep Kill shale scattered along the Cambrian-Ordovician boundary.

The next belt west of the Normanskill shale belt is that of the Snake Hill shale. Beginning very broadly in the north, where it extends from west of Saratoga lake to east of the Hudson river, it contracts to a narrow band, where it dives under the Helderberg plateau near Feura Bush.

The last belt is that of Schenectady beds which occupies the western half of the Schenectady and Albany sheets, with a triangular area of Canajoharie shale along the northern margin.

It would appear from this simple arrangement of the belts that they formed a regular series or succession of formations, the lower Cambrian at the bottom and the Schenectady beds at the top. This is, however, not at all the case. On the contrary, the work of the author, as set forth in the Geology of Saratoga Springs and Vicinity (Cushing and Ruedemann, '14) and other publications, has brought out the fact that two entirely different sets of formations are piled up here along side of each other. We have assumed that these were formed in two different troughs, more or less separated from each

other, possibly by a longitudinal bar. We have designated one as the eastern trough and the other as the western trough. The formations of both troughs are now in close contact, principally owing to the fact that the rocks of the eastern trough have been carried westward by folding and overthrusting along numerous fault planes (see chapter 4 on Structural Geology).

Systems	*Western Trough*	*Eastern Trough*
Upper Devonian	.....	Rensselaer grit
Middle Devonian	Hamilton shale and flags	.....
	Marcellus shale	.....
	Onondaga limestone	.....
	Schoharie grit	.....
Lower Devonian	Esopus grit	.....
	Oriskany sandstone	.....
	Becraft limestone	.....
	New Scotland beds	.....
	Kalkberg limestone	.....
	Coeymans limestone	.....
Silurian	Manlius limestone	.....
	Rondout waterlime	.....
Ordovician Silurian interval	Brayman shale	.....
Upper Ordovician	Indian Ladder beds	.....
Middle Ordovician	Schenectady beds	.....
	Canajoharie shale	Snake Hill shale
	(Glens Falls limestone)	Tackawasick limestone and shale
	(Amsterdam limestone)	Rysedorph conglomerate Magog shale
Lower Ordovician	.....	Normanskill shale (Bald Mountain limestone) Deep Kill shale Schaghticoke shale
Ozarkian	(Little Falls dolomite)	.....
	(Theresa formation)	.....
	(Potsdam sandstone)	.....
Lower Cambrian	.....	Troy shales and limestones Diamond rock quartzite Nassau beds Schodack shale and limestone Bomoseen grit
Precambrian	Precambrian rocks	Precambrian rocks

As a result of this division we must, from the beginning, separate the formations into two series. A whole group of formations, which we know, from the Saratoga and Glens Falls quadrangles, to underlie the western trough, do not appear on the surface in the capital district. They are buried there deep under the shales. Nevertheless, we will add them to the series for the sake of completeness. The two series beginning with the youngest formations, are shown in the preceding table. Those not exposed in the capital district, but in adjoining quadrangles and undoubtedly present here although underground, are put in brackets. As a matter of fact, some have recently been reached in deep wells.

The strange fact appears at once in this table that today there is no formation common to the two sets or troughs. In the Cambrian and Ordovician periods this is due to an alternating draining and submerging of the two troughs, so that when one was submerged the other was drained; in the Silurian and Devonian it is largely due to the erosion of the formations outside of the Helderbergs.

A Paleozoic Rocks of the Western Trough

There is no doubt that the Potsdam sandstone, the Theresa formation (with the Hoyt limestone member), the Little Falls dolomite, the Amsterdam limestone, the Glens Falls limestone and the Canajoharie shale are all underlying the Schenectady beds in the western trough, for they all are well developed in the Saratoga quadrangle directly to the north of the Schenectady quadrangle, and their general southwest dip would carry them beneath the Schenectady beds. The Canajoharie beds are exposed at the northern margin of the Schenectady quadrangle, in Ballston Spa, and extend undoubtedly under the drift southwestward, as indicated on the map. It is not necessary here to describe these formations, they have been fully reported on in the Geology of Saratoga Springs and Vicinity by Cushing and Ruedemann. It may suffice to state that the Potsdam formation consists, just north of the capital district, of 50 to 150 feet of buff and white silicious sandstone, often with a conglomerate at the base. This grades into the Theresa formation, which is 150 to 200 feet thick and consists of alternating beds of sandstone and dark gray dolomite. A local, more calcareous phase of the upper Theresa formation that is found west of Saratoga, is the Hoyt limestone. It consists of alternating beds of black limestone and gray dolomite, with some black oolites, and contains the famous Cryptozoon reef of the Lester State Park. The Little Falls dolomite is a thick formation of 350 to 400 feet of massive beds of dark gray and

light gray dolomite. It is seen along the fault-scarp in Saratoga Springs. On the Little Falls dolomite rest in this region 40 to 60 feet of a blue crystalline, quite fossiliferous limestone, known as Amsterdam limestone and referred to the Black River stage of the Ordovician system. It is poorly exposed on the Saratoga quadrangle, being shown at Rock City Falls. The Amsterdam limestone is followed by 40 feet of alternating shale and limestone, the Glens Falls limestone, of the age of the basal Trenton formation. It is a weak formation, seen only in well sections in the Saratoga region.

1 **The Canajoharie shale.** The Glens Falls limestone is followed by a great formation of black shale, the Canajoharie shale. It is of the same age as the lower Trenton limestone at Trenton Falls and in the Mohawk valley. This formation may be 1000 feet thick in this district; yet, on account of the softness and weakness of the shales, it is mostly buried deeply under drift. It is, however, well seen about Ballston Spa, as at the Iron Spring, and along Kayaderosseras creek, above the village. It enters the capital district at Ballston Spa and, being buried under drift, forms the underlying rock surface for an unknown distance south, probably as far as Ballston lake, as indicated on the areal map.

These soft black carbonaceous, more or less calcareous, argillaceous shales contain hardly any intercalations of sandstones or cherty beds as the shales of the other formations of the capital district do, and they are therefore characterized by their uniform, carbonaceous, fine-grained character. They form a broad belt in the lower and middle Mohawk valley, being replaced westward by the Trenton limestone, which is of the same age. Just west of the Schenectady quadrangle they reach a thickness of more than 1200 feet in Adebahr hill, south of Rotterdam Junction. This great belt of black shales then swings east and northeast around the foothills of the Adirondacks and passes up into the Champlain valley, where it is found near Ticonderoga and especially on the Vermont side. The shale was considered in the older literature as of Utica age, until the writer recognized its fauna as being of older age. (Ruedemann '01, '08, '12, '14, '19.) At Canajoharie, which is the type locality of the shale, it was found at the base intercalated with basal Trenton limestone (Ruedemann, 1912, p. 21)[1].

[1] The fossils of all formations here described can be studied to great advantage in the Hall of Paleontology (eastern hall) of the State Museum. All more important formations are represented there in the high cases with their characteristic and common fossils, as well as outcrop and paleogeographic maps.

The fauna is a very characteristic one. It consists of graptolites and small individuals of brachiopods, mollusks, trilobites and ostracods, all indicating an unfavorable condition for marine life, as is also done by the black carbonaceous shale that contains much pyrite and thus suggests conditions of foul water in the depths where the shale was deposited. Nevertheless some layers contain a great number of the small shells. The fauna consists of the following species:

Sponges:	Cyathodictya? tubularis *Ruedemann.*
	Sponge spicules
Graptolites:	Corynoides calicularis *Nicholson*
	Dicranograptus nicholsoni *var.* parvulus *Rued.*
	Diplograptus amplexicaulis (*Hall*)
	D. vespertinus *Rued.*
	D. macer *Rued.*
	Mesograptus mohawkensis *Rued.*
	Climacograptus strictus *Rued.* (C. "putillus" *auct.*)
	C. spiniferus *Rued.*
	Glossograptus quadrimucronatus *var.* cornutus *Rued.*
	Lasiograptus (Thysanograptus) eucharis (*Hall*)
Machaeridians:	Lepidocoleus jamesi (*H. & W.*)
Bryozoans:	Spatiopora *sp.*
	Prasopora simulatrix *Ulrich*
Brachiopods:	Leptobolus insignis *Hall*
	Lingula curta *Hall*
	Schizocrania filosa *Hall*
	Dalmanella rogata *Sardeson* (D. "testudinaria" *auct.*)
	Rafinesquina alternata (*Emmons*), small
	Plectambonites sericeus (*Sowb.*) H. & C.
Pelecypods:	Prolobella? trentonensis (*Hall*)
	Pterinea insueta (*Emmons*)
	Whiteavesia *sp.*
	Ctenodonta nuculiformis? *Hall*
	Ctenodonta *sp. nov.*
	Clidophorus *sp.*
Pteropods:	Hyolithes pinniformis *Rued.*
Gastropods:	Clathrospira subconica (*Hall*)
	Liospira cf. rotuloides (*Hall*)

Cephalopods:	Orthoceras hudsonicum *Rued.*
	O. arcuolineatum *Rued.*
	O. cf. amplicameratum *Hall*
Trilobites:	Triarthrus becki *Green*
	Isotelus *sp.*
	Calymmene senaria *Conrad var.*
Ostracods:	Primitiella unicornis *Ulrich*
	Ulrichia? bivertex *Ulrich*

The characteristic fossils of the Canajoharie shale that do not occur in the Utica shale are:

Corynoides calicularis
Diplograptus amplexicaulis
Diplogr. (Mesogr.) mohawkensis
Glossograptus quadrimucronatus mut. cornutus
Prolobella? trentonensis
Pterinea insueta
Ulrichia? bivertex
Primitiella unicornis

On the other hand, many of the Canajoharie forms are found in the contemporaneous Snake Hill shale of the eastern trough.

We have been able to distinguish five zones (Ruedemann, '12, '19, p. 126) in the Canajoharie shale of the lower Mohawk valley, in ascending order as follows:

Zone of Mesograptus mohawkensis.
Zone of Diplograptus amplexicaulis, Corynoides calicularis, etc.
Zone of Glossograptus quadrimucronatus cornutus.
Zone of Lasiograptus eucharis.
Zone of Climacograptus spiniferus, Diplograptus vespertinus, etc.

The writer found early in his work some outcrops of black shale of the characteristic appearance of the Canajoharie shale in the Snake Hill belt of the capital district. One of these indicated on the map is along the Alplaus creek about a mile and a quarter south-southeast of Burnt Hills. This locality has afforded besides *Corynoides calicularis, Glossogr. quadrimucronatus* mut. *cornutus, Lasiograptus eucharis,* and *Leptobolus insignis,* the cephalopod *Orthoceras hudsonicum* that preserved the embryo shell (protoconch) (Ruedemann, '12, p. 112) in this locality. It is probable that this small outcrop represents an inlier of Canajoharie shale in Schenectady beds, part

of a tilted block near the Ballston Lake fault that has become exposed by erosion.

Another interesting exposure of black shale of Canajoharie appearance was found years ago by Doctor Clarke within sight of James Hall's grave in a road metal pit of the Rural Cemetery. It furnished a very remarkable fauna that has been described by Ruedemann ('01, '08) and consists of:

Mastigograptus circinalis *Rued.*
Corynoides calicularis *Nicholson.*
Glossograptus quadrimucronatus *mut.* cornutus *Rued.*
Lasiograptus eucharis (*Hall.*)
Climacograptus strictus *Rued.*
Eopolychaetus albaniensis *Rued.*
Pontobdellopsis cometa *Rued.*
Leptobolus insignis *Hall.*
Schizambon canadensis *Ami.*
Hormotoma cf. gracilis (*Hall.*)

Glossograptus quadrimucronatus mut. *cornutus* Rued. was described from the splendid material of this locality (Ruedemann, '12) as well as the strange worms, Eopolychaetus and Pontobdellopsis.

The writer considered this locality and the belt in which it lies, first as Utica shale (Ruedemann, '01) and after the Snake Hill shales and Canajoharie shales had been separated from the mass of the "Hudson River shales" held this occurrence as due to the infolding of Canajoharie shale with the Snake Hill formation in the much disturbed region ('12.) Closer study, however, of the structure of the capital district and recognition of the fact that the Canajoharie and Snake Hill shales belong to different troughs and that the Snake Hill shale is underlain by the thick Normanskill shale, Rysedorph Hill conglomerate and other terranes that have been pushed by overthrust over on the western trough, make it impossible to imagine how a thin belt of the Canajoharie shale could appear so far east in the Snake Hill rocks. We are therefore forced to the conclusion that temporary connections existed between the two troughs or of both troughs with a third basin, probably in the north that allowed *Glossograptus quadrimucronatus cornutus,* a floating graptolite, to enter the Snake Hill trough. It is in this connection of some significance that the cemetery locality has furnished besides the graptolites strange fossils that have not been observed in the Canajoharie shale, as especially the worms, one of which (*Pontobdellopsis cometa*), how-

ever, has been collected in the Snake Hill shale below Mechanicville. While the brachiopod *Schizambon canadensis* is known only from Canada, a similar form has, however, been described as *Schizambon albaniensis* (Ruedemann, '19, p. 105) from the Snake Hill beds at Watervliet. It thus seems after all that this occurrence has as close relations faunistically with the Snake Hill shale as it has with the Canajoharie shale. We have separated the outcrop of the Rural Cemetery on the map as a Canajoharie shale belt mainly to emphasize the presence of this Canajoharie phase of the Snake Hill shale.

2 **Schenectady beds.** The Canajoharie is overlain in the capital district by the Schenectady beds. They appear in the farthest southwest corner of the Saratoga quadrangle in the town of Galway and thence extend in a broad belt southward and westward forming the surface rock in the whole area between Schenectady and the Helderberg escarpment, entering the Schoharie valley as far as Schoharie village. In the capital district they form a belt six to eight miles wide, along the western margin.

The Schenectady formation consists of about 2000 feet of grits and sandstones with interbedded black and gray argillaceous shales, the two forming a monotonous, uniformly alternating series throughout this great thickness. The sandstone beds are quarried about Schenectady and Aqueduct. In the latter place where the Mohawk river in its postglacial course breaks through a ridge of these harder beds an excellent section of a portion of the formation is furnished. These gray, impure sandstones and gray to black argillaceous shales have until recently been generally correlated with the "Hudson River," Lorraine and Frankfort formations, mainly for the reasons that they overlie black (Canajoharie) shales which were identified with the Utica shale and that they are lithologically like the Lorraine beds. Investigations by the writer ('12, '14) have, however, shown that this thick formation contains a fauna not younger than Trenton and that the underlying black shale is not Utica but early Trenton in age.

The Schenectady beds are overlain by the Indian Ladder beds. The latter are of younger than Utica (of Eden) age. Provided there is no hiatus between the Schenectady and the Indian Ladder beds corresponding to the Utica shale, it is to be inferred that the upper part at least of the Schenectady is of Utica age, although the fauna does not give any support to this view. Indeed, Doctor Raymond ('16) has suggested that the Schenectady beds are of Utica

and probably also of Frankfort age. The fossil evidence, however, is in favor of the Trenton age of the formation and the Utica aspect of a portion of the fauna is undoubtedly due to the shaly facies. This evidence will be given later when the fauna is discussed. To this may be added that the Schenectady formation rapidly dwindles westward and that the Utica, as well as the Frankfort shales, do the same eastward in the upper Mohawk valley.

The thickness of the formation has not been measured; it is inferred from the width of the belt and the general dip. There are, however, continuous sections of more than 1000 feet, like that published by Cumings ('00, p. 45) on Waterstreet hill near Rotterdam, to the west of the capital district; and in a well at Altamont the drill went through 2880 feet of sandstone and shales before reaching the Trenton limestone (Ruedemann, '12, p. 38).

The cause of the astonishing thickness of the Schenectady shales is to be sought in their deposition in a basin, formed by sinking foreland in front of the rising Green Mountain folds to the east; which basin was rapidly being filled with sediments. The shallow water origin of most of the shales and sandstones of the Schenectady beds is proven by the shrinkage cracks found in the thinner sandstones (as at the Bozen kill), the frequent layers of mud pebble beds, cross bedding with plunge structure, very rapid change of thickness of beds and other features.

The writer ('12, p. 41) has expressed the following views regarding the causes of the structure of the Schenectady beds:

> The constant alternation of more or less coarse sandstone with shales is indicative of a frequent shifting of the conditions, presumably through currents, either reversal (tidal) or continuous currents. There is sometimes clear evidence of absolutely regular or rhythmic shifting. Such a place for instance was observed in an abandoned quarry on the Bozen kill between Altamont and Delanson. The base is here formed by a compact bed of sandstone some 15 feet thick. This sandstone is abruptly followed by dark argillaceous shale in which higher up thin sandstone layers appear, that become more frequent until another thick sandstone bed is formed, like the basal one. This in turn is cut off by a shale that gradually yields to sand. The whole cycle is in this place repeated three times, shales and sandstones being each of equal thickness, the whole indicating a most remarkable regularity of change of deposition which on account of the very shallow character of the rocks of that locality may well have been a condition due to reversal or tide currents.

P. G. Sheldon ('28) has just published a paper regarding the sedimentation conditions in the Middle Portage rocks and has described conditions exactly duplicated in the Schenectady beds, for

instance at the Bozen kill. He finds that these Portage sandstones begin abruptly above the shale, as a massive sandstone with scattered mud pebbles, that above this flat sedimentation prevails in the middle and minute cross bedding and ripple marks at the top. This succession is the result of a regularly diminishing current, which in the first stage kept the sediment thoroughly churned, then in the middle produced distinguishable channels and finally diminished enough to produce ripples at the bottom. Sheldon sees the cause in fluctuations in the effective strength of the transporting waters. If fluctuations in the power of moving water alone is the cause, the alternations in the Schenectady beds would indicate gradually increasing currents from the shale to the sandstone.

The best outcrops of this formation in the capital district are along the Mohawk below Schenectady, especially at Aqueduct and Rexford Flats, and at French Mills on the upper Normanskill. In both these localities the heavy sandstone beds, characteristic of the upper portion of the formation, may be seen. At Aqueduct they are in a very regular alternation with shale. At French Mills two beds each eight feet thick are exposed. The formation, especially its gritty and sandy beds, comes also to the surface over a large area on the Glenville ridge, northwest of Schenectady, along the margin of the map. This ridge is undoubtedly due to the competent character of the grits and sandstones that prevail especially in the upper part of the formation. The alternating shales and sandstones (called blue-stones) have been quarried for many years between Schenectady and Aqueduct, largely for crushed stone. Very heavy sandstone beds (15 feet thick and more) are found in the upper portion of the formation, west of Altamont.

The flora and fauna of the Schenectady beds consist of:

Plants:	Sphenophycus latifolius (*Hall*)
Graptolites:	Dictyonema multiramosum *Rued.*
	Azygograptus *sp. nov.*
	Mastigograptus *sp. nov. cf.* simplex *Walcott*
	M. *sp. nov.*
	Diplograptus vespertinus *Rued.*
	Climacograptus spinifer *Rued.*
	C. typicalis *Hall*
	Lasiograptus (Thysanograptus) eucharis (*Hall*)
Crinoids:	Joints
Starfish (Brittle Stars):	Taeniaster schohariae *Rued.*

Brachiopods:	Lingula (Pseudolingula) rectilateralis *Emmons mut.* major *Rued.*
	Lingulasma elongatum *Rued.* ('16, p. 70)
	Leptobolus insignis *Hall*
	Dalmanella rogata *Sardeson*
	Rafinesquina ulrichi *James*
	Plectorthis plicatella *Hall*
	Orbiculoidea *sp.*
Worms:	Serpulites *sp.*
Pelecypods:	Saffordia ulrichi *Rued.*
Gastropods:	Cyrtolites *cf.* ornatus *Conrad*
Conularids:	Conularia trentonensis *Hall var.* multicosta *Rued.*
Cephalopods:	Cyrtoceras *sp. nov.*
	Spyroceras bilineatum (*Hall*)
	Trocholites ammonius *Conrad*
Trilobites:	Triarthrus becki (*Green*)
	Isotelus gigas *Dekay*
	Cryptolithus tesselatus *Green*
Ostracods:	Primitia
	Eurychilina *cf.* subrotunda *Ulrich*
Eurypterids:	Eurypterus pristinus *Clarke and Rued.*
	E. megalops *C. & R.*
	E.? (Dolichopterus?) stellatus *C. & R.*
	Eusarcus triangulatus *C. & R.*
	E. ? longiceps *C. & R.*
	Dolichopterus frankfortensis *C. & R.*
	D. latifrons *C. & R.*
	Hughmilleria magna *C. & R.*
	Pterygotus nasutus *C. & R.*
	Stylonurus ? limbatus *C. & R.*

This fauna contains on one hand, elements of the Utica fauna, on the other, Trenton biota, and finally a large element of its own. The Utica elements are for the most part forms connected with the shaly facies and therefore already appearing in the Canajoharie shale. Such are *Climacograptus typicalis, Lasiograptus eucharis, Leptobolus insignis.* The forms pointing to the Trenton age are: *Conularia trentonensis, Spyroceras bilineatum, Triarthrus becki* (the Utica form being *T. eatoni*), *Cryptolithus tesselatus.* The species apparently restricted to the Schenectady beds are: *Sphenophycus latifolius, Dictyonema multiramosum, Taeniaster schohariae, Saffordia ulrichi* and especially the eurypterids.

The peculiar seaweed *Sphenophycus latifolius* was originally described by Hall from the "Hudson River shale" (Schenectady beds) at Schoharie. The writer has also found it as the most common fossil in the blue-stone quarries about Aqueduct and at French Mills, and still in the highest beds of the formation above Altamont, as well as in other localities. It is therefore the most reliable index fossil of the Schenectady beds.

The brittle star was found only in a single specimen by the writer below Schoharie village.

The most striking element of the fauna are the eurypterids. This is the largest Ordovician eurypterid fauna that has as yet become known. Indeed, before this fauna was discovered a few fragments, a body ring and a leg, of a Utica form, and some fragments from the Cincinnati region, which had been described as graptolites, were the only Ordovician eurypterids known. Unfortunately the principal locality is now wholly lost. This was the Dettbarn quarry on the outskirts of Schenectady, between Van Vranken avenue and the river. The quarries have been filled in and the district has been built over. The eurypterids were found there by the writer in the shale layers between the sandstone (blue-stone) banks, together with the graptolites, trilobites and other fossils. Smaller collections of less favorably preserved eurypterid material were also obtained on Waterstreet hill near Rotterdam Junction, in the blue-stone quarries about Duanesburg and near Delanson. It is therefore probable that the seaweed *Sphenophycus* and the eurypterids, as well as some of the graptolites, are well distributed through the whole thick formation.

It is quite apparent that the hundred-fold repetition of sandstone or grit beds and shale together with the eurypterids, seaweeds and scattered graptolites and other marine fossils indicate conditions of deposition different from those usually found. We have already seen that the beds were laid down in a basin or trough extending north-south or more correctly north-northeast to south-southwest in the direction of the later Green mountain folding, and that this basin was rapidly sinking. The writer sees in the lithic and faunal conditions evidence of currents that brought in the material probably from the northeast; in times when they were very strong the sandstones were deposited; when they were weak the shales were formed, the black shales with the graptolites indicating the times of least motion of the water. Others would consider these beds as the result of rapidly changing depth of water and the moving up or down of the shore line, and still others see in them delta deposits.

3 Indian Ladder beds. The Indian Ladder beds have their type locality, the Black creek ravine at the Indian Ladder, just beyond the edge of the capital district. They extend from there, rapidly thinning, below the Helderberg cliff, as far as New Salem, where they can still be recognized in the ravine above the village. They are well exposed to the west of the Indian Ladder, below Haile's cave and will be fully described by Miss Goldring in the Guide of the Indian Ladder region.

The writer ('12) separated this formation from the Schenectady beds, after the discovery of a fauna in the Black creek ravine, that is younger than Utica age and corresponds to that of the Southgate member of the Eden shale about Cincinnati and in age to the Frankfort shale of central New York.

The type section is along the upper left branch of Black creek, forming the fall and deep ravine at the Indian Ladder. The section comprises here about 410 feet (aneroid measurement), of which the lowest 100 feet are dark gray to black argillaceous shales with two thick sandstone beds (each about four feet)[1] while the next 100 feet are of a character not met with in the Schenectady beds. They consist of rapidly alternating gray shales and thin yellow rusty-looking, somewhat calcareous sandstone layers, one-half to one inch or more thick. The uppermost part of this portion becomes quite sandy. Nearly 100 feet are there covered while some 120 feet at the top consist of prevailingly heavy sandstone beds with intercalated dark arenaceous and argillaceous shales, and an occasional limestone band. The top is formed by a white hard sandstone bank three and one-half feet thick and consisting largely of rounded sand grains. This is separated by shale, one layer of which consists of pyrite, from an underlying gray sandstone bed, also composed of rounded grains. The sandstone beds of this upper part of the formation are extremely irregular courses. In one case a bed was seen to run out within ten feet from four feet to one-half a foot. In the excellent section exposed near the first fault-line, about one mile southeast of the Indian Ladder, a considerable thickness of dark gray shale is followed by a ten-foot bed of solid sandstone, then 20 feet of alternating dark shale and thin beds of sandstone, the latter increasing toward base, and a last seven-foot sandstone bed on top, upon which the Brayman shale rests.

The Indian Ladder beds have an extremely barren aspect. Very thorough search has furnished us a small graptolite faunule in the

[1] In Bulletin 162, figure 5 is the lower thick-bedded sandstone with shale alternations and figure 6 the overlying alternating shale and thin fossiliferous limestone beds, the two figures having been confused by the editor.

shales of the lower 200 feet and another faunule in the thin calcareous sandstone intercalations of the second hundred feet. A few bands of the latter proved to be covered with the remains of a microfauna, especially small crinoid joints.

The shale has furnished:

Dictyonema arbusculum *Ulrich*
Diplograptus *cf.* nexus *Rued.*[1]
Dicranograptus nicholsoni *Hopkinson.*

The calcareous sandstone fauna consists of:

Cystids:	Calyx plates and columnals of cystid allied to Cheirocrinus
Crinoids:	Crinoid columnals (Heterocrinus)
Machaeridians:	Lepidocoleus jamesi (*H. & W.*)
Bryozoans:	Hallopora onealli (*James*) *Ulrich*
	Arthrostylus tenuis *Ulrich*
	Helopora *sp. nov.*
	Rhinidictya *cf.* parallela (*James*)
Brachiopods:	Rafinesquina ulrichi (*James*)
	Plectambonites centricarinatus *Rued.*
	P. plicatellus (*Ulrich*)
	Dalmanella multisecta (*Meek*)
Trilobites:	Cryptolithus bellulus (*Ulrich*)
	Acidaspis crossota *Locke*
	Calymmene *sp.*

In the New Salem section the Indian Ladder beds are exposed in the ravines leading from the village to the new state road. Here for about 80 feet gray and black, partly sandy shales are observed. Thirty feet below the base of the Manlius the yellowish-weathering calcareous intercalations, so characteristic of the lower Indian Ladder beds in the Indian Ladder section, are observed through an exposed interval of 15 feet; farther up blocks of the heavy top sandstones are seen in little disturbed position. Years ago the writer collected in the shale of this locality *Dicranograptus nicholsoni* and *Climacograptus typicalis* (variety with somewhat longer distal spines). This is the only outcrop on the Albany quadrangle of the Indian Ladder beds that is not doubtful. Small outcrops of dark blue to olive-tinted argillaceous shales farther east, just under the cliff, are lithologically noncommittal and have failed to furnish fossils.

[1] *Diplograptus peosta* cited by the writer in 1912 (p. 51) is a much later (Maquoketa) form of the west. *Diplograptus nexus* occurs in the Whetstone Gulf (lower Lorraine) formation of central New York.

The Indian Ladder beds with their restricted horizontal distribution, east and west, in spite of the great thickness that they attain at the Indian Ladder, represent a puzzling formation, especially since their fauna is nowhere else represented in eastern New York. It is, however, of the same age as that of the Moose Creek member of the Whetstone Gulf formation of central New York, corresponding to the Southgate member of the Eden formation of Ohio. It is to be inferred from the distribution of the rocks and the character of the fauna that the Indian Ladder beds represent an independent advance of the Eden sea from the south northward in one of the long troughs developing in the Appalachian region. In Pennsylvania the Martinsburg shale represents in part the Eden formation and it is probable that this isolated occurrence of a formation, younger than the Utica, has there its derivation. (Ruedemann, '25, p. 152, fig. 8.)

4 **Brayman shales.** The extremely heavy top bed of the Indian Ladder beds, a sandstone bank seven feet thick, is overlain by two feet four inches of a greenish sandstone to coarse arenaceous shale, thickly charged with iron pyrites, at the Indian Ladder. This bed is soft and rots away so easily that it is exposed only below the falls and at the caves. It has receded far back of the cliff and is usually covered by talus material. A good exposure is, however, shown at the first fault-line, about one mile southeast of the Indian Ladder, where two feet four inches of very pyritiferous Brayman shale are seen that is separated from the underlying heavy sandstone bed (seven feet thick) by a disconformity plane, full of pyrite.

On the Albany quadrangle it has dwindled to about ten inches about New Salem, where it is exposed in a small glen one-half mile south of New Salem. It is not exposed again farther east at the base of the cliff.

This thin bed of greenish sandy shale has been variously correlated. Prosser and Rowe ('97) who first described it from the Indian Ladder and New Salem region considered it as the attenuated Clinton formation. They thus connected it with the so-called Clinton shales of the neighborhood of Cobleskill. These shales reach there 40 feet in thickness, are olive or grayish clay shales, loaded with concretions of iron pyrites of all sizes, although generally not much larger than a man's fist. This strange formation has never furnished any fossils and its age has therefore remained uncertain. Grabau ('06) proposed the name Brayman shale, from the village of Braymansville on the Cobleskill, for the shales. While Hartnagel, Clarke and others were inclined to consider the Brayman shale of Salina age, Grabau would correlate it only with the lower

part of the lower cement bed at Rosendale. Ulrich and Ruedemann independently reached the conclusion that it probably is a residual bed or soil of the Ordovician representing the large hiatus between the Indian Ladder beds and the Cobleskill beds of Niagaran age (Ruedemann, '12, p. 56).

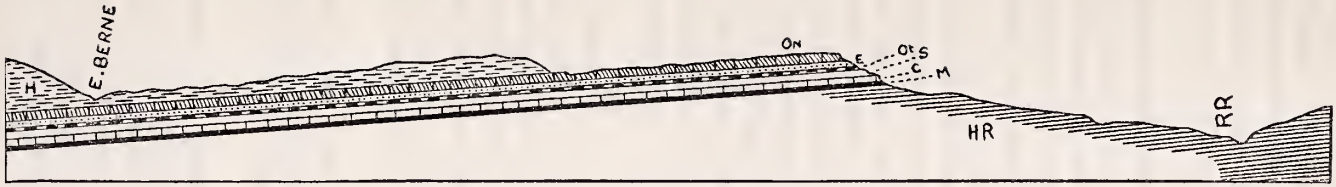
This conclusion is based in part on the character of the shale, and in part on its overlapping of various Ordovician formations (Frankfort shales in west, Schenectady beds in Schoharie region, Indian Ladder beds farther east). The Brayman shale is therefore not directly attachable to any of the Ordovician formations, but independent of them. On the other hand, Grabau (*op. cit.* p. 127) has argued that the Brayman shale is more sharply separated by its lithic character and the nature of the contact from the overlying waterlime than from the underlying sandstone. He would therefore draw the Siluro-Champlainic boundary somewhere below in the sandstones and consider the uppermost sandstone beds as equivalent to the Binnewater sandstones of the Rondout cement region.

B Silurian and Devonian Rocks of Both Troughs

5 Rondout Waterlime. The Brayman shale is sharply separated from the overlying waterlime. This latter bed, which was formerly known as the "Salina waterlime," and which was later correlated with the Rondout waterlime horizon, is of varying, but small thickness. It is exposed in but five places in the region, namely, at the Indian Ladder just outside of the Albany quadrangle, where it is seen along Bear Path under the cliff, especially under the waterfall and measures three and three-fourths to four and three-fourths feet. It is again seen in the small glen one-half mile south of New Salem (Prosser & Rowe, '99, p. 338) where the Brayman shale is exposed. It is there six and one-half feet thick; it measures 12 feet in the South Albany quarry; and finally it is found in the large quarry at South Bethlehem. It is there about 12 feet thick.

In the Cobleskill region this formation has thickened to 60 feet, the lowest six feet of which are mined for the manufacture of cement at Howes Cave. In the capital district the bed contains no cement, but consists of drab impure magnesian limestones, in three or four layers with some shaly intercalations. As at Rondout the surface (the uppermost in the South Bethlehem quarry) of some beds is characterized by mud-crack structures, mostly of pentagonal form. These indicate that the fine lime mud which formed the bed was probably exposed at times (low tide) to the drying influence of the sun.

No fossils have been observed in the capital district localities mentioned. Grabau has observed at Howes Cave fragments of *Favosites helderbergiae* var. *precedens* which have passed up from the underlying Cobleskill limestone. Since the latter is of Silurian age, there can be no doubt of the Silurian age of the Rondout waterlime whatever the age of the Brayman shale may be.



Figures 3 and 4 Sections through Helderberg formations in the northwestern part of Albany county and in the vicinity of New Salem. (From Darton). *H*, Hamilton and Marcellus shales; *ON*, Onondaga limestone; *E*, Esopus shale; *O|R;* Oriskany sandstone; *B*, Becraft limestone; *S*, New Scotland beds; *C*, Coeymans limestone; *M*, Manlius limestone and Rondout waterlime; *HR*, (Hudson River group), Normanskill and Snake hill shales.

6 Manlius limestone. The Manlius was originally known as the Tentaculite limestone, a name derived from the abundant occurrence on the slabs of the little straight shells of *Tentaculites gyracanthus,* a supposed pteropod. Later the formation, following the present custom of deriving names from the most typical locality, was termed the Manlius limestone, after Manlius near Syracuse.

In the capital district the Manlius is a very characteristic, easily recognized formation in the lower part of the vertical Helderberg cliff (figures 53, 71, 74, 76). It consists of thin-bedded, dark blue limestone of fairly pure composition, in layers one to three inches thick, the layers being especially thin in the lower part with alternating lighter and darker beds (ribbon-limestone of authors). The thin limestone slabs are of remarkable hardness and resistance; they break with a ringing sound and weather with a characteristic light color. This formation is, however, most easily recognized by the immense numbers of the tentaculites upon certain surfaces, while others are covered with the little brachiopod *Spirifer vanuxemi,* and others again with the fairly large ostracod *Leperditia alta.* It is on account of this hardness of the rock that the Manlius forms such a distinct vertical cliff, either jointly with the overlying Coeymans limestone, as at the Indian Ladder, or often by itself as in localities between New Salem and South Bethlehem, as, for example, on the Clarksville road and above Feura Bush.

The best exposure in the Albany region is at the Indian Ladder, where the whole thickness is shown in the cliff. The thickness is there given by Prosser ('99, p. 30) at 31½ feet for the typical Manlius limestone and 14½ feet for the transitional beds from the Manlius to the overlying Coeymans limestone. In a later paper ('07) the same author has, however, given the formation a thickness of 54⅔ feet at the Indian Ladder, with still a transition bed of two feet above it.

Owing to displacements along fault-lines the Manlius comes to or nearly to the top of the vertical cliff in two places south of the Indian Ladder, and it can be traced fairly persistently along the foot of the cliff.

Excellent exposures on the Albany quadrangle are furnished by the small quarry near the state road above New Salem, where 25 feet of Manlius limestone are exposed; in the new large quarry of the Albany Crushed Stone Co. one and one-half miles southeast of Feura Bush; and in Callanan's quarry at South Bethlehem. The section in the small glen one-half a mile south of New Salem has furnished Prosser 32½ feet of typical Tentaculite limestone and

12½ feet of transitional layers above with *Spirifer vanuxemi* and *Leperditia alta*. Darton ('94, p. 441) states that the average thickness of 30 feet for the formation is maintained throughout Albany county. We have measured 45 feet of Manlius in the section east of New Salem, drawing 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 New Salem quarry exhibits a series of features that clearly indicate the tide-flat conditions under which the Manlius limestone was deposited. There are besides the thin bedding of the limestone thin shaly films separating the limestones, mud cracks and faint ripple marks, comminuted shells, parallel arranged Tentaculites-tubes and piled-together masses of Leperditia shells, also mud pebbles in the bottom beds. As many as three Stromatopora beds are seen; one eight to nine feet thick occurs in the true Manlius formation. In the transition beds are three feet four inches of extremely thin-bedded shaly material full of black grains, apparently phosphate of lime. Flat coral stocks of Stromatoporas are also seen here at the top of the transition beds.

The Stromatopora bed of the Manlius is also seen in the little glen south of New Salem and on the road from Albany to Clarksville, in the floor of an abandoned quarry about a mile southwest of Stony hill, and again three-fourths of a mile farther west at the foot of the cliff in the deep reentrant.

Owing to the intensive work, the exposures in the gigantic South Bethlehem quarry are continually changing. The heavy Stromatopora bed is probably always visible at the top of the Manlius limestone and in the middle of the quarry also five to ten feet of Coeymans limestone above it. Mr Hartnagel has measured in Callanan's quarry the following section:

	Depth in feet
Upper Manlius	15
Waterlime with Leperditia	4
Lower Manlius	36
Waterlime	14
Hudson River Beds.	

Sieberella cocymanensis (*galeate* auct.) was found to appear not until at least 20 feet above the Manlius. A fault in the upper Manlius may cause a duplication of beds.

The fauna of the Manlius is very meager, although it has afforded in other regions, as that of Jerusalem Hill in southern Herkimer county, some very remarkable fossils, such as strange crinoids and cystids. The talus of the cliff in the capital district

will hardly furnish anything else but the bryozoan: Monotrypella arbusculus *Hall;*
the brachiopod: Spirifer vanuxemi *Hall.*
the small pelecypods: Megambonia aviculoidea *Hall* and
Modiolopsis? dubia *Hall.*
the pteropod: Tentaculites gyracanthus (*Eaton*) *Hall* and
the ostracod: Leperditia alta (*Conrad*) *Hall.*
Of these *Spirifer vanuxemi* Hall, *Tentaculites gyracanthus* and *Leperditia alta* can always be found.

To these must be added the Stromatoporas, which formed coral reefs that can now be seen for long distances in the cliff, in section, both in the Manlius and Coeymans limestones. They consist of great horizontally connected subglobular masses, of concentric structure. They belong to an extinct class of organisms that probably was related to the Hydrozoa. The latter today form similar coral stocks, as in the genus Millepora, which comprises some of the most important recent reef-builders. The Indian Ladder form has been described as *Syringostroma barretti* by Girty ('94).

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.*

Geologists of the First Geologic Survey, in the '30's and '40's of the last century, distinguished the Lower and Upper Helderberg limestones that were separated by a sandstone or grit bed, the Oriskany sandstone. Under the leadership of James Hall the Upper Helderberg beds were classed with the Devonian, the Lower with the Silurian. Later Clarke in following the more refined demarcation of the Silurian-Devonian boundary carried out in Europe, brought the Lower Helderberg boundary limestones into the Devonian because of their close faunal relationships with the "Hercynian" of Europe, with the exception of the Manlius, and comprised the limestones below the Oriskany sandstone as the Helderbergian group. The Manlius was retained in the Silurian because its small fauna shows no such relationship, but is rather Silurian in

aspect. The Manlius has been the object of argument as to its age ever since. This is not the place to enter into a discussion of this mooted question; it may suffice to state that while most authors follow Clarke, some would also place the Manlius with the Devonian and others put the division line between the Silurian and Devonian within the Manlius. As stratigraphic methods become steadily more refined, it is certain that the question will be finally answered satisfactorily. So far as the Manlius of the eastern Helderberg cliffs which may not entirely coincide with the typical Manlius of Onondaga county is concerned, it would seem that the observation of a distinct irregular unconformity between the Manlius and Coeymans at the Indian Ladder (see below), as well as about Catskill, with Manlius pebbles in the base of the Coeymans as observed there by Professor Chadwick, would indicate the presence of at least a local unconformity between the Manlius and the Coeymans.

7 **Coeymans limestone** (figures 53 and 73). The Coeymans limestone was known to the earlier geologists as the Lower Pentamerus limestone or Pentamerus limestone in general from the most common brachiopod *Pentamerus galeatus* (now *Sieberella coeymanensis*). Clarke and Schuchert in 1899 proposed the new name from the village of Coeymans in Albany county. The Coeymans limestone is the principal cause of the Helderberg cliff. Its massive character forms the cliff.

It is the most striking Helderberg formation through the thickness and hardness of its beds; for these, combined with the vertical jointing and the softer transition beds below, make the Pentamerus limestone stand up in magnificent vertical cliffs over 50 feet high, and usually projecting beyond the underlying Manlius and Rondout beds, which are inclined to form caves and shelters; as those about the Indian Ladder.

The most massive beds are in the lower part while toward the top the beds become more thin-bedded.

The Coeymans retains its thickness of about 50 feet[1] over a remarkably large area, from Schoharie past the Indian Ladder and New Salem to Rondout, while eastward it decreases to 45 feet at Becraft Mountain near Hudson. It also extends farther west than the other Helderbergian formations, namely as far as the vicinity of Manlius, Onondaga county.

[1] Prosser gives 50 feet at the Countryman hill—New Salem sections; Grabau about the same at Schoharie. Darton gives 65 feet but includes the Manlius-Coeymans transition beds. Harris, on the other hand, gives the thickness as 32 feet and that of the Manlius as 63.7 feet, including the transition beds with the latter.

The beds are usually several feet thick, of bluish-gray color, weathering light gray and fairly regularly bedded, but there is, as pointed out by Darton "also an irregular subbedding into flat, interlocking lenses and corrugations, the outlines of which are brought out by weathering. Occasional shale partings occur and also nodules and thin lenses of chert." The rock itself is described by Grabau as "mainly a rather coarse semicrystalline limestone composed of fragments of shells, crinoids and corals. At intervals the rock is a nearly typical shell limestone or coquina with the brachiopod shells composing it largely in a perfect state of preservation. These weather out in relief on the exposed edges of the rock and with care may be collected from these surfaces."

The fauna is a rather small one and consists almost entirely of brachiopod shells which, entire or broken, largely compose the rock. There are also a number of trilobites which the formation has in common with the overlying New Scotland beds. The fossils are hard to obtain unless the rock has been slightly burned.

By far the most common and diagnostic fossil which rightly gave the formation its name is the *Sieberella (Pentamerus) galeata* (Dal.) H. & C. It received its name from the characteristic helmetlike shape of the shells, and these stout shells are found everywhere in the formation. The next common brachiopods are the *Uncinulus mutabilis* (Hall), a subglobular form with many ribs and the long-ranged *Atrypa reticularis* (Linn.) Dal. Besides these are recorded from the Albany quadrangle by R. B. Rowe (p. 349):

Strophonella punctulifera (*Con.*)
Stropheodonta (Brachyprion) varistriata (*Con.*)
Spirifer vanuxemi *Hall.*
S. perlamellosus *Hall.*
Rhynchonella semiplicata (*Con.*)
Meristella laevis (*Vanuxem*)
Orthis (Orthostrophia) strophomenoides *Hall* (?)
O. *sp.*
Anastrophia verneuili (*Hall*)? and the coral
Favosites helderbergiae *Hall.*

The lower transition beds contain *Spirifer vanuxemi* and *Stropheodonta varistriata* as abundant fossils.

In the Schoharie region and in Herkimer county the Coeymans limestone has furnished a number of beautiful crinoids and of strange cystids, as *Lepocrinites gebhardi* with its carrotlike anchor and nutlike head. These may also still turn up in the district. The small

crinoid *Homocrinus scoparins* was found in great numbers in Litchfield, Herkimer county, by Doctor Clarke and the writer, together with the peculiar starfish *Hallaster forbesi* (Hall). There were crinoid plantations growing in that region in Coeymans time, apparently in more quiet water than prevailed farther east.

8 New Scotland beds (including *Kalkberg limestone*). The New Scotland beds are at once the least conspicuous and the most fossiliferous member of the Helderbergian series. They are not conspicuous, forming gentle slopes above the Coeymans cliff, because they consist of thin-bedded, very impure shaly limestones and calcareous shales, varying in color from gray to gray-brown; they weather readily and hence form soil-covered gentle slopes that are often used for grazing and quite frequently used by farms, while the broad back slope of the Coeymans, extending from west of Stony hill to South Bethlehem is mostly wooded. Good outcrops are therefore rare, and much sought after by collectors on account of the splendid collecting that the New Scotland beds afford. It was the stamping ground of the pioneer collectors of the Albany Survey; Hall was often in Clarksville and his assistants, Beecher, Clarke, Simpson, Schuchert, the Van Deloos, Walcott and Whitfield, used to walk out there Sundays from Albany and often return the same day with their bags filled to capacity. Especially Bradford Allen's farm, two miles this side of Clarksville, on the Albany road, was searched every year, the field there being strewn with weathered-out fossils, silicified bryozoans, corals, trilobites and silicified brachiopods. G. B. Simpson told me that he gathered the largest portion of the New Scotland material for volume 6 of the Paleontology of New York on this farm. Also the Oniskethau creek below Slingerland's Mill was famous among collectors; this place as well as the stone fences in the vicinity were a harvesting ground, especially for trilobites. The creek and fences furnished the remarkable trilobites *Lichas pustulosus, Dalmanites pleuroptyx, Phacops logani* etc., as well as beautifully preserved gastropods of the genera Platyceras and Strophostylus, bryozoans and brachiopods. At the sawmill at the end of the section the trilobite *Acidaspis tuberculatus* is regularly found. In later years the ground around the spring (Voorheesville water works) below the "Parrish house" (Kenny Parrish) on the old road leading up from New Salem has been much frequented by college classes in geology.

To these earlier enthusiastic and industrious collectors the formation was known as the "Delthyris shaly limestone," from its most

common and characteristic fossils, the brachiopods *Spirifer perlamellosus* Hall and *S. macropleura* (Conrad) known also by the older names *Delthyris perlamellosus* and *D. macropleura.* Before, the formation was also known as "lower shaly limestone" and "Catskill shaly limestone," names that were applied by the geologists of the first Survey. Clarke and Schuchert ('99) proposed the name "New Scotland beds," from the town of New Scotland in which Clarksville and the other mentioned fossil localities are located. The village of New Scotland is on Schenectady beds.

The shale, while resting flat in the northern and middle Helderberg region of the Albany quadrangle, is very soft and readily weathered. Where, however, it has been folded, as in the southern portion of the quadrangle, south of South Bethlehem, it is traversed by slaty cleavage and much harder. It also possesses a distinct slaty fracture cleavage and greater hardness along the fault south of the Indian Ladder.

Above New Salem, in about the middle of the formation along the new road, layers of fossil-bearing lime concretions are seen.

The thickness of the New Scotland beds averages about 100 feet according to Darton; Prosser measured 120 feet in the Countryman hill section, beginning a little northwest of New Salem and 127 feet in the Clarksville and Oniskethau creek section. Miss Goldring and myself found 105 feet for the formation below the Parrish house where the contact with the overlying Becraft limestone is exposed. As in the measurements of the Manlius and Coeymans limestones, there is not only slight variation from locality to locality, but the differences also result from the uncertainty of the boundaries and the presence of transition beds.

In the Schoharie region Grabau found 115 feet and at Becraft mountain 70 to 75 feet, while at Kingston the thickness is estimated at 100 feet. It is therefore safe to say that, as Darton concluded, the thickness averages about 100 feet.

The transition beds between the Coeymans and New Scotland beds are so strongly marked by parallel seams of black flint and a mixed fauna at Catskill, Greene county, that they have been separated by Chadwick as "Kalkberg limestone." (Kalkberg, meaning limestone mountain, is the local Dutch name for the Helderberg ridge.)

In the capital district the Kalkberg is not so distinctly set off from the adjoining formations, but yet recognizable. At the Indian Ladder it was pointed out to Miss Goldring and the writer by Professor Chadwick that the formation is there 20 feet thick, the beds charac-

terized by being a little heavier, not weathering so yellow and the fossils being siliceous, with some chert. The thick stems of the crinoid *Mariacrinus stoloniferus* and the brachiopods *Bilobites, Spirifer perlamellosus* and *S. cyclopterus* are common in the bed, also *S. coeymanensis* occurs.

Farther up in the New Scotland formation heavier beds are found that contain only the small brachiopod species of Lingula and Orbiculoidea.

South of Callanan's quarry, near the edge of the Albany quadrangle, Miss Goldring and the writer found the Kalkberg formation well recognizable, represented by firmer beds than those farther north in the Helderbergs and containing chert. Also the uppermost bed of the Coeymans is here filled with chert. The Kalkberg is here 20 to 25 feet thick and while readily recognized it grades into the Coeymans below and the typical New Scotland above so that the boundary lines are hard to draw. We have mapped it with the New Scotland formation because it belongs topographically with it.

Owing to variations in hardness the Kalkberg often forms one or two local subterraces, as above New Salem; another subterrace appears in the higher New Scotland where cherts and more silicious admixture produce somewhat harder beds.

The fauna is too large to be listed fully here. It is interesting to know, however, that according to a survey I made for this purpose, there are cited in the volumes of the Paleontology (volumes 3, 4 and 7) and Director's reports from the New Scotland beds [1] of Clarksville the following numbers of species of each class:

Calcareous algae (Ischadites, Receptaculites)	2
Sponges	1
Corals	10
Bryozoans	71
Brachiopods	62
Lamellibranchs	9
Gastropods	21
Conularids	1
Trilobites	7
Cephalopods and ostracods	0

There are altogether 184 species recorded as occuring in the New Scotland beds of that region. The two outstanding classes in this fauna are the bryozoans and brachiopods; the mollusks are only well represented by the gastropods; the trilobites are prominent as a faunal element, not so much by variety of species as by number of individuals, but they are far surpassed by the bryozoans and brachiopods.

[1] Some cited merely as Lower Helderberg beds of Clarksville. The lists from the Indian Ladder would much increase this number.

Prosser and Rowe ('99, p. 338, 349) have listed 26 species from the New Salem section and 43 forms from the New Scotland beds of Clarksville but they did not make any effort to collect from the bryozoan beds. I will merely cite here the species they have recorded as common or abundant:

Clarksville (listed by Rowe):

Corals: Streptelasma strictum *Hall*

Brachiopods: Spirifer macropleurus (*Conrad*)
S. cyclopterus *Hall*
Leptaena rhomboidalis (*Wilckens*)
Stropheodonta (Leptostrophia) becki *Hall*
Strophonella punctulifera (*Conrad*)

Trilobites: Dalmanites pleuroptyx (*Green*)

New Salem section (below Parrish House) (listed by Prosser):

Bryozoans: Fenestella *sp.*

Brachiopods: Stropheodonta (Leptostrophia) becki *Hall*
Spirifer perlamellosus *Hall*
Leptaena rhomboidalis (*Wilckens*)
Trematospira globosa *Hall*
Spirifer cyclopterus *Hall*
S. macropleurus (*Conrad*)
Strophonella punctulifera (*Conrad*)

9 Becraft limestone. The Becraft limestone was formerly known partly as Scutella or Encrinal limestone and partly as Upper Pentamerus limestone. The name "Becraft limestone" was introduced by N. H. Darton ('94) with the sanction of James Hall. It is derived from the well-known Devonian outlier Becraft mountain, just outside of Hudson, Columbia county.

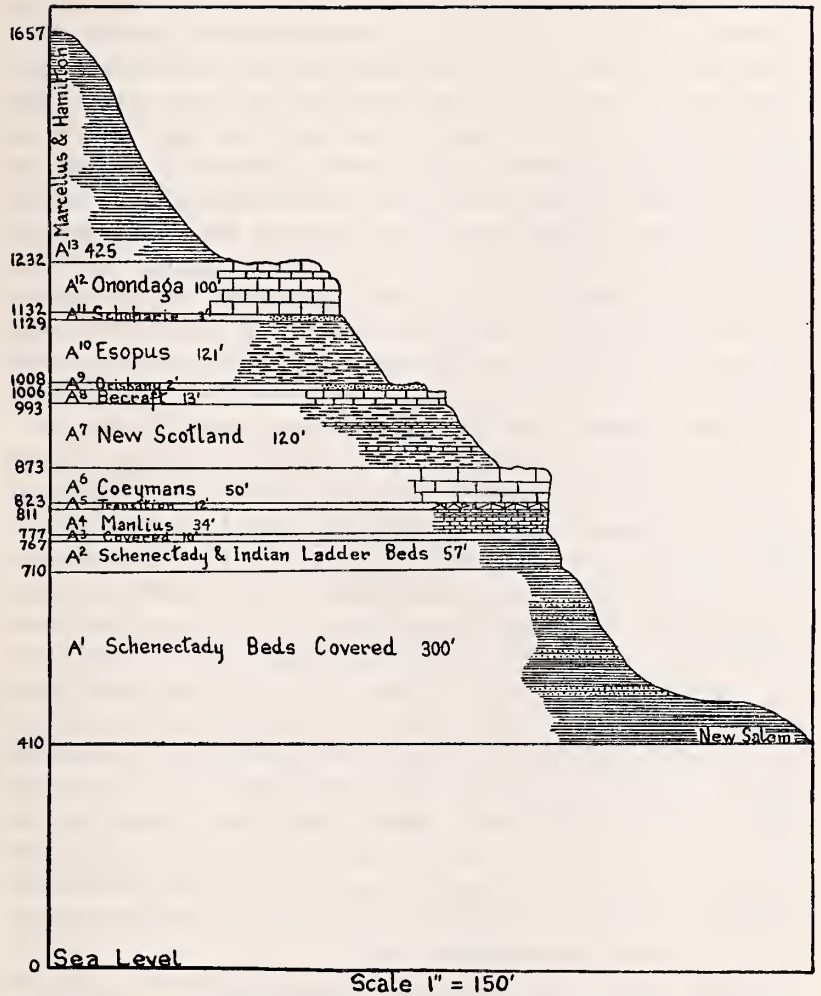


Figure 5 Section of Countryman hill, near Salem. (From Prosser & Rowe). Shows the two cliffs produced by the Upper and Lower Helderberg limestones.

It is the uppermost member of the Helderbergian (Lower Helderberg) limestones and in the earlier correlations formed the top of the Silurian, while now it is the top member of the Helderbergian division of the Lower Devonian.

It is a heavy bedded, light gray, coarsely crystalline limestone and largely composed of fossils, mostly brachiopods and crinoids. The formation is not very thick in the capital district, only the lower part of the whole Becraft, as it is exposed farther south, as about Catskill, being present. Darton found its thickness to average 15 feet but states that at some points it appears to be slightly less. Prosser and Rowe measured 13 feet in the Countryman hill section and 20 feet near Clarksville. Miss Goldring and the writer found a thickness of but 12 feet a mile northeast of the hamlet of Oniskethau, and only about nine feet along the new Indian Ladder road, but 27 feet two and one-fourth miles south-southeast of New Salem. It seems thus that the formation varies considerably between 12 and 27 feet in thickness in the capital district. It shows much greater thickness farther south; at Becraft mountain it measures 45 feet.

In spite of its small thickness the formation is quite prominently exposed forming a distinct flat in many places of the Helderberg region in the capital district. Just outside of the latter it is now well exposed by the new road, leading uphill from the Indian Ladder, where it shows some shaly intercalations. The new state road from New Salem to the Indian Ladder crosses it one-quarter of a mile from the edge of the sheet and about one mile from the Indian Ladder, and it runs along the west side of the road for a mile and a quarter on this side of that crossing. Along the old road leading around Countryman hill it is well exposed at the Parrish house, which stands on it, showing there just below the house the contact with the subjacent New Scotland beds. Back of the house, where the joint system of the formation is well exposed (also well seen along Indian Ladder road), the old "Beaverdam road," the first road that led from Schoharie to Albany is still recognizable. It took advantage of the bare rock surface of the Becraft flat.

A good contact of the Becraft and New Scotland beds is also seen two and a quarter miles south-southeast of New Salem, where the road leading south of New Salem climbs the escarpment. The Becraft is also shown in typical development full of scutellas along the new state road from Albany to Clarksville, a mile and a quarter this side of Clarksville before one reaches the crossroads connecting with the Feura Bush–Indian Fields road and at this crossroad the contact with the superjacent Oriskany sandstone is exposed.

The new New Salem–Wolf hill state road gives fair collecting in the New Scotland beds at the left in the first woods of the New Scotland plateau and then along the road in successive outcrops of the Becraft, Oriskany, Esopus and Onondaga formations (the latter in large quarries).

The Becraft is covered by drift south of Oniskethau, but again is well exposed along the road leading southwest into the Helderbergs from South Bethlehem.

Although the Becraft limestone is composed of shells and shell fragments, its fauna is not very large. The most conspicuous fossil, from which it received its name "Scutella limestone," from a fancied resemblance of the fossil to the sea urchin Scutella, is the basal portion of a large crinoid, *Aspidocrinus scutelliformis* Hall. These fossils are solid, from one to two inches in diameter, usually flatly bowl-shaped plates with a small central circular depression. They were considered by Hall and later authors as the base of the calyx of a large crinoid. Miss Goldring ('23) has found them to be the basal expansions of crinoid columns, the columns themselves being as yet unknown. The scutellas are found everywhere in the Becraft limestone and form its best index fossil, although they appear in the upper part of the New Scotland limestone. The shields are rendered crystalline, like all echinoid remains, by secondary infiltration, often of pinkish or glistening white color and therefore readily seen; they also stand out in relief on the weathered surfaces.

In the lower part of the Becraft limestone large crinoid columns or their scattered joints are common, and this fact gave the rock the name of "Encrinal limestone." Its last name of "Upper Pentamerus limestone" it received from the brachiopod *Sieberella* (formerly *Pentamerus*) *pseudogaleatus* (Hall). This is also helmet-shaped, as the Pentamerus of the Coeymans limestone, but bears no ribs on the middle. It predominates especially in the upper portion of the Becraft limestone.

Prosser ('99, p. 341) cites the following fossils from the Becraft limestone at the Parrish house:

Crinoids:	Aspidocrinus scutelliformis *Hall*	(abundant)
Corals:	Lichenalia torta *Hall*	(rare)
	Streptelasma strictum *Hall*	(r)
	Favosites sphaericus *Hall*	(r)
Brachiopods:	Spirifer concinnus *Hall*	(a)
	Sieberella pseudogaleata *Hall*	(a)
	Atrypa reticularis (*Linn.*) *Dal.*	(a)

Wilsonia ventricosa (*Hall*).....(r)
Uncinulus nobilis (*Hall*).....(common)
U. campbellanus (*Hall*)..... (r)
Schizophoria (*formerly* Orthis) multistriata *Hall* ..... (c)
Rhipidomella (*formerly Orthis*) oblata *Hall*.... (r)
Spirifer cyclopterus *Hall* (?)..... (r)
Leptaena rhomboidalis (*Wilckens*)..... (r)
Orthothetes *cf.* woolworthana (*Hall*)..... (r)

From Clarksville Rowe records ('99, p. 351):

Crinoids: Aspidocrinus scutelliformis *Hall*..... (aa)
Brachiopods: Stropheodonta becki *Hall*..... (rr)
Leptaena rhomboidalis (*Wilckens*)..... (rr)
Spirifer concinnus *Hall*..... (rr)
Strophonella punctulifera (*Conrad*)..... (a)
Atrypa reticularis (*Linn.*) *Dal*..... (a)
Orthis (Rhipidomella) discus *Hall*..... (rr)
O. (R.) oblata *Hall*..... (r)
O. (Dalmanella) planoconvexa *Hall* (?)..... (rr)
Orthothetes woolworthana (*Hall*)..... (rr)

10 **Oriskany sandstone.** The Oriskany sandstone in the capital district averages only one to two feet, yet it is one of the best known formations among collectors of fossils and geologists, partly on account of its remarkable fauna of heavy shells and partly on account of its important position at the base of the upper Helderberg formation or Oriskanian in the Helderbergs. In America, formerly, it was even the base of the Devonian. It is also topographically important, because it is itself extremely hard and resistant and, being followed by soft shales, it forms a distinct broad platform in many parts of the Helderbergs, altogether out of proportion to its thickness.

The formation was first called the Oriskany sandstone by Hall and Vanuxem ('39) after the Oriskany Falls in Oneida county. While it is very thin in the capital district, it thickens considerably southward along the Hudson and extends far to the south, north and southwest.

At its type locality, the Oriskany Falls, the formation consists of 20 feet of nearly pure, white fossiliferous siliceous sandstone. In the Helderbergs it is a very dark, bluish-gray, hard, quartzitic sandstone with a strong admixture of calcareous matter which increases southward but is variable in the Helderbergs. It is this lime which is dissolved out in the exposed rock and leaves behind a brown porous

sandstone. While it is very difficult to distinguish the fossils in the fresh rock or to extract them, they are shown in the decayed rock as beautifully preserved external and internal molds. It is for this reason that in the days of widespread paleontologic enthusiasm in New York State the wonderful collections of Oriskany fossils were mostly obtained in old stone fences especially around Schoharie and in the Helderbergs of Albany county. A splendid collection, now on exhibition in the State Museum, was later obtained in weathered joint cracks at Glenerie near Kingston in Ulster county.

Darton ('94, p. 439) found the Oriskany sandstone to vary in Albany county from one to four feet and to average about three feet over the greater part of the area. He also found that for several miles south from Callanan's corner it appears to be absent, the Esopus shales and Becraft limestone appearing to be in direct contact in several places. Prosser and Rowe ('99, p. 336) measured two feet in the Countryman hill section and one foot in the Clarksville section. We found one and one-half feet along the new Indian Ladder road near the edge of the Albany quadrangle and three feet one inch in a ledge that crosses the Oniskethau creek one and one-half miles below Clarksville.

As already pointed out by Darton, the Oriskany sandstone is much more exposed than one should expect from the thickness of the bed. It is now very well shown along the new Indian Ladder road at the bottom of a road metal quarry in the Esopus shale about one and one-quarter miles this side of the Indian Ladder. The Oriskany, 18 inches thick, is here a very dark rock, obviously very siliceous, and with many well-rounded sand grains on the surface. Its contact with the underlying Becraft is sharp and irregular and a "welded" contact, the two formations being so tightly adhering that they can be broken out in one piece of rock. The sharp irregular contact and the great differences in rock composition and faunas between the two formations indicate a marked disconformity. The Port Ewen formation, well exposed in the Kingston region and southward, is missing here in this interval. Its fauna is a mixture of New Scotland elements and prenuncial Oriskany forms. The Port Ewen formation is therefore grouped with the Oriskany sandstone. It is also present again farther west at Howe's Cave and Schoharie.

The Oriskany continues on the Becraft along the road in many places as a thin layer of a few inches that remained from weathering. The contact with the overlying Esopus shale is also sharp; yet the lower beds of the Esopus are flinty and still quite similar to the Oriskany. The top of the Oriskany in most outcrops is marked by the curving bushes of *Taonurus cauda galli* (see below, p. 59).

Another good outcrop of the Oriskany is back of the barn of the Parrish house on the old Countryman hill road and north of that house for a considerable distance in the road itself. The rock is here two feet thick. Along the New Salem-Wolf hill state road it is shown on the left side, before the road cut in the Esopus is reached. A very well exposed ledge crosses the Oniskethau creek, one and one-half miles below Clarksville, and the contact between the Becraft limestone and the Oriskany sandstone is shown at the last four corners before one reaches Clarksville.

The fauna of the Oriskany is especially notable by the large size and thick shelled character of the forms, denoting turbulent water conditions in the sea of that region, evidently along an advancing shore line. The most characteristic and common of these are large brachiopods, namely: *Spirifer arenosus* and *S. murchisoni, Hipparionyx proximus, Rhipidomella musculosa, Leptostrophia magnifica, Plethorhyncha barrandei, Camarotoechia oblata* and *Rensselaeria ovoides.* These are associated with two large lamellibranchs, viz. *Pterinea textilis* var. *arenaria* and *P. gebhardi;* and large gastropods, *Strophostylus expansus* and *Platyceras nodosum.*

Prosser ('99, p. 341) collected at the Parrish House:

Brachiopods:	Spirifer arenosus (*Conrad*)	(a)
	S. arrectus *Hall*	(a)
	S. pyxidatus *Hall*	(r)
	Rensselaeria ovoides (*Eaton*)	(c)
	Eatonia peculiaris (*Conrad*)	(c)
	Meristella lata *Hall*	(r)
	Leptocoelia flabellites (*Conrad*)	(r)
	Orthis (Rhipidomella) musculosa *Hall*	(c)
	Hipparionyx proximus (*Vanuxem*)	(r)
	Orbiculoidea ampla (*Hall*)	(r)
	Orthis *sp*	(r)
	Stropheodonta *cf.* magniventra *Hall*	(r)
Gastropods:	Platyostoma ventricosa *Conrad*	(r)
	Platyceras nodosum *Conrad*	(r)

11 **Esopus grit.** The Esopus grit was known to the earlier geologists as the cauda galli or cocktail grit. It received its name from the abundant markings on the bedding planes resembling a rooster's tail, already noticed on the top surface of the Oriskany sandstone. Darton ('94) introduced the name "Esopus grit" (Esopus slates) after the excellent exposures along Esopus creek below Saugerties in Ulster county.

The Esopus grit (figures 54 and 77) is a blackish, gritty or sandy shale of very uniform character, weathering to a dark brown color. It is remarkably barren of organic remains, the cocktaillike markings that abound on the bedding planes being the only signs of life in the formation. These were named *Spirophyton* (*Taonurus*) *cauda galli* and considered as impressions of "fucoids" or seaweeds; they are essentially bundles of sigmoid furrows rising in a spiral curve around a central tube. They have more recently been considered as inorganic wave marks (Grabau, '06, p. 168) and finally been shown by Sarle to be produced by mud-swallowing worms, that move in a spiral about the central tube. The State Museum has on exhibition two specimens of Taonurus that actually show the worms in place at the outer edge of the markings. These are from the Hamilton shale of Western New York.

The lower eight feet of the Esopus grit in the road metal pit along the new Indian Ladder road are highly siliceous or flinty and filled with Taonurus-markings, indicating close relations of the Esopus grit with the Oriskany sandstone, of which in part it may be a facies. The middle portion is more argillaceous, the upper part becomes again strongly siliceous, and the last five or six feet are a heavy sandstone, well shown in the Clarksville-Oniskethau section. This sandstone passes gradually into the Schoharie grit, showing also close connection between the Esopus grit and Schoharie grit. Prosser and Rowe drew the line in the Oniskethau valley, where the Schoharie fossils appear. Southeast of Blodgett hill, near the southern edge of the Albany quadrangle the Schoharie grit is reduced to two feet or less and the Esopus appears to be in places in direct contact with the Onondaga limestone. It also is so below Daniel O'Connell's home above the Indian Ladder road.

Darton ('94, p. 438) found an average thickness of 100 feet in the Helderberg mountains; Prosser and Rowe ('99, p. 348) measured 121 feet in the Clarksville and Countryman hill sections; Miss Goldring and the writer found 120 feet above the new Indian Ladder road just below the O'Connell house, and 105 feet on the southeastern slope of Countryman hill, while above the Parrish house there are only about 100 feet of Esopus shale. The Esopus seems thus to vary in thickness between 100 and 120 feet on the Albany quadrangle. Southward this formation becomes much thicker; at Becraft mountain and at Rondout it is about 300 feet, including the Schoharie and at Port Jervis about 700 feet. It thence extends to New Jersey and Pennsylvania. In the other direction toward Scho-

harie it loses in thickness and disappears not far west of Otsego county.

In the landscape of the Helderberg mountains the Esopus shale forms a very characteristic gentle slope between the terraces of the Oriskany sandstone and the Onondaga limestone that widens considerably southward from Countryman hill and is, as a rule, given up to grazing. Toward the southern edge of the sheet where the Helderberg formations become flexed into anticlines, the Esopus shale becomes harder and develops more strongly a slaty cleavage already apparent at Clarksville; as a result it stands out in very sharp ridges of barren aspect, as seen on the geologic map two miles south and southwest of South Bethlehem. This condition extends thence southward.

The best outcrops of this formation in the capital district are along the new Indian Ladder road, the Wolf hill road and in the gorge below Clarksville, in a road metal pit along the road a mile southeast of Callanan Corner and along the roads leading south from Callanan Corner and southwest of South Bethlehem near the edge of the map. The Taonurus-markings are especially well seen in the small inlier of Esopus shale in Onondaga limestone at Clarksville along the creek (see map) and along the road this side of Clarksville.

12 **Schoharie grit.** The Schoharie grit was named so by Vanuxem in 1840. Its chief distinction is the great wealth of fossils. It is largely only a local formation found principally in the Schoharie valley, in Albany and Otsego counties and in the Hudson river valley, and it is only six to seven feet thick in the Schoharie valley. Yet this bed has furnished 123 species of fossils, the great majority large and striking forms and restricted to the Schoharie grit!

The Schoharie grit, when fresh, is a dark bluish gray, impure siliceous limestone which weathers to a dark buff, porous sandstone. In the capital district it is found best exposed about Clarksville between the Esopus and Onondaga formations and again near the edge of the quadrangle south of South Bethlehem. In some places the Onondaga and Esopus are in direct contact. This variable occurrence of the Schoharie grit is obviously due to the fact that it is probably no more than a sandy facies of the basal Onondaga limestone. This is clearly shown by the fact that the Schoharie merges into the overlying Onondaga, as already observed by Darton. There are known to us two large boulders where the Onondaga limestone and Schoharie grit are directly alternating. One of these, reproduced in figure 55, lies by the road, one and a quarter miles south of Keefer Corner opposite the house of Isaac Spanier. Here two layers of

Schoharie grit, seven and five inches thick are separated by 11 inches of Onondaga limestone, which again in the middle has a thin band of Schoharie grit two inches thick. Another similar block lies in front of the N. Blair farm south of the Albany quadrangle and west of Indian Fields just opposite the great Hannacroix waterfall. On the upper Oniskethau creek between Countryman hill and Wolf hill Miss Goldring and the writer observed several large boulders of Schoharie grit with an intercalated six-inch band of Onondaga limestone, the numerous fossils (corals and cephalopods) passing freely across the welded contacts. These boulders are undoubtedly of local origin and prove the actual alternation of Onondaga limestone with Schoharie grit in some part of the Helderberg region.

The northernmost outcrop of the Schoharie grit in the Albany quadrangle is at the base of the Onondaga cliff south and west of the Parrish house where Prosser and Rowe measured two feet one inch. It is next seen below the old road leading from New Salem over the southern slope of Countryman hill to the new Wolf hill road. There 22 inches of Schoharie grit are seen at the foot of the Onondaga cliff.

In the section along the new Wolf hill road the Schoharie grit is well exposed with a thickness of about three feet resting on similar sandy Esopus grit. The next outcrops are those about Clarksville where the erosion of the Onondaga limestone has left the Schoharie grit well exposed at the foot of the upper gorge and the top of the lower gorge. Prosser and Rowe measured here three feet. Miss Goldring and the writer found on top of the gorge (south side) two feet seven inches of typical Schoharie grit and below 12 inches of gritty shale layers weathering like Schoharie grit and transitional to the Esopus shale. The contact with the Onondaga is here sharp, the bottom layer of the Onondaga being soft and weathered out. The upper two feet of the Schoharie grit are very fossiliferous, the corals filling the upper eight inches. A good outcrop of three feet of Schoharie grit was found in the falls of a southern tributary of Oniskethau creek three-fourths of a mile east of Oniskethau hamlet. One and one-fourth miles east-southeast of this locality the Schoharie grit is exposed in the road. The greatest thickness of the Schoharie grit occurs near the Callanan Corner-Coeymans road, three-fourths of a mile south of Callanan Corner on the slope in the woods to the right. Here six to eight feet of Schoharie grit were found and the Schoharie and Onondaga are seen to be interfingering in places and welded in others, with the lower Onondaga somewhat sandy. Professor G. H. Chadwick (abstract of Geological Society meeting, '27)

on the other hand, has found in the Catskill region disconformities at the top and bottom of the Schoharie member indicated by glauconite.

Finally, there are outcrops near the southern edge of the sheet west of the South Bethlehem-Coeymans road, the Schoharie measuring there two and one-half feet. Schoharie grit appears also half a mile to the east of this road at the foot of the steep Esopus cliff as a result of folding.

These occurrences would suggest a fairly continuous outcropping of the Schoharie grit at the base of the Onondaga although it may be absent west of Callanan Corner and in places north of Clarksville. Darton ('94, p. 438) states that to the north and west of Clarksville there are a few exposures of the base of the Onondaga limestone, in which the grit is seen to be absent.

While thus the Schoharie grit varies in the capital district from nothing to eight feet and also at Schoharie reaches not more than five or six feet according to Grabau ('06, p. 180), some 150 to 200 feet of strata at Becraft mountain have been referred to the Schoharie grit, although in rock aspect they are more similar to the Esopus grit, since some of the characteristic Schoharie fossils have been found in them.

The fauna is the most remarkable feature of this formation. Thin as the formation is, it usually abounds with fossils. The whole fauna has been listed by Grabau (*op. cit.* p. 325). He enumerates 123 species, namely, bryozoans, 2; brachiopods, 33; pelecypods, 14; gastropods, 12; pteropods, 2; cephalopods, 44; trilobites, 16. Grabau lists no corals but the fauna of the Schoharie grit in Albany county is largely composed of corals and cephalopods. Prosser and Rowe (*sp. cit.* p. 352) cite Zaphrentis and Streptelasma *sp.* as abundant in the Clarksville section. 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 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* and *Conolichas hispidus*. 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 stone fences and of favorable outcrops does not discourage or stop the pursuit.

Rowe ('99, p. 352) gives the following list of fossils from the Clarksville section:

Corals:	Zaphrentis *sp*	(a)
	Streptelasma *sp*	(c)
Brachiopods:	Strophonella ampla (*Hall*)	(r)
	Atrypa reticularis (*Linn.*) *Dal*	(aa)
	Pentamerella arata (*Conrad*)	(a)
	Meristella (Pentagonia) unisulcata (*Conrad*)	(rr)
	M. nasuta (*Conrad*)	(aa)
	Centronella glans-fagea *Hall*	(r)
	Orthis (Rhipidomella) peloris *Hall* (?)	(r)
	O. (R) alsus *Hall*	(r)
	O. (Schizophoria) propinqua *Hall* (?)	(rr)
	Spirifer raricostatus (*Conrad*)	(r)
	S. duodenaria *Hall*	(rr)
	S. fimbriatus (*Conrad*)	(rr)
	Orthotetes pandora (*Billings*)	(rr)
	Chonetes hemisphericus *Hall*	(r)
	Cyrtina hamiltonensis *Hall*	(rr)
	Stropheodonta perplana (*Conrad*)	(rr)
	S. inaequiradiata *Hall*	(rr)
	S. demissa (*Conrad*)	(r)
	Coelospira camilla *Hall*	(r)
	Amphigenia elongata (*Vanuxem*)	(rr)
Pelecypods:	Cypricardinia planulata (*Conrad*)	(r)
	Conocardium cuneus (*Conrad*)	(c)
Cephalopods:	Orthoceras zeus *Hall* (?)	(rr)
	Orthoceras *sp*	(c)
	Cyrtoceras *cf.* eugenium *Hall*	(rr)
Trilobites:	Phacops cristata *Hall*	(r)
	Dalmanites anchiops (*Green*)	(r)

13 **Onondaga limestone.** The other great cliff of the Helderbergs seen from the Albany plain above the lower one of the Manlius-Coeymans limestones is that of the Onondaga limestone. It forms a gray band, more interrupted than the lower, fairly half way up to the top of the Helderbergs. The conspicuous summer home of Daniel O'Connell, which can be seen above the new Indian Ladder road from the Albany plain, stands upon the platform formed by the Onondaga limestone at the edge of the cliff.

The Onondaga limestone which has a very wide distribution, far surpassing that of the other Helderberg formations (see below) was at first known as Onondaga (Hall), Corniferous (Eaton) and Seneca (Vanuxem) limestone in western New York, the names being applied to different divisions of the formation by the geologists of the first survey. The name "Onondaga limestone" proposed by Hall in 1839 includes now also the cherty division (Corniferous) and the purer upper limestone (Seneca) (figures 55, 75, 77).

The Onondaga limestone is a moderately pure, massively bedded, light blue-gray limestone containing lenses of chert in parallel layers, especially in the lower part of the formation. The distribution of the chert is very irregular and it is abundant in some localities and sparse in others. According to Prosser and Rowe ('99) the upper nine feet are entirely free of chert; below this are 15 feet in which chert is very abundant. In the lower part of the formation chert was encountered but in rather small quantities. In the town of New Scotland quarry, on both sides of the New Salem–Wolf hill state road, five courses of chert, each four to six inches thick are seen.

The Onondaga limestone is, according to Prosser and Rowe, 100 feet thick in the Countryman hill section and 85 feet in the Clarksville and Oniskethau creek section. About Cobleskill Prosser measured 95 feet.

This thick formation of pure limestone is quarried in many places, as at Cobleskill. It furnishes excellent road metal and is therefore quarried along the Wolf hill road, as mentioned before.

The rock is traversed everywhere by a very perfect system of intersecting joint fissures. These help to produce the cliff by the breaking away of rock along the vertical joints. Weathering out by solution in the relatively pure limestone into broad and deep fissures, they have produced in places an underground drainage, as about Thompsons lake and many small "sinks," that are depressions in which the drainage of a greater or lesser area disappears. Such phenomena of the underground drainage of limestone regions which are exhibited on a gigantic scale in Kentucky where the Mammoth cave is a part of the system, and in the Karst region of the Dalmatian Alps are known as "Karst phenomena." The caves and springs at the foot of the Indian Ladder are further instances of such Karst phenomena in the Lower Helderberg limestones. In the broad Onondaga terrace at the foot of Bennett, Copeland and Blodgett hill many such sinks are seen, especially near the base of the Marcellus-Hamilton hills, forming a conspicuous and characteristic feature of this formation, as stated by Darton ('94, p. 437).

Owing to the contrast in resistance to weathering between the compact Onondaga formation and the overlying Marcellus shale, the latter has been widely eroded away from the Onondaga limestone and the former forms now a continuous terrace along the Helderbergs above the cliff. This terrace is not very wide on the slope of Countryman hill where the O'Connell house stands on it, but becomes more than a mile wide south of Countryman hill and forms the broad stretch of good farming land, on which the village of Clarksville and the hamlet of Oniskethau stand. The map also shows distinctly how the roads follow this terrace, often running for miles on the bare rock, as for example the Clarksville-Oniskethau road and Oniskethau-Callanan Corner road at the foot of Copeland hill.

The best outcrops of the formation are those at the town quarry of New Salem and around Clarksville, especially in the gorge of the Oniskethau creek above the village and in Ingraham's quarry.

The fauna is characterized by the corals; not so much in species as in individuals. Much of the Onondaga limestone was undoubtedly formed by coral reefs. Such reef rock filled with corals is well shown at the boat landing of Thompsons lake and in the cliffs south of it. The State Museum contains a restoration of a portion of such a reef, built from large coral stocks obtained about LeRoy south of Rochester. These coral stocks show the size to which the corals grew. 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. Of these species are: corals, 5; bryozoans, 3; brachiopods, 27; pelecypods, 1; gastropods, 3; pteropods, 1; cephalopods, 7; trilobites, 10. While numerically the brachiopod species prevail, in individuals the corals are the most prominent element of the fauna. They are species of Favosites, Zaphrentis and Cyathophyllum. Among the brachiopods very large forms as *Strophеodonta 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.

Rowe ('99, p. 352) cites the following 16 forms from the Onondaga limestone of the Clarksville and Oniskethau creek section:

Corals:	Zaphrentis gigantea (*LeSueur*)	(rr)
	Z. corniculum (*LeSueur*)	(rr)
Bryozoans:	Fenestella biseriata *Hall*	(rr)
Brachiopods:	Meristella unisulcata (*Conrad*)	(r)
	Leptaena rhomboidalis (*Wilckens*)	(r)
	Atrypa reticularis (*Linné*) Dalman	(aa)
	A. spinosa *Hall*	(aa)
	Pentamerella arata (*Conrad*)	(c)
	Stropheodonta concava *Hall*	(r)
	S. textilis *Hall*	(rr)
	Spirifer duodenarius *Hall*	(a)
	S. macra *Hall* (?)	(rr)
Gastropods:	Platyceras dumosum *Conrad*	(c)
Cephalopods:	Cyrtoceras *sp.*	(rr)
Trilobites:	Dalmanites (Coronura) aspectans *Conrad*	(rr)
	Phacops cristata var. pipa *Hall*	(rr)

It appears from this list that the fauna of the Onondaga limestone in the capital district is not very rich. It will be shown, however, in Miss Goldring's guide to the Indian Ladder region, that close by in the Thompsons lake region a very rich fauna, especially also of genera of corals, stocks of Edriophyllum, etc., not mentioned either by Grabau or Prosser and Rowe, flourished.

14 Marcellus beds. The Onondaga limestone in the capital district is abruptly followed by dark shales—the Marcellus shales. In western New York the boundary is less marked owing to the presence of calcareous beds in the Marcellus. Chadwick (abstract for Geological Society meeting, '27) has found a very distinct erosion surface at the top of the Onondaga limestone, in the Catskill region, which, in his view "appears to dispose finally of the theory of 'contemporaneous overlap'," by the Marcellus black shale.

The type locality of the Marcellus beds (Hall, '39) is at Marcellus in Onondaga county. It is typically represented there as black shale, (Marcellus black shale,) with some calcareous intercalations and an upper division of gray shale (Cardiff shale of Clarke and Luther, '04).

At Schoharie Grabau ('06, p. 206) found about 180 feet of black fissile shales which split up into thin leaves and become more or less rusty on exposure. They are there poorly exposed since they have weathered so much that they form the gentler slopes in the hillsides above the Onondaga terrace and are mostly covered by soil. The same is true in the capital district, where the Marcellus shales form good pasture land on the lower slopes of the hills above the Onondaga, but lack outcrops.

As a result, neither Darton nor Prosser and Rowe were able to establish the boundary with the overlying Hamilton flags and shales and the thickness of the formation. Darton did not use the term "Marcellus" and distinguished 600 feet of "Hamilton black shales" that are overlain by the Hamilton flags and shales. He describes this formation as consisting "in greater part of shales, hard above and softer below with occasional thin, intercalated beds of flaggy sandstones among its upper members. Its basal beds are in some places so dark that they have been mistaken for coal, and many attempts have been made to work them for coal." Also Prosser and Rowe ('99, p. 335) in the Countryman hill section did not undertake the separation of the Marcellus and Hamilton in the 425 feet of rock that they found above the Onondaga limestone because they found the slope covered with soil. They mention, however, the gradual change in the lithologic characters from the Marcellus to the Hamilton in the Helderberg region and the fact that the Marcellus shales have a greater thickness than in central and western New York. Prosser ('98, p. 56) has measured 170 feet up the hill to the south of the New Salem road.

In the Clarksville and Oniskethau section they ascribe 300 feet to the Marcellus. They measured their section in a gully in the rear of the house of Elias Mathias (Clarksville). They found there the lower 100 feet covered, after that about 80 feet of black argillaceous shales, then 30 feet of shales of this character interspersed frequently with layers of slightly calcareous dark sandstone above which are 85 feet of dark, argillaceous shales. Above this the shales suddenly become more arenaceous in character.

Miss Goldring, who in mapping the Berne sheet, had to establish the exact boundary, and the writer made a thorough search for the Marcellus-Hamilton boundary in the capital district. In a general way it was found that the four larger hills of the region, namely Countryman hill, Bennett hill, Copeland hill and Blodgett hill, show a more or less distinct shoulder, usually about half way up, which is due to a marked stiffening of the beds by the prevalence of sandy flags. We decided to draw the line in that neighborhood, just below

the shoulder, especially since above that line undoubted Hamilton fossils appeared. We were fortunate enough to find a continuous section through the Marcellus from the Onondaga contact to the Hamilton contact on the upper Oniskethau creek, north of Wolf hill, crossing the boundary of the Albany and Berne quadrangles.

The Marcellus consists in that section of 170 feet (aneroid measurement) of black fissile carbonaceous shales which end abruptly with an earthy, pyritiferous soft black shale against the heavy sandstone beds, forming a waterfall and alternating with gray blocky shale of the Hamilton. There are but few sandy beds in the Marcellus in the lower five feet and the upper half, the rest is all black fissile shale. In one horizon of the upper part, about 35 to 40 feet below the top, a course of large calcareous concretions, two to four feet in diameter and one to two feet thick appears in the beds. The lowest somewhat sandy beds were quite fossiliferous, *Liorhynchus limitaris* (Vanuxem) and *L. mysia* Hall being noted especially.

Another good section from the Marcellus into the Hamilton has been opened along the state road from Keefer Corner to Indian Fields. It is here seen that while the fissile black shale, typical of the Marcellus, ends rather abruptly, dark argillaceous shales, with an increasing amount of intercalated sandy flags, continue still for some distance, these beds lithologically partaking somewhat of a transitional character. It is these beds which Darton united with his Hamilton black shales. The fauna in these beds, though very meager, is distinctly Hamilton in character. These lower dark Hamilton shales with intercalated thin sandstone beds are also well exposed in road metal pits along the road leading east from Keefer Corner. Here also the shoulder formed by the lowest Hamilton is well displayed. Going up the abandoned road that passes Koong hill on the east, one soon reaches the typical Hamilton with large specimens of *Spirifer granulosus* and can well observe the gradual change from fissile dark shale to gray shale, that breaks more blocky on weathering.

The Marcellus itself is well exposed this side of Keefer Corner along the Albany road, down to the Onondaga flat. The thickness amounts there to about 200 feet.

A third good exposure of the Marcellus-Hamilton boundary has been produced by the new cut-off in the Clarksville-Dormansville road, one and a half miles south of Clarksville.

Restricting the Marcellus shale to 170 to 200 feet in the capital district, we draw the line where Prosser and Rowe found the inter-

spersion of sandstone layers to begin, namely at 180 feet from the base and exclude the upper 120 feet of their Marcellus.

A good Marcellus fauna was found along the road one-fourth of a mile northeast from Lawson lake, with abundant *Styliolina fissurella,* Hall, (minute needlelike pteropod shells) and small lamellibranchs (*Lunulicardium marcellense* Vanuxem).

Rowe ('99, p. 353) cites from the Marcellus of the capital district (collected from gorge at foot of Bennett hill):

Chonetes mucronatus *Hall* (a)
Glyptocardia speciosa *Hall* (a)
Coleolus tenuicinctus *Hall* (r)
Goniatites (Parodiceras) discoideus *Conrad* (c)

The finding of the *Parodiceras discoideus,* a goniatite (coiled cephalopod) in the Clarksville region is of some interest so far as it indicates the continuation of the fauna of the Agoniatite limestone into the capital district. In the Schoharie region and west of it the Marcellus shale contains calcareous intercalations (Cherry Valley and Agoniatites limestones) that carry a striking fauna of large cephalopods not found anywhere else. A remarkable slab with that fauna from the neighborhood of Syracuse is on exhibition in the State Museum. The writer once, in connection with Doctor Clarke's work on the Marcellus shale ('03), tried to trace these limestones eastward but found them to disappear. This goniatite would suggest a continuation of at least some elements of the fauna in this direction, unless the occurrence is due to postmortem drifting of the shells, cephalopod shells, owing to their gas-filled air-chambers, being liable to be carried far out of their life zones.

15 Hamilton beds. The Hamilton beds are the highest formation in the Helderbergs of the capital district and form there the tops of the highest hills (figures 45, 46, 52), as also of the "Helderberg mountain" proper, in the southwest corner of the quadrangle. Only a part of the thick Hamilton is preserved there, the remainder having been eroded away, and there is no doubt that also the thick upper Devonian formations, the Sherburne flags, Oneonta shales, and the great mass of the Catskill beds, once spread thousands of feet thick over the Helderberg region and far beyond, and that all have been carried off as waste by the rivers.

The Hamilton beds (name proposed in 1840 by Vanuxem) comprise in the Albany quadrangle a great series of thin-bedded sandstones with intercalated beds of dark often bluish to greenish shales.

As we have already seen, the lowest 200 feet have on the whole darker colored shales and less sandstone than the remainder.

Prosser ('99, p. 243) has calculated the total thickness of the Hamilton in the town of Berne directly adjoining the Albany quadrangle on the west as between 1415 and 1720 feet. Darton ('94, p. 434) estimated the Hamilton flags and shales at 700 feet and the Hamilton black shales at 600 feet; subtracting 170 feet for the Marcellus from these 1300 feet leaves 1130 feet for the Hamilton. Of this great thickness of the Hamilton formation, reaching possibly 1700 feet, probably not much more than 600 feet are present in the highest ridge on the Albany quadrangle, the Helderberg mountain, which continues northward into Wolf hill and Countryman hill. Prosser found in the Clarksville section to the top of Wolf hill 300 feet of Marcellus and 490 feet of Hamilton shales. Assigning about 170 feet to the Marcellus, there would be about 620 feet of Hamilton in that section, as we define it.

The lowest 100 to 130 feet of these are still dark to black argillaceous shales with intercalations of beds of dark slightly calcareous sandstone. The shales are, however, sandy enough to break blocky, a feature which becomes more distinct as one goes upward in the section. The dark to blackish color persists for 200 feet more, the shales being, however, more distinctly arenaceous and weathering to a brownish color. At the same time the sandstone intercalations increase steadily and the fossils become more abundant. The latter appear in large numbers about 300 feet above the base, where the shales have become greenish and bluish. The sandstones are not evenly distributed through the formation and vary greatly in thickness. Much of the sandstone is dark gray, moderately fine grained and splits readily along the bedding planes into slabs one-half inch to three inches thick. These sandstones have given rise to the "flagstone" industry that flourished for many years and to some extent still persists, in the region west of Albany county and south to Kingston. The thickness of the beds of flagstones is exceedingly variable. They often reach 10 to 15 feet. The sandstones and the shale intercalations are in the upper part divided in about equal proportions, and the heavy sandstone courses give rise to conspicuous outcrops and to a series of minor terraces.

As Darton has pointed out ('94, p. 434), the sandstones and shales change into each other horizontally in a very irregular manner. This fact as well as the cross-bedding observed at times, and the prevalence of brachiopods and lamellibranchs in the fauna (see below)

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 more arenaceous, until along the Hudson river arenaceous shales and sandstones prevail. This change in lithologic character has given rise to changes of name (Cornwall shale, Hartnagel; Mount Marion, Grabau; Ashokan shale, Chadwick).

The fauna of the Hamilton beds is exceedingly rich and it may with more detailed study permit the division of the formation into life zones. 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: worm-trails, 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 their striking species of Aviculopecten, Liopteria, 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.

Of fossil localities on the Albany quadrangle may be noted the top of Copeland hill with *Spirifer granulosus* in slightly calcareous layers; a ravine on the eastern slope of Koong hill, where *Spirifer granulosus, S. mucronatus, Chonetes coronatus, Ambocoelia umbonata,* species of Grammysia, etc., occur. On the Keefer Corner-Indian Fields road, one-quarter mile from the southern edge of the quadrangle, a ledge on the side of the road held numerous fossils in the lowest layers, among them species of Pleurotomaria and Palaeoneilo. The top of the Helderberg mountain, where the road crosses it, held calcareous layers in the heavy sandstone beds, full of fossils, especially brachiopods as *Spirifer mucronatus, Chonetes coronatus, Orthothetes chemungensis* var. *arctostriatus,* etc. The road leading on the west side of the Helderberg mountain from Cass hill to Dormansville passes for a good part of its length over Hamilton ledges where Hamilton fossils are visible, sometimes finely preserved. Especially at a waterfall in about the middle of the road, three miles north of Dormansville, fossils were abundant, among them a

Conularia, *Lingula punctata, Tropidoleptus carinatus, Chonetes coronatus, Modiomorpha mytiloides.* Rowe ('99, p. 353–54) collected in gullies of Wolf hill the following forms:

1 Found about 200 feet above base of Hamilton (that is about 300 feet above):

Brachiopods:	Lingula punctata *Hall* (?)	(rr)
	Chonetes deflecta *Hall*	(c)
	Newberria claypolii (*Hall*) ?	(rr)
	Pentamerella pavilionensis (*Hall*) ?	(rr)
	Camarotoechia congregata (*Conrad*)	(rr)

2 Found over 400 feet (that is about 500 feet) above base of Hamilton:

Brachiopods:	Spirifer acuminatus (*Conrad*)	(a)
	S. mucronatus (*Conrad*)	(c)
	Tropidoleptus carinatus (*Conrad*)	(rr)
	Athyris spiriferoides (*Eaton*)	(rr)
	Chonetes deflecta *Hall*	(c)
	Strophalosia *cf.* truncata (*Hall*)	(r)
Pelecypods:	Pterinea flabella (*Conrad*)	(r)
	Nyassa arguta *Hall*	(aa)
	Leptodesma rogersi *Hall*	(rr)
	Actinopteria subdecussata *Hall*	(rr)
	Liopteria dekayi *Hall*	(rr)
	L. bigsbyi *Hall*	(rr)
	Palaeoneilo maxima (*Conrad*)	(rr)
	P. constricta (*Conrad*)	(r)
	Modiomorpha concentrica (*Conrad*)	(rr)
Pteropods:	Tentaculites bellulus *Hall* (?)	(rr)

C Paleozoic Rocks of the Eastern Trough

The Paleozoic rocks that have been distinguished in the eastern trough are in descending order:

Devonian	Rensselaer grit
Middle Ordovician	Snake Hill shale
	Tackawasik limestone and shale
	Rysedorph Hill conglomerate
Lower Ordovician	Normanskill shale
	Bald Mountain limestone
	Deep Kill shale
	Schaghticoke shale

Lower Cambrian (Taconian)	Schodack shale and limestone
	Troy shales and limestones
	Diamond rock quartzite
	Bomoseen grit
	Nassau beds

The Lower Cambrian rocks presumably rest, as everywhere else, on the Precambrian foundation of the known crust, probably gneisses, schists and injected plutonic rocks, as granite, syenite etc. They have nowhere yet been seen at the base of the eastern trough; but since we know them for the western trough, from the southern spurs of the Adirondacks near Saratoga, it is legitimate to assume that like rocks underlie the eastern trough.

C[1] Lower Cambrian rocks (Taconian). The Lower Cambrian rocks of the capital district are a section of a belt of Lower Cambrian rocks that extends from Canada through eastern New York, New Jersey, to Pennsylvania and beyond. They are a great mass of slates, quartzites and brecciated limestones that was first termed the Georgia group by Hitchcock ('61) from Georgia, Vermont. In 1891 Walcott proposed the term "Georgian group" for the Lower Cambrian. More recently, on finding that term preoccupied, the term "Waucoban" was proposed by the same author. Still the Lower Cambrian is currently known as the Georgian beds.

There is still another name, however, with a distinct right to adoption. That is the name "Taconian." Emmons in 1842 proposed the term "Taconic system," from the Taconic mountains in eastern New York, for the rocks older than the Potsdam that he was convinced he had discovered in the slate belt of eastern New York. The acrimonious discussion that followed ended with the complete suppression of Emmons' term for the Cambrian of America. Lapworth ('91) has pointed out that this term has the right of priority for the Lower Cambrian and Schuchert ('18) has independently arrived at the same conclusion and now uses the term "Taconian" for the Lower Cambrian ('19, '24). Since the Taconic mountains, just east of the capital district, as well as the capital district itself, were the chief fields of Emmons' studies, it seems quite appropriate that the term should be used here.

The character of the Taconian rocks of the capital district has been very carefully described by Dale ('04) both as to macroscopic and microscopic characters. The reader is referred to this work, as well as to his paper on the New York-Vermont Slate Belt ('93) for details of the composition of the rocks.

The Lower Cambrian formations form a belt of rocks directly east of the great overthrust fault, being part of "Logans fault" (see below). They begin near the north edge as a narrow strip between the Snake hill beds and the Normanskill shale. The belt widens and unites with another belt coming from the east, on the north side of the Rensselaer grit plateau about Raymertown. At the southern edge of the capital district it has attained a width of 11 miles. It contains two areas of Ordovician rocks; one of these is about nine square miles, including Mount Rafinesque (locally known as Bald mountain) and Rice mountain, two conspicuous hills that rise about 1000 feet above the plain (Mount Rafinesque 1107 feet high, and Rice Mountain 925 feet high). Another smaller area, that covers about two square miles is situated in the town of North Greenbush, west and south of Aries lake (locally Snyder's lake). The structure of these two areas is quite complex and will be described in the chapter on the tectonics of the region. There is also resting on the Lower Cambrian a small outlier of half a square mile of the Upper Devonian Rensselaer grit south of North Nassau, that is a residual patch left by the erosion of the Rensselaer grit plateau. And another larger separated area just projects with its northern point into the capital district at East Nassau.

By far the most prevailing rock of the whole belt is a dark greenish-gray siliceous shale or slate. It is, so to say, the groundmass in which all the rocks, quartzites, red and purple shales, limestones and sandstones are distributed (figure 6).

The folded structure of these rocks, combined with their unequal hardness, has through the unequal operation of erosion upon these different materials, produced a very irregular topography, with many rock hills running in the general direction of the prevailing strike (N.N.E.). As has been already mentioned in the chapter on topography, these rock hills are accompanied by numerous glacial hills, usually of smoother outline, and often rock hills and glacial hills are combined.

As Dale has pointed out ('04, p. 14) there are certain rocks of the Lower Cambrian that have marked characteristics peculiar to the Lower Cambrian in the capital district. The most important of these are a metamorphic olive grit, usually weathered a light brick red, a calcareous sandstone and an associated limestone breccia. The latter "may be taken as an almost infallible indication of Cambrian age." There is further a limestone conglomerate of peculiar character, and several kinds of quartzose beds and quartzites, besides the red and purple shales.

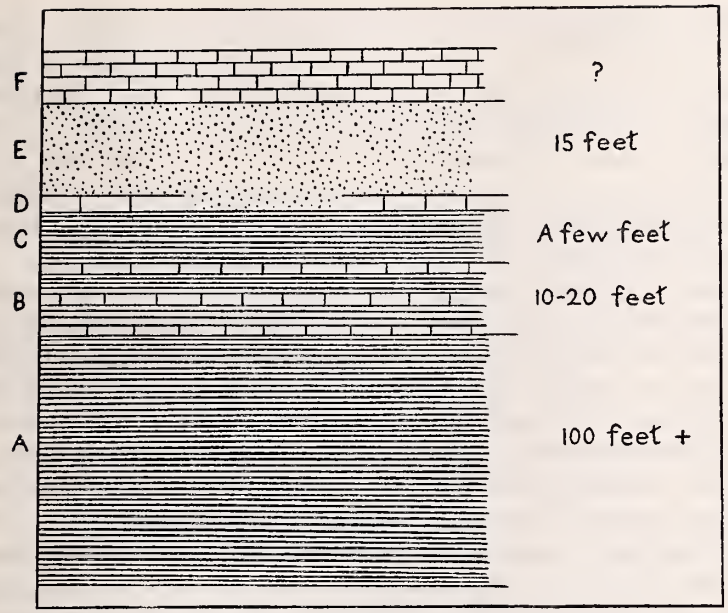


Figure 6 Columnar section of the Lower Cambrian series exposed at Troy, worked out by A. F. Foerste (see Dale. '94, p. 26). *A*, red and green shale, in places with small quartzite beds; *B*, light blue dolomitic limestone intercalated as fine layers and sometimes forming "brecciated pebbles" in the shale; *C*, shale with or without limestone beds; *D* and *E*, quartz sandstone more or less calcareous, sometimes replaced by sandy shale; *F*, light blue dolomitic limestone

The greenish-gray, red and purple Cambrian shales, as well as those of the Ordovician, have farther north been changed by the regional metamorphism that has affected the rocks east and northeast of the capital district, into the well-known roofing slates that have created an important industry in Washington county and the adjoining parts of Vermont. In our district the rocks were close to the western limit of the folded region and therefore subjected to much less intense compression and very little metamorphism. While they are distinctly harder and more resistant than the shales of the western trough, and in distinction to them possess a well-defined cleavage, thereby splitting slaty, the latter is nowhere of such a character as to produce a roofing slate. Very often several cleavage systems or partings divide the rock into sticklike fragments, a fact which leads to a quicker decay of the rock into a clayey subsoil and soil and contributes considerably to the improvement of the land. (See chapter on economic geology.)

The greenish-gray shale is, according to Dale ('04, p. 16), under the microscope seen to be "a very fine-grained aggregate of muscovite and chlorite scales, angular quartz grains, rarely plagioclase grains, with brownish dots which are probably limonite." The muscovite (white or potash mica) as the matrix of the shale is of great importance for the soil, since it furnishes potash. The green color of the shale is due to the chlorite. When there is a strong admixture of chlorite, the shale becomes very green.

The reddish shales derive their color from the hematite or red iron ore, that is a constituent in varying amounts, thereby producing different intensities of color. The color is especially deep red in the belt west of Burden lake, exposed both along the road and on top of the ridge. It is purplish in many other places, as notably in the gorge of the Poestenkill, above Troy. The purple color is due to a mixture of limonite and chlorite. Finally, there are also black and dark gray shales, which derive their color from the carbon.

In the Lower Cambrian of the capital district there is seen none, or very little of the deep bluish black shale such as the graptolite shales of the Ordovician are. Such black shale as has been found, has never furnished any trace of graptolites or any other fossils.

The "olive grit," which weathers brick red, is an important rock in the slate belt of Washington county, where it covers large areas, and apparently underlies the roofing slate (Dale, '99, p. 180). It becomes less frequent farther south, where it is still found near the western edge of the Cambrian belt, as far south as North Greenbush. It is a typical graywacke, and is described by Dale ('99, p. 179) 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.

As outcrops in our district are cited (Dale, '04, p. 15):

One-half mile east of Lake Ida, in Troy, and also north of its eastern end; one-half mile southwest of Wynantskill; at the mill dam in Raymertown; at Brunswick Center; in Lansingburg, at Oakwood Cemetery, on the north side of the outlet of the pond, where it contains organic impressions and is in contact with the Ordovician shale; and at a point a mile south of Grant Hollow.

The southernmost outcrop seen by the writer is along Mill creek, a mile east of Teller Hill. Also this is close to the Cambrian-Ordovician boundary.

The most characteristic rock of the Cambrian of the region is the calcareous sandstone with associated limestone breccia. As described by Dale ('04, p. 15):

This rock usually consists of roundish quartz grains held together by a cement of crystalline and granular calcite or of dolomite. On the weathered surface these grains stand out in relief and are slightly opalescent . . . . This sandstone very often includes beds of bluish fossiliferous limestone from one-half to one inch thick, which are generally brecciated, probably because of their greater rigidity under lateral compression than the intervening sandstone.

The most picturesque outcrop of this brecciated limestone is a vertical wall of the rock, two feet thick, standing up on the left of the road leading from the Albany-West Sand Lake highway to Aries lake, one-quarter of a mile from the main road. Figures 56 and 57 are pictures of this most interesting place. Dale ('96, p. 569; '04, p. 15) has given a sketch of a portion showing several small beds of limestone broken up and pushed across one another.

The calcareous sandstone is further described by Dale as "frequently associated with (either passing horizontally into or underlain at no great interval by) a quartzite in which the cement is either very slightly calcareous or sericitic. Both sandstone and quartzite are apt to be traversed by a network of veins and veinlets of quartz, which, owing to the rapid weathering of the $CaCO^3$ of the cement, project on its surface. This sandstone crops out in Oakwood Cemetery in Lansingburg, and continues north-northeast for a mile to a hillock, known locally as 'Diamond Rock',[1] on account of its abundance of quartz crystals; these occur in association with such veins."

A very common constituent of the shale beds, especially the red shale which regularly alternates with it, are quartzose beds weathering rusty brown, from one-half to two inches thick. The cement of these beds is described by Dale as sometimes pure silicious, or partly silicious and partly calcareous or sericitic, and sometimes entirely dolomitic. We shall see that the red and green shales with alternat-

[1] The glimmering quartz crystals of Diamond Rock have given origin to a beautiful Indian legend, told by Sylvester. According to this legend, they represent the petrified tears of a Mohican mother who waited on this rock for 20 years for the return of her son, who had gone to Canada to recover from the Algonquins the bones of his brother, to secure rest for him in the other world. The legend states the Indian fulfilled his mission, but the mother's tears are on the rock to this day.

ing thin quartzite bands, form a definite member of the series. There are in these red and green shales also greenish coarse and fine quartzite beds, which owe their greenish color to an abundance of admixed chlorite or chlorite schist fragments. This latter quartzite is remarkable for the fact that it frequently bears the fossil *Oldhamia occidens*.

Dale ('04, p. 17) has fully set forth the difficulty, or rather the impossibility, of determining exactly the thickness of these beds, "because they consist so largely of closely folded and easily weathering shale and because there are so few deep cuts across them." Dale and his efficient assistant Prindle have, however, worked out a number of detailed sections, from which they were able to construe a stratigraphic series and arrive at an estimate of the thickness of the formation.

Dale ('99, p. 178) has estimated the thickness of the Lower Cambrian at two places, on Mount Hebron and east of North Granville, in the slate belt of Washington county, and found about 1400 feet; the measurements of Pumpelly, Wolff and Dale ('94, p. 190) in the Green mountains in Massachusetts have given 800 to 900 feet for the Lower Cambrian quartzite. Dale, adding to this the Lower Cambrian part of the overlying Stockbridge limestone in Vermont Valley, which measures 470 feet, arrives at 1270 to 1370 feet for the Lower Cambrian in that region. His table of the divisions in Rensselaer county, copied below gives a maximum thickness of 1225 feet. As we do not know the thickness of the basal member, as pointed out by Dale, the maximum of 1400 feet may be easily exceeded. "At any rate from 335 to 1400 feet of it are exposed." We have not made any efforts to secure new measurements in 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.

The following is the table published by Dale ('04, p. 29) showing the Lower Cambrian series as exposed in Rensselaer county. We have added in the first column the names proposed by us for the formations in 1914 (p. 69).

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

NAME OF 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.....	*a* 20–200
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 quartzite 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 five 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. Minimum, 286. *b* Oldhamia occurs in A, C or E, and quite possibly in all three. Maximum, 1225+.

A comparison of the two series of divisions, published by Dale for the slate belt of Washington county and Vermont and that for Rensselaer county, shows considerable differences, the most important of which are the much greater development of the Bomoseen grit in the north, and the absence of the "Black patch grit," Cambrian roofing slates and the "Ferruginous quartzite and sandstone" in the capital district. We have on the Schuylerville quadrangle ('14 p. 66) been able to distinguish only three units, the Schodack shales and limestones, Eddy Hill grit (the Black patch grit) and the Bomoseen grit, and mapped only the Schodack shales and limestones and the Bomoseen grit. In the capital district the following members can be distinguished in descending order:

16 Schodack shale and limestone. This is the Cambrian black shale of Dale and typically his division *I* to which we have added the neutral greenish shale *J*, that is usually associated with it. The formation is characterized by the thin-bedded limestones, and the beds of brecciation pebbles, as well as by carrying the Olenellus fauna in these pebbles and thin-bedded limestone. Its typical locality comprises the fine exposures two miles south of Schodack Landing, N. Y., in the cliffs above the tracks of the New York Central Railroad and the belt of these rocks in the town of Schodack, N. Y. The pebble beds are shown there to great advantage. It is these beds that were described as intra-formational conglomerate. They are also well exposed in the old quarry in Beman Park above Troy, where once a stone crusher was in operation and where S. F. Ford, a Troy jeweler, made his collections of Lower Cambrian fossils with incredible patience and perseverance, proving for the first time by comparison of these fossils with the Bohemian and Canadian material the actual pre-Potsdam age of the beds.

The often large rounded limestone pebbles which fill the rock are, as Foerste has shown (Dale, '96, p. 569) not beach pebbles, but brecciation pebbles, produced by the separation of thin limestone beds by successive plication and cleavage, as shown in the diagram. Still there are also true beach pebbles in the formation, as noted by Dale.

The Schodack shale and limestone has furnished nearly all the known faunas of the Lower Cambrian of the capital district, with the exception of the Oldhamias. Walcott, in his monumental Cambrian Brachiopoda ('12), has brought together lists of all fossil localities that have furnished material to the National Museum. These are by far the most complete lists, owing to Walcott's long specialization in Cambrian research. We are here citing these localities from the capital district for the benefit of local collectors. (*op. cit.*, p. 162, 188, 200, 212, 266, 277). Walcott's locality numbers are in parenthesis.

1 (*2b*) Lower Cambrian limestone just north of Beman Park, in the northeastern part of the city of Troy; Troy quadrangle (U. S. G. S.); Rensselaer county, N. Y. (H. E. Dickhaut, 1899)

Micromitra (Paterina) labradorica	Obollella crassa
Bicia gamma	Botsfordia caelata
B. Whiteavesi (type locality)	Billingsella salemensis

2 (*2d*) Arenaceous limestone in the knobs just east of Beman Park and southwest of Brunswick, near Troy etc. (H. F. Dickhaut, '99)
Obolella crassa

3 (*27*) Even-bedded and conglomerate limestones on the ridge in the eastern suburb of Troy etc. (Cooper Curtice, '83)

Obolella crassa
Bicia gamma
Botsfordia caelata
Acrothele nitida (type loc.)
Archaeocyathus rarus (*Ford*)
A. rensselaericus (*Ford*)
Scenella retusa (*Ford*)
Stenotheca rugosa (*Hall*)
Platyceras primaevum *Billings*
Hyolithellus micans *Billings*
Hyolithes americanus *Billings*
H. communis *Billings*
H. communis emmonsi *Ford*
H. impar *Ford*
H. *sp.*
Microdiscus lobatus (*Hall*)
M. speciosus *Ford*
Elliptocephala asaphoides *Emmons*
Olenoides fordi *Walcott*
Solenopleura nana *Ford*

4 (*44a*) Limestone on Valatie kill. near the line between Nassau and Schodack townships, near line between Troy and Kinderhook quadrangles etc. (C. D. Walcott, '87)
Acrotreta sagittalis taconica
Microdiscus connexus Walcott

5 (*72*) (Same horizon as *72a*) Limestone 5 miles (8 km) east of Albany, 1 mile southwest of Wynantskill, (C. D. Walcott and T. N. Dale, '93)
Obolus prindlei

6 (*338K*) Limestone two to five miles southwest of Wynantskill, Rensselaer county (L. M. Prindle, '93)
Obolus prindlei

7 (*338n*) Western belt of conglomeratic limestone, Rensselaer county, N. Y.
Yorkia washingtonensis
Microdiscus lobatus (*Hall*)

8 (*338g*) (Hall, '47, p. 290) Calcareous beds, two miles northeast of Troy
Obolella crassa

9 (*367*) Conglomerate and limestone, Troy
Lingulella schucherti (type locality)
Microdiscus schucherti
Protypus hitchcocki (Whitfield)
These species may be from different localities.

10 (*367i*) (Hall, '47, p. 290). Shales near Troy
Botsfordia caelata (type locality)

These localities are marked on Dale's map ('04) by a red circle and they have been identified on our map by stars.

The fauna consists almost entirely of small and primitive forms, but it is to be emphasized in this connection that, barring some scattered and mostly doubtful Precambrian fossils, this is the oldest fauna as yet known. It consists for the most part of small primitive brachiopods, of the genera Obolus, Lingulella and Acrotreta, some very rare primitive sponges (Archaeocyathus), and corallike forms; of primitive gastropods of simple cap-shape (Scenella, Stenotheca, Platyceras), supposed pteropods (Hyolithes) and small and primitive trilobites as Microdiscus (now Goniodiscus), Olenoides, Solenopleura.

The most common species are *Obolella crassa* and *Botsfordia caelata,* (formerly Obolella), whose interior structure was made out by Ford from Troy material; *Hyolithellus micans, Goniodiscus lobatus* and parts of the somewhat larger trilobite *Elliptocephala asaphoides.* These forms may yet be obtained in Beman Park with sufficient assiduity, as well as in localities northeast of Troy. Some of the old Troy localities are not any more accessible; on the other hand, some good new outcrops have appeared, as the ones on the north and east sides of the campus of the Rensselaer Polytechnic Institute, where for instance, the brachiopods (Obolella) can be collected back of the dining hall.

In Vermont and Pennsylvania the Lower Cambrian has afforded stately trilobites, as *Olenellus thompsoni,* similar to forms observed in other parts of the world in Lower Cambrian beds. From these the division is internationally known as the Olenellus beds.

17 **Troy shales and limestones.** The Troy shale is closely associated with the Schodack beds, which it underlies. It consists of 25 to 100 feet of colored shales with small beds of calcareous quartzite. The shale has furnished *Oldhamia occidens* Walcott, a calcareous alga; a calcareous sandstone, in the upper part, Hyolithes and Hyolithellus. These beds are well exposed at Troy, at the dam in the Poestenkill below Mount Ida lake, and in the gorge of the Poestenkill, there with Oldhamia. Below the Poestenkill dam the shale is overlying the overthrust fault. The belt continues east of Rensselaer, where Hyolithellus was found halfway between Defreestville and Best (coll. C. F. Kilfoyle).

18 **Diamond Rock quartzite** (figure 58). This name was proposed by Ruedemann ('14, p. 70) for division *G* of Dale's Rensselaer county series. It is 10 to 40 feet thick, composed of granular quartzite and associated calcareous sandstone and well exposed in

Oakwood cemetery and the "Diamond Rock" in Lansingburg (North Troy), from which it takes its name. It has not afforded any fossils to our knowledge.

19 **Bomoseen grit.** This name was proposed by Ruedemann ('14, p. 69) for Dale's "olive grit." This formation of olive-colored, brick-red-weathering grit, which is a prominent member of the Lower Cambrian series in southern Vermont and Washington county of New York, and there reaches a thickness of 200 feet, is but little exposed in the capital district, and always, in the western portion of the belt, in association with the Troy and Schodack beds.

The formation seems to be quite barren of fossils. We have not seen any in the rock and the only record of a fossil we can find is that of *Obolella crassa* in Walcott ('12, p. 188).

27a Reddish sandstone about one mile (1.6 km.) east of Lansingburg, north of Troy, Cohoes quadrangle (U. S. G. S.), Rensselaer County, N. Y. (Curtice, '83).

20 **Nassau beds** (figure 59). This name was proposed by Ruedemann ('14, p. 70) for divisions *A* to *E* of Dale's series in Rensselaer county. In the capital district the Bomoseen grit is underlain by the lowest division, the Nassau beds, which consist of a series of reddish and greenish shales, alternating with small beds of quartzite, mostly one to two inches thick. There are three groups of these alternating reddish and greenish shales and quartzite, the uppermost of which is more than 500 feet thick in places. These three groups are separated by two massive beds of greenish quartzite that reach 40 to 50 feet in thickness. The intercalated small quartzite beds of probably all three sections contain *Oldhamia occidens*. The entire group is 150 to 800 feet thick.

With the exception of two localities of Oldhamia in the Troy beds (one in the gorge of the Poestenkill, about two miles east of Troy, and the other in the Moordener kill, one and one-half miles above Schodack Depot), the others are in the Nassau beds. Dale has entered these occurrences on his map ('04), one on the upper reaches of the Valatie kill, a mile south of Burden lake, another one and one-half miles farther down the kill at a sawmill dam, and a third at the left of the Albany-Pittsfield state road, a mile east of Nassau village. We found a fourth locality in the Nassau beds, also in small quartzite beds, on the slope east of the road halfway between Nassau village and Nassau pond. This locality showed fairly good collecting and furnished some specimens that added materially to our knowledge of the problematic fossil by exhibiting

the bases of the tufts of filaments. The writer has published a separate paper on this occurrence (Ruedemann, '29) and referred the fossils to the calcareous algae. Unfortunately the hillside has been taken up for cottage building and the locality may be soon destroyed.

Areal distribution of Lower Cambrian formations. Dale had neither attempted to map his divisions of the Lower Cambrian separately nor suggested an areal arrangement of the same. He gave, however, the principal outcrops of the characteristic rocks of the divisions, namely "sandstone and limestone breccia," "typical red and green shale with small quartzite beds," and "olive grit" by symbols. We have also found it impracticable to separate the four higher divisions, the Schodack, Troy, Diamond Rock and Bomoseen beds, because they are too much involved with each other by folding and the great majority of the outcrops exhibit only the greenish gray shales that are common to the Schodack and Troy beds. The four higher groups form distinctly the western division of the Lower Cambrian beds, while the Nassau beds form the eastern division. We have therefore mapped these two groups separately. The Nassau beds are readily recognized by the frequent bands of alternating red shale and small quartzite beds.

In general, it is quite obvious that the Lower Cambrian formations are arranged in ascending order from east to west, the lowest division, the Nassau beds, being farthest east. These are followed by outcrops of Bomoseen grit in the northern part of the capital district, as about Raymertown, south of Haynersville and as far south as Wynantskill. At the other hand, the Bomoseen grit is again exposed east of Rice mountain, and especially frequently and typically along the west edge of the Cambrian belt in the narrow strip west of Mount Rafinesque and Rice mountain from Speigletown northeast to Melrose, and also east of Troy along the Poestenkill, above the Troy beds. We also found the Bomoseen grit well exposed a mile south of Dale's localities, in abandoned quarries south of the Wynantskill, between South Troy and Albia, and less than half a mile from the overthrust line, and still much farther south, east of Grand View hill (Greenbush) on the upper Mill creek. It is thus apparent that the readily recognizable Bomoseen grit appears in at least four (possibly five) different belts, and in three of them far away from its normal place, next to the Nassau beds. These Bomoseen grit belts indicate the repeated alternation or intermingling of the Lower Cambrian in the western belt of the Cambrian area due to folding and overthrusting.

The middle and upper Cambrian rocks are lacking in the eastern trough, presumably by nondeposition.

C ² Ordovician rocks of the eastern trough. *Hudson River shale.* Mather ('40) in the First District Report of the New York Survey, designated the great mass of shale in the Hudson valley the "Hudson River shale," and considered it to be younger than the Utica. This name and this correlation were maintained, until it was found that the Hudson River shale contains a great variety of formations of different ages, practically all older than Utica. The name has no more stratigraphic meaning, but it is still used by some for the entire terrane of shales in the Hudson River valley, especially when the age of the formation in question has not been established.

21 Schaghticoke shale. The name "Schaghticoke shale" was proposed by Ruedemann ('03) for a formation that is typically exposed in the bed and the banks of the Hoosic river at Schaghticoke, Rensselaer county, N. Y. It is characterized by the graptolites *Dictyonema flabelliforme* var. *acadicum* Matthew, and *Staurograptus dichotomus,* Emmons var. *apertus* Rued., which have been described with their growth-stages, from material obtained at Schaghticoke, in Memoir 7 of the New York State Museum. Besides these two graptolites there were also found *Clonograptus* cf. *milesi* Hall, a form from northern Vermont described by Hall, large spicules of the sponge Protospongia and the minute primitive brachiopod *Acrotreta bisecta* Matthew, and *A.* cf. *belti* (Davidson) Matthew; species known from the Dictyonema beds of Cape Breton, N. S. and Navy island, St John, N. S., respectively.

The rock at Schaghticoke has a most characteristic appearance. It is composed of very fine bedded, black and dull greenish to olive siliceous and argillaceous slates with intercalations of thin gray to white limestone beds (figures 60 and 64). The latter, consisting of hard gray, very fine grained limestone, are but six inches thick.

The Dictyonema flabelliforme zone or Dictyonema-bed is known in America from the lower St Lawrence region, Cape Breton island and the St John basin (N. S.). It is widely spread in Europe, in Great Britain, Scandinavia, Belgium, Bohemia, Esthonia and other countries, thus constituting one of the most important guide-horizons. It was generally considered as marking the top of the Cambrian, but was at the time of the publication of the writer's paper placed at the base of the Ordovician by European, especially Scandinavian, authors. In New York it rests on the Lower Cambrian from which it is separated by a great hiatus. It is followed by the lithologically identical Deep Kill shale, thus giving no conclusive evidence as to its stratigraphic position. While it is currently placed at the base of

the Ordovician in Europe and in this country, it is still to be remembered that in Great Britain, where the Cambrian was first recognized and defined, this zone is still held as being in the Cambrian. The current view in this country is perhaps best expressed in the chart (table 1) of Bassler's Bibliographic Index ('15, plate 1), where the Schaghticoke shale is placed at the base of the Canadian (Beekmantown) and directly overlying the Ozarkian. In eastern Europe, the Dictyonema shale introduces an extensive Ordovician transgression, and it seems to do the same in the northern part of the Appalachian geosyncline.

In mapping the Schuylerville quadrangle, an outcrop of the shale with its characteristic fauna was found in a cut of the Hudson Valley Railroad, about a mile north of Schuylerville, and thence traced across the Hudson river. The rock there consists for the most part of light greenish gray, glazed argillaceous shale that weathers to a light drab, with intercalations of coarser, more or less sandy mud shale and small streaks of black shale containing the graptolites. It there also contains three and one-half feet of coarse grit with black calcareous and argillaceous pebbles and large, scattered, rounded sand grains. One part of the formation is characterized by a number of calcareous sandstone beds one-eighth foot to one foot thick which weather into a characteristic chestnut brown sandy crust.

It is thus seen that the rock has changed considerably in lithic aspect north of its type locality. It has not been observed again in the capital district outside of Schaghticoke, on the Cohoes quadrangle. It is, however, undoubtedly present in many other places in the slate belt of the district, but owing to its small thickness, hidden in the great mass of Normanskill shales.

We find at Schaghticoke a minimum thickness of 30 feet, but the thickness is most probably considerably more.

The Dictyonemas and Staurograpti are not found mingled in the same beds at Schaghticoke and it is quite obvious that they belong to different horizons. We have therefore distinguished the two zones as:

b Zone of Staurograptus dichotomus.

a Zone of Dictyonema flabelliforme.

22 **Deep Kill shale.** In 1902 the writer described as the Deep Kill shale the graptolite shales of Beekmantown age which he had discovered along Deep kill in Rensselaer county, N. Y., exposed in a continuous series of rocks. This splendid outcrop begins a quarter of a mile above the hamlet of Grant Hollow in the creek bed, and extends to the dam of the reservoir of the Troy water-

works in the Deep Kill gorge. It has been very fully described in New York State Museum Bulletin 52 (also Volume 55, Report of the New York State Museum for 1901, p. 546-605, 1903), because it is the only complete section through the Beekmantown graptolite shale known as yet south of that at Point Levis, near Quebec.

The occurrence is an inlier in the Lower Cambrian rocks, which surround it on at least three sides and on the north and south overhang the ravine, in which the Deep Kill shales are exposed. The exposure of the rock at Schaghticoke is of the same type. It is also in the gorge of a river and surrounded by Lower Cambrian on higher levels. For the tectonic significance of this feature see chapter on structural geology.

It was estimated by the writer that the rocks of this section must have attained a total thickness of 200 to 300 feet. Dale ('04, p. 33), who has recorded some other outcrops of Beekmantown shale in the capital district, roughly estimated the thickness in these localities at 50 feet, but considers it a possibility that some of the green shales without banded quartzites and without fossils belong to this formation, and therefore, he holds his estimate to be a minimum.

The Deep Kill shale is most characteristically represented by finely banded quartzite beds that in places are very calcareous and are associated with greenish and grayish shales, resembling the lower Cambrian shales. Along the Deep kill we have the following succession of rocks (the letters refer to the figure):

b Limestones (more or less silicious) with shaly intercalations	4′ 0″
c Sandy shales and grits	2′ 8″
d Greenish siliceous shale and black graptolite shale	0′ 8″
Graptolite bed 1	
e Thin-bedded shales, grits and limestones	1′ 8″
f Greenish silicious shale and black graptolite shale	1′ 9″
Graptolite bed 2	
g Greenish silicious shale	2′ 9″
h Thin-bedded, dark gray limestone	14′ 3″
i Greenish silicious beds and black graptolite shale	2′
Graptolite bed 3	
j Greenish silicious beds and sandy shales (two thin seams of bluish black shale with graptolites)	5′ 5″
k Dark gray thin-bedded limestone layers	5′ 9″
l Greenish silicious beds and black graptolite shale	7′ 4″
Graptolite bed 4	
m Thin-bedded limestone with shale partings	16′
n Covered	8′ 9″
o (Quarry) Two to three-foot banks of hard, fine-grained thin-bedded layers (banded greenish gray and lighter). Many tenuous, graptolitiferous partings of black shale	52′
Graptolite bed 5	
q Covered (distance of 825′)	(100′+)

r Exposure at north side of dam, 135 feet long, mostly greenish gray quartzite, with some brecciated layers and some thin bands of gray limestone..... (70'+)
Graptolite bed 6 (3') and graptolite bed 7 (2')

Worth noting in this section is the appearance of a breccia and coarse-grained sandy shale in *c,* the uneven surface of the limestone layers in *h,* and the still more undulating or interlocking surfaces in *k,* and limestone breccia in *l.* Still more important is the distinct alternation of calcareous beds and silicious and graptolite shales, indicating at least five cycles of deposition between *b* and *o,* either due to oscillations in the depth of the trough, or to changes in currents.

The writer ('03) divided the Deep Kill graptolite shales as exposed at the type locality, into three main zones, namely,

a Tetragraptus zone, comprising graptolite beds 1 and 2

b Zone of Didymograptus bifidus and Phyllograptus anna. Graptolite beds 3, 4 and 5.

c Zone of Diplograptus dentatus and Cryptograptus antennarius, Graptolite beds 6 and 7.

Later ('19, p. 119), the writer found it advisable to divide each of the zones into two subzones, since the graptolite faunas of the two or more graptolite beds of each zone show differences in their faunal composition that correspond to those recognized in other regions, notably Great Britain and Sweden. Furthermore, another zone below the deepest Deep Kill zone exposed at the Deep kill is indicated by an occurrence, discovered by L. M. Prindle on the road between Defreestville and West Sand Lake (Dale, '04, p. 30). This contains forms of the Clonograptus zone of Quebec and Europe. We have accordingly distinguished the following subzones in ascending order. ('19, p. 121):

I. Zone of Clonograptus flexilis and Tetragraptus } Tetragraptus
II. Zone of Phyllograptus typus and Tetragr. quadri-brachiatus } beds

III. Zone of Didymograptus
  a Subzone of D. nitidus, D. patulus
  b Subzone of D. extensus, Goniogr. thureaui } Didymograptus beds

IV. Zone of Didymograptus bifidus
  a Subzone of Goniogr. geometricus, Phyllogr. anna
  b Subzone of Didymogr. similis, Phyllogr. typus

V. Zone of Diplograptus dentatus
  a Subzone of Climacogr. pungens, Didymogr. forcipiformis
  b Subzone of Phyllogr. angustifolius, Retiogr. tentaculatus
  c Subzone of Desmogr. and Trigonogr. ensiformis

The first zone, that of Clonograptus flexilis and Tetragraptus, is represented only by a faunule that was obtained by Prindle in a small road metal pit between Defreestville and West Sand Lake (marked on map as fossil locality) about four and one-half miles east of Albany. The outcrop consists of light greenish and darker silicious slate with interbedded yellowish weathering, thin (one inch thick) quartzite layers, the beds resembling very much those of Schaghticoke and the Deep Kill. The following fossils were found in this locality:

Dictyonema murrayi *Hall*..... c
Clonograptus cf. flexilis *Hall*..... cc
Tetragraptus quadribrachiatus *Hall*..... c
T. serra *Brongniart*..... c

We placed ('04, p. 426) this faunule as the Clonograptus zone at the base of the Deep Kill zones. It has since been found by Raymond, ('04, p. 523) to form the base of the Point Levis series in Quebec, that corresponds to our Deep Kill series.

The locality on the West Sand Lake road has on more recent visits not afforded any more fossils. It is, however, undoubted that the zone is present in other localities and will appear in new outcrops. The Deep Kill beds cross the eastern slate belt of the capital district, for the writer has found them at Rensselaer and again south of the capital district at Stuyvesant Landing, in the railroad cut just below the station and there with the characteristic alternation of dark green and black shales with whitish calcareous and silicious beds.

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 bed at Point Levis, but the zone is undoubtedly present in the Ordovician 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 ('03, '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.

The lowest zone at the Deep kill (graptolite bed 1) is the zone of Didymograptus nitidus and D. patulus.

The fauna of this zone at the Deep kill is the following:

Callograptus salteri *Hall*..... r
Bryograptus lapworthi *Rued*..... c

Dichograptus octobrachiatus *Hall*..... rr
Tetragraptus fruticosus *Hall*..... c
T. serra *Brongniart*..... r
Didymograptus nitidus *Hall*..... c
D. patulus *Hall*..... cc
Phyllograptus ilicifolius *Hall*..... r
P. angustifolius *Hall*..... rr

The next zone, that of Didymograptus extensus and Goniograptus thureaui (graptolite bed 2) contains:

Dictyonema furciferum *Rued*..... r
Dendrograptus flexuosus *Hall*..... c
D. fluitans *Rued*..... r
Callograptus salteri *Hall*..... c
C. *cf.* diffusus *Hall*..... r
Bryograptus lapworthi *Rued*..... cc
B. pusillus *Rued*..... rr
Goniograptus thureaui *McCoy*..... cc
G. geometricus *Rued*..... r
G. perflexilis *Rued*..... cc
Loganograptus logani *Hall* (?)..... cc
Dichograptus octobrachiatus *Hall*..... cc
Tetragraptus quadribrachiatus *Hall*..... cc
T. amii *Elles & Wood*..... c
T. fruticosus *Hall*..... cc
T. serra *Brongniart*..... c
T. similis *Hall*..... cc
T. taraxacum *Rued*..... r
T. pygmaeus *Rued*..... c
Didymograptus extensus *Hall*..... cc
D. nitidus *Hall*..... c
D. patulus *Hall*..... cc
D. nicholsoni *var.* planus *E. & W.*..... r
D. filiformis *Tullberg*..... r
Phyllograptus ilicifolius *Hall*..... cc
P. angustifolius *Hall*..... r
P. anna *Hall* (in uppermost layers)..... r
Temnograptus noveboracensis *Rued*..... c

Other fossils:

Dawsonia monodon *Gurley*..... c
D. tridens *Gurley*..... c
Caryocaris curvilatus *Gurley*..... c

Graptolite bed 2 is covered on every bedding plane with a multitude of beautifully preserved graptolites. As this list shows it also produces a great variety of forms, among them the most beautiful Deep Kill graptolites, the many-branched regular Goniograptus forms and the stately four-branched species of Tetragraptus, notably *T. fruticosus,* one of the most striking graptolites known. It will be noted that there are no less than seven species of Tetragraptus present in that bed, and five of Didymograptus. In number of individuals, however, the Didymograpti prevail by far. No less than nine species of this bed were new to science, and have not been found in any other locality. Some large magnificent slabs from this horizon are on exhibition in the State Museum. Since the rock with the graptolites is a very hard black slate, large surfaces can be obtained in this locality with the proper tools (large chisels and bars). The Museum has sent collections of graptolites, mainly from this ledge to represent the Deep Kill fauna, to all parts of the world in exchange for other graptolite faunas.

The Dawsonias are doubtful organisms. Similar bodies lately, have been considered by Manck ('26) as identical with the gonangia or reproductive sacs of Diplograptids after they have separated from the colony and burst open to discharge the spawn (described by Ruedemann, '97). *Caryocaris curvilatus* is a small crustacean peculiar to the graptolite beds in Great Britain and in eastern and western North America. The small list of associates of these graptolites is completed by worm-tubes (*Serpulites interrogans* Rued.) found in these graptolite beds at the Deep kill (Ruedemann, '16, p. 86).

The zone of Didymograptus extensus and Goniograptus thureaui is undoubtedly present in more localities than have been recorded so far. We have found *Loganograptus logani* and *Tetragraptus quadribrachiatus* in a road metal pit in Rensselaer (corner High street and Third avenue) formerly considered by us as belonging to the Normanskill. The rock consists of black, gray and greenish as well as some reddish shale and in part contains silicious bands as at the Deep kill, and in another a two-foot bed of black chert. It is possible that in this locality, with its much contorted beds both Deep Kill and Normanskill shales are intermixed.

Beautiful specimens of *Caryocaris curvilatus* were collected in a road metal pit one-quarter of a mile south of Aries lake (Snyders lake), where the road reaches the top of the hill.

Goniograptus thureaui and other Deep Kill fossils of this zone were also collected in typical Deep Kill rocks south of the capital district at Stuyvesant Landing.

The zone is also present on the southern slope of Mount Rafinesque and southeast of Tomhannock.

The fauna found in the two Didymograptus zones has a world-wide distribution. It is known from Europe, Asia, America and Australia. *Goniograptus thureaui,* for example, was first described in Australia.

b Zone of Didymograptus bifidus and Phyllograptus anna. The first subzone of this horizon is that of Goniograptus geometricus and Phyllograptus anna. It is found in graptolite beds 3 and 4 of the section. The fauna consists of:

Dictyonema furciferum *Rued*	r
Dendrograptus flexuosus *Hall*	r
Ptilograptus geinitzianus *Hall*	rr
P. tenuissimus *Hall*	rr
Goniograptus thureaui *McCoy*	c
G. geometricus *Rued*	cc
G. perflexilis *Rued*	r
Dichograptus octobrachiatus *Hall*	r
Tetragraptus quadribrachiatus *Hall*	r
T. fruticosus *Hall*	cc
T. clarkii *Rued*	c
T. pendens *Elles*	r
T. similis *Hall*	c
T. pygmaeus *Rued*	r
T. lentus *Rued*	r
Didymograptus similis *Hall*	r
D. acutidens *Lapworth*	rr
D. gracilis *Törnquist*	c
D. ellesae *Rued*	c
D. törnquisti *Rued*	r
D. bifidus *Hall*	cc
Phyllograptus typus *Hall*	c
P. angustifolius *Hall*	c
P. anna *Hall*	cc
Sigmagraptus praecursor *Rued*	rr

It will be noted that this fauna is still very close to that of the underlying Didymograptus beds. There are still three species of Goniograptus, seven of Tetragraptus, six of Didymograptus and three of Phyllograptus. The relative abundance of the species has,

however, greatly changed, the delicate *Goniograptus geometricus* being now the most common form; among the Tetragrapti two new species, *T. clarkii* and *pendens* have appeared; among the Didymograpti the leading species of the preceding horizon, *D. extensus, nitidus* and *patulus* have entirely disappeared; *D. bifidus* appears now in great number and serves as a guide fossil for the horizon; among the Phyllograpti, *P. typus* appears for the first time in the section and the diminutive *P. anna* is the most common form.

The second subzone of the zone of Didymograptus bifidus and Phyllograptus anna is that of Didymograptus similis and Phyllograptus typus. It is found in graptolite bed 5. The fauna consists of:

Callograptus salteri *Hall*	r
Didymograptus similis *Hall*	c
D. bifidus *Hall*	cc
D. nanus *Lapworth*	r
D. caduceus *Salter*	c
Phyllograptus typus *Hall*	cc
P. ilicifolius *Hall*	r
P. anna *Hall*	c

The fauna of this subzone is a rather small one, as represented in graptolite bed 5. The most common graptolites are *Didymograptus bifidus* and *Phyllograptus typus.* The latter and *Didymograptus similis* are the most characteristic forms.

c The last zone of the Deep Kill section we termed in 1903 that of Diplograptus dentatus and Cryptograptus antennarius.

We have in 1919 divided it into three subzones, namely:

a Subzone of Climacogr. pungens, Didymogr. forcipiformis

b Subzone of Phyllogr. angustifolius, Retiogr. tentaculatus

c Subzone of Desmograptus and Trigonogr. ensiformis

The first of these subzones is known to us only from the Ashhill quarry at Mount Merino near Hudson, and concerns us here no further, although it is to be assumed that it is also present in the capital district and even in the Deep Kill section, and may be discovered there some day.

The subzone of Phyllograptus angustifolius and Retiograptus tentaculatus is represented by graptolite bed 6. This has furnished:

Phyllograptus angustifolius *Hall*	c
P. anna *Hall*	c
Diplograptus dentatus *Brgt*	r
Trigonograptus ensiformis *Hall*	r
Retiograptus tentaculatus *Hall*	r

This faunule is interesting mainly, as that of the Ashhill quarry, by its mixture of distinct elements of the earlier period, when only graptolites without axes (order Axonolipa) existed, with those of the later era, when the graptolites with axes (Axonophora) prevailed. They are here represented for the first time in the Deep Kill section by the genera Diplograptus, Trigonograptus and Retiograptus.

Finally there is the last subzone of the Deep Kill series, that with Desmograptus and Trigonograptus ensiformis. This, found in graptolite bed 7, has afforded:

Dictyonema rectilineatum *Rued*	r
Desmograptus cancellatus *Hopkinson*	c
D. intricatus *Rued*	c
D. succulentus *Rued*	c
C. cf. diffusus *Hall*	r
Ptilograptus plumosus *Hall*	rr
Loganograptus logani *Hall*	rr
Dichograptus octobrachiatus *Hall*	rr
Tetragraptus quadribrachiatus *Hall*	rr
Didymograptus caduceus *Salter mut.* nana *Rued*	c
D. incertus *Rued*	rr
Strophograptus trichomanes *Rued*	c
Diplograptus dentatus *Brgt*	cc
D. inutilis *Hall*	r
D. longicaudatus *Rued*	rr
D. laxus *Rued*	c
Glossograptus hystrix *Rued*	r
G. echinatus *Rued*	rr
Trigonograptus ensiformis *Hall*	cc
Climacograptus? antennarius *Hall*	cc
C. pungens *Rued*	r
Retiograptus tentaculatus *Hall*	r

To these graptolites may be added two strange forms of brachiopods which the writer collected in this horizon. One is a gigantic Lingula, about two inches long, and identical or closely related to *L. quebecensis* Billings, a similarly large form that is known from the graptolite shales of Quebec. The other form, also of enormous size for brachiopods, is semicircular, four inches wide and more than two inches long, with very tenuous, chitinous, phosphatic shell. Clarke ('07, p. 606) has described this shell as *Eunoa accola.* It is possible that these brachiopods, with their large, flat, tenuous shells. led a planktonic or swimming life like the graptolites.

The graptolite fauna of this zone is characterized by the wonderful mixture of dendroid forms of the genera Dictyonema, Desmograptus and Ptilograptus, on one hand, with a multitude of true graptolites (Graptoloidea) on the other; and among these, again, of the older forms without axes, Dichograptus, Loganograptus, Tetragraptus, Didymograptus, with the later and more advanced types with axes, of the genera Diplograptus, Glossograptus, Trigonograptus, Climacograptus, Retiograptus.

The appearance of this new class of graptolites, the Axonophora, that characterizes the faunas of the later Ordovician and Silurian in the last Deep Kill zone, has seemed to the writer to indicate an important break between that zone and the preceding zones. It is for this reason that he has correlated this zone (with its three subzones) with the Lower Chazy rather than with the Beekmantown, with which the preceding undoubtedly must be correlated.

23 Bald Mountain limestone. The Bald Mountain limestone has been described by the writer ('14, p. 75) from the fine quarries at the foot of Bald mountain in Washington county (Schuylerville quadrangle), where the overthrust of the Lower Cambrian on the Ordovician is wonderfully exposed. It there contains a Beekmantown fauna and is of considerable thickness, as much as 70 feet or more south of the Bald mountain quarries, and as tests have shown, is in these quarries of greater purity than any other limestones in the State.

The Bald mountain limestone disappears about three and one-half miles south of Middle Falls and five and one-half miles south of the Bald mountain quarries, nor has it been traced northward. This would appear to give it a purely local development, in place of the Beekmantown graptolite shales, which, it is true, have not been found on the Schuylerville quadrangle. Since, however, the short belt of the limestone is exposed only just below the great overthrust line and bounded by overthrust planes above and below, thus appearing as a great wedge carried along, it may well be present in the capital district, hidden under the overthrust Cambrian rocks, and it may come to the surface at any place, especially near the great overthrust plane. A similar wedge of Trenton limestone, is, as we shall see presently, present in the capital district in the southeast corner of the Troy quadrangle.

As a matter of fact, there is exposed on Rysedorph hill, east of Greenbush, just north of the conglomerate cliff, a ledge of white limestone that has the appearance of the Bald Mountain limestone and does not seem to be referable to any formation in the district.

It has as yet not furnished any fossils that would solve the riddle of its age.

That the Bald Mountain limestone continues through the eastern slate belt and may form a portion of the Wappinger limestone (also known as the Neelytown, Newburgh or Barnegat limestone) on the Poughkeepsie and Newburgh quadrangles, is strongly suggested by the identification by Ulrich in the Bald Mountain limestone (Ruedemann, 14, p. 77) as *Eccyliopterus planidorsalis* and *E. planibasalis* Ulrich MS. of gastropods, years ago announced by Whitfield as *"Maclurea magna,"* from the limestone southwest of Newburgh (Holzwasser, '26, p. 42).

24 Normanskill shale. The name "Normanskill shale" was used by Ruedemann in 1901 for beds typically exposed at the Normanskill at the southern outskirts of Albany, at Kenwood (figure 48).

This formation contains a large and cosmopolitan graptolite fauna. Hall described in volume 1 of the Paleontology of New York (1843) the more common forms of the fauna from the "black glazed slates on the Normanskill, near Albany," under the heading "Utica slate and Hudson river group," accompanied by three beautiful steel-engraved plates. He added 11 species from the "Hudson river group near Albany," in the appendix to volume 3 of the Paleontology ('59) together with figures of supposed reproductive vesicles (*ibid.* p. 507).

The neighborhood of Albany has thereby become classic ground for the largest and best known graptolite fauna of America, that of the Normanskill shale. While the old locality, which was the foundation for a mill just above the Kenwood bridge, as well as the mill itself, has long ago disappeared, new outcrops are continually opened in the neighborhood of Albany, especially across the river. The richest ground for Normanskill graptolites was found for a time when the West Shore Railroad was built in 1883 in the cut just below Glenmont (a railroad station), one and one-half miles south of Kenwood. This locality, which to the old collectors was known as Van Wies Point (a promontory in the river) or "The Abbey" (a near-by inn) furnished magnificent large slabs with splendidly preserved fossils, among them the complete compound colonies of Diplograptus, never found anywhere before or since in such perfection (described by Ruedemann, '95, plate 4, from material lent by Hall, in connection with other material the writer had obtained at Dolgeville, N. Y.). A part of this splendid material is now on exhibition in the State Museum.

Small collections can still be obtained at the old localities, in the cut of the Delaware and Hudson Railroad at Kenwood and in that of the West Shore Railroad at Glenmont. For larger collections one has to go across the river and outside of the capital district.

The belt of Normanskill rocks crosses the district diagonally from the northeast corner to a little east of the southwest corner, where it dives under the Helderberg series of formations. For a long distance the belt runs along the Hudson river, crossing it in the southern part of Albany. Independent areas of Normanskill beds are formed in the Mount Rafinesque—Rice mountain outlier northeast of Troy and in a large area north of the Rensselaer plateau and east of the Lower Cambrian belt. A smaller outlier, that also contains Deep Kill shale, occurs west and southwest of Aries lake (Snyders lake).

Lithologically the Normanskill shale is a varied formation; the great mass of probably 2000 feet consists of mostly dark gray to black argillaceous shales, but also red and green shales and heavy beds of chert and grit. The latter two are especially characteristic of the formation so that it can be recognized by them when fossils are not available.

The chert, formed by the induration of black to dark green shale, occurs in beds varying from two feet in thickness to ten and more. Dale ('99, p. 186) calls it "a siliceous and feldspathic slate," formed probably from "a feldspathic mud, with quartz fragments and muscovite scales." Our finding of graptolites on the Schuylerville quadrangle in the chert would also indicate the origin of the chert beds from mud similar to that forming the shale. The chert has a peculiar way of weathering white or light gray and has therefore been distinguished as the "white-weathering chert," or "white beds" by Dale ('99, p. 185). The white color may be due to a kaolinization of an originally feldspathic mud (Dale, '99, p. 186), or to the loss of carbon on kaolinization (Dale, '04, p. 36). The white-weathering cherty beds do not form in the capital district such prominent outcrops or even ridges as they do on the Schuylerville quadrangle to the north, for instance on Willard mountain. Still they are well exposed in several localities, as below Glenmont on both sides of the state road before it crosses the railroad. The white ledges are seen there everywhere projecting through the sod and they can be seen as cliffs in the woods to the west of the road. They are also well exposed in the long cut of the Boston and Albany Railroad below Grandview Hill, south of Greenbush (now Rensselaer) and they form the top of that hill.

An outlier of this rock occurs also just north of Waterford and another smaller one, in a small but prominent hill, just west of the Delaware and Hudson tracks at Watervliet, where the peculiar appearance of the rock has led to fruitless mining operations.

Another most characteristic and typical rock of the Normanskill formation is the grit. It is usually associated with the cherty beds. It has been very carefully described by Dale ('99, p. 187) as "the Hudson grit." This Normanskill grit is, according to Dale, easily recognized.

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.

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; the particles of clastic rocks were found to consist of shale, micaceous quartzite, calcareous quartzite, limestone or dolomite, shale and flint. The most abundant were found to be quartzite, slate and shale.

We will have occasion to return to the significance of the feldspar-content (orthoclase and plagioclase), as well as of the particles of various fragmental rocks in the grit.

The grit beds are ever present in the Normanskill shale, ranging in thickness from two feet to 30 feet, and in many localities, especially where erosion is deep and drift cover heavy, they are the only rocks of the formation appearing on the surface, as in some ravines on the west side of the river. The grit is, or was, quarried in many places in the Hudson valley, especially farther south. In the capital district, where the nearby Helderbergs furnish excellent road metal, it is only of local importance. There is a large quarry in the grit at Kenwood on the south side of the Normanskill creek.

Besides the black and gray shales with interbedded grit and white-weathering chert, there are also masses of reddish, purplish and greenish shales with small quartzite bands, often disturbingly similar to the Cambrian rocks. These shales, which are not protected by the grits and cherts do not appear so often, however, on the surface in the capital district. They are best shown on the top of the great cross-fold of Mount Rafinesque northeast of Troy.

The shales with limestone and the limestone conglomerate, both with Trenton faunas, which Dale included in the Hudson shales, are here separated (see p. 104) and placed on top of the Normanskill formation. Dale ('04, p. 37) gave the following divisions of the Hudson formation as exposed in Rensselaer county:

Descriptions of strata	*Fauna*	*Estimated thickness in feet*
1 Black shale with arenaceous limestone (Ruedemann's stations 24–26)	Diplograptus amplexicaulis	1200–2500?
2 Black and gray shale with interbedded grit	Normanskill graptolite fauna	
3 Similar shale with limestone and limestone conglomerate.....	Trenton fauna in limestone and cement of conglomerate	
4 Black, silicious, white-weathering, cherty-looking shale.....		
5 Reddish, purplish, greenish shale with small quartzite bands.		

Of these groups of rocks, No. 1 is our Snake Hill formation, No. 3 is the Tackawasick shale and limestone and the Rysedorph Hill conglomerate.

We have presented evidence ('14, p. 89) from the Schuylerville quadrangle which makes it probable that the grit is nearest the base of the formation and the white-weathering chert above.

Another question which can not be satisfactorily answered as yet is that of the thickness of the Normanskill formation. Dale ('99), in his table (facing p. 178) of Cambrian and Silurian formations of the slate belt of eastern New York and western Vermont, assigns to the Hudson grits 500 + feet; to the Hudson white beds 400 feet or less; to the Hudson shales 50 + feet; to Hudson red and green slate 100 + feet. We had an opportunity to make some estimates on the west side of Willard mountain on the Schuylerville quadrangle (Ruedemann, '14, p. 91), as follows: grit, 500 ± feet; white beds, 400 ± feet; shale, 100 ± feet. The capital district has not furnished any further evidence on the thickness of the formation. From both Dale's and our own estimate we would consider 1000 feet as a minimum for the Normanskill shale, with a possibility that it goes to double this thickness.

The fauna of the Normanskill shale, as brought together in the capital district, mainly at Glenmont, consists of 56 species, as follows:

Ptilograptus poctai *Rued*..... rr (Gl.)
Dictyonema spiniferum *Rued*..... rr (Gl.)
Odontocaulis hepaticus *Rued*..... r (Gl.)
Desmograptus tenuiramosus *Rued*..... rr (Gl.)

Thamnograptus capillaris (*Emmons*)..... c (K. etc.)
Didymograptus sagitticaulis *Gurley*..... cc (K. etc.)
D. serratulus (*Hall*)..... c (K., Lans. etc.)
D. subtenuis (*Hall*)..... cc (K. etc.)
Azygograptus? simplex *Rued*..... c (K., Gl., Lans.)
Leptograptus flaccidus *mut.* trentonensis *Rued*..... cc (Gl.)
L. flaccidus var. spinifer *E. & W. mut.* trentonensis *Rued*..... c (Gl.)
Syndyograptus pecten *Rued*..... rr (Gl.)
Amphigraptus divergens (*Hall*)..... rr (K., Gl.)
A. multifasciatus (*Hall*)..... rr (K.)
Nemagraptus gracilis (*Hall*)..... cc (K., Gl. etc.)
N. gracilis *var.* succularis (*Hall*)..... c (K., Gl.)
N. gracilis *var.* distans *Rued*..... r (Gl.)
N. gracilis *var.* approximatus *Rued*..... r (K., Gl.)
N. exilis *Lapworth*..... c (Gl.)
N. exilis *var.* linearis *Rued*..... c (K., Sp.)
Dicellograptus mensurans *Rued*..... r (K.)
D. divaricatus (*Hall*)..... c (K., Gl.)
D. divaricatus *var.* rectus *Rued*..... r (K., Sp.)
D. divaricatus *var.* bicurvatus *Rued*..... c (Gl., K.)
D. divaricatus *var.* salopiensis *Elles & Wood* r (K.)
D. intortus *Lapworth*..... rr (Sp.)
D. gurleyi *Lapworth*..... cc (Gl)
D. sextans (Hall)..... cc (Poest., Troy, K., Gl., Tomhannock etc.)
D. sextans *var.* exilis *Elles & Wood*..... r (Gl.)
D. sextans *var.* tortus *Rued*..... c (K.)
Dicranograptus nicholsoni Hopkinson *var.* parvangulus *Gurley*..... cc (Gl.)
D. nicholsoni *var.* diapason *Gurley*..... c (Gl.)
D. ramosus *Hall*..... c (K., Gl., Cas., Mt O.)
D. spinifer *E. & W*..... r (Gl.)
D. spinifer *var.* geniculatus *Rued*..... r (Gl.)
D. furcatus (*Hall*)..... cc (K., Gl.)
D. furcatus *var.* exilis *Rued*..... r (K.)
D. contortus *Rued*..... c (K., Mt O.)
Corynoides curtus *Lapworth*..... cc (Gl., K., Troy, Cas.)
C. gracilis *Hopkinson*..... cc (Lans.)

C. gracilis *mut.* perungulatus *Rued*	cc	(Gl., Sp.)
Diplograptus incisus *Lapworth*	cc	(Gl., K. etc.)
D. acutus *Lapworth*	cc	(Gl., K. etc.)
D. angustifolius *Hall*	c	(Gl., K., Lans. etc.)
D. (Glyptograptus) euglyphus *Lapworth*	c	(Gl., Sp.)
D. euglyphus *var.* pygmaeus *Rued*	cc	(Lans.)
Glossograptus ciliatus *Emmons*	c	(K., Gl. etc.)
G. whitfieldi (*Hall*)	cc	(K., Gl. etc.)
Cryptograptus tricornis (*Carruthers*)	cc	(K., Gl. etc.)
Climacograptus parvus *Hall*	cc	(K., Gl., Cas., Mt O., Poest.)
C. modestus *Rued*	cc	(Lans.)
C. scharenbergi *Lapworth*	c	(Gl.)
C. bicornis *Hall*	cc	(K., G. etc.)
Retiograptus geinitzianus (*Hall*)	r	(K., Gl. etc.)
Lasiograptus mucronatus (*Hall*)	cc	(K., G. etc.)
L. bimucronatus (*Hall*)	c	

We have added the principal graptolitiferous localities of the capital district in parentheses, K. meaning Kenwood; Gl., Glenmont; Lans., Lansingburg; Cas., Castleton; Poest., Poestenkill at Spring street, Troy; Mt O., Mount Olympus in Troy; Sp., Speigletown. All of these localities are denoted by stars on the geologic map.

There is no doubt that the Normanskill formation covers a long interval of time and is composed of a number of subzones. This is suggested not only by its great thickness of over 1000 feet, but also by the fact that the graptolite faunules of the different localities show considerable differences. We have so far been unable to find a continuous section and therefore can only surmise, and have only indirect evidence to offer as to the succession of the faunas. There are distinguishable at least two, possibly three, different associations of forms. The most important of these is the typical Normanskill fauna of Kenwood and Glenwood, which is also by far the richest. This fauna is usually found associated with the Normanskill grit and the white-weathering chert, and is most probably the lowest of the faunas. Lapworth in 1887 distinguished two subfaunas in the graptolite beds of the St Lawrence shale of this age, namely a lower one, with *Coenograptus gracilis,* his Coenograptus zone of Griffin cove and the Marsouin river, and a higher one, apparently destitute of *Coenograptus gracilis,* the Cove Fields and Orleans subfauna; the former he correlated with the Middle Llandeilo of Great Britain,

the latter with the highest Llandeilo or lowest Caradoc beds of England. It is evident that the typical Normanskill graptolite fauna, which contains *Nemagraptus (Coenograptus) gracilis,* corresponds to the first subzone.

From the upper zone Lapworth cites:

Diplograptus foliaceus *Murchison var.*
D. amplexicaulis? *Hall*
D. truncatus (?) *Lapworth*
D. euglyphus *Lapworth* (?)
Corynoides calycularis *Nicholson*
Dicellograptus *sp.*
Dicranograptus tardiusculus (?) *Lapworth*
Dicranograptus ramosus *var.* spinosus *Lapworth*
Climacograptus bicornis *Hall*
C. two *sp.*
C. scharenbergi *Lapworth*
Cryptograptus tricornis *Carruthers.*

Most of these species are Normanskill forms, especially so the positively identified species, yet the most characteristic Normanskill forms are lacking. Gurley ('96) distinguished the two zones as the Upper and Lower Dicellograptus zones in Canada. He gave a large list of graptolites from Magog, Quebec (near the Vermont line) as characterizing this zone. A smaller list of this fauna had already been given by G. M. Dawson ('94), and a larger one with figures was published in 1902 by C. H. Richardson. These three lists show rather strong discrepancies, especially Gurley's, which differs from the others by citing a considerable number of new species (manuscript names). Professor Richardson was kind enough to allow me to select typical material from his large collection now in Syracuse University. Inspection of this shows that the graptolites are strongly distorted or deformed by being stretched in one direction and compressed in that at right angle, in the manner described for the material from the Hoosic tunnel by the writer ('08, pl. 25, p. 7–9). This deformation is undoubtedly responsible for Gurley's new species.[1]

The writer ('08, p. 29) has united the Cove Fields faunas, the Upper Dicellograptus fauna and that from Magog under the term "Magog shale," but erroneously also referred the beds at Watervliet, Troy (Rushers quarry), Sandy hill and Van Schaick island to this zone and termed it from the guiding fossil of the last named localities

[1] The Magog fauna will be revised in another publication.

the zone of Diplograptus amplexicaulis. Later studies have proved that these beds belong to a later zone, that we unite now with the Snake Hill beds. In recognition of this fact, we have ('19, p. 122, 130) designated these later beds as Magog shale (or zone of Cryptograptus tricornis insectiformis) and the upper division of the Normanskill shale as zone of Corynoides gracilis. From an inspection of Professor Richardson's material we have been convinced that the term "Magog shale" can be properly applied only to the upper division of the Normanskill.

This is distinguished from the lower zone by the reduction in species and individuals of the genera Dicellograptus, Dicranograptus and Didymograptus and the prevalence of Diplograptidae, especially the genera Diplograptus and Climacograptus. Also two species of *Corynoides, C. calicularis* and *gracilis* cover whole bedding planes. In the capital district it is *C. gracilis* that prevails. A typical locality of the upper horizon was found by the writer at the north end of Lansingburg, at the power house of the traction company. It afforded besides the Normanskill species: *Didymograptus serratulus, Azygograptus? simplex, Dicranograptus ramosus, Climacograptus parvus, C. modestus, C. bicornis* and *Diplograptus acutus,* the following peculiar elements of its own: *Diplograptus amplexicaulis* var. *pertenuis, Diplograptus euglyphus* var. *pygmaeus, Climacograptus eximius* and *Corynoides gracilis.*

No other fossils but a few minute brachiopods with chitinous shells occur in the Normanskill shale with the graptolites. These are *Paterula amii* Schuchert, *Schizotreta papilliformis* Rued. and *Leptobolus walcotti* Rued. Only the latter is seen more frequently. In a quarry near Catskill, however, the writer discovered a fauna of eurypterids associated with the graptolites. This is the oldest eurypterid fauna known. It was described by Clarke and Ruedemann in the Eurypterids of New York.[1] No trace of these strange associates of the Normanskill graptolites has as yet been found in the capital district.

The correlation of the great mass of Normanskill rocks has been the subject of considerable doubt. As mentioned before, it was originally with the "Hudson river beds" placed above the Utica and correlated with the Lorraine. Lapworth's correlation of the Coenograptus zone of Canada with that of Great Britain suggested a greater age than Utica for the formation; also Dale's work in the

[1] The writer ('12, p. 411) has given Professor G. H. Chadwick credit for having discovered this eurypterid fauna, but is informed by Professor Chadwick that he directed my attention only to the graptolite fauna, not being aware of the eurypterids, and that these were found by myself.

slate belt ('99, table p. 178) led to the inference that the Hudson shales, cherts and grits may be replaced westward by limestone, that represents Trenton, Chazy and Beekmantown. The discovery of the Rysedorph Hill conglomerate (see below), apparently intercalated in the Normanskill and carrying Trenton fossils as well as the finding of the Normanskill below the zone with Diplograptus amplexicaulis, led the writer ('01) to the conclusion that the Normanskill shale could not be younger than middle Trenton and that it corresponds to a part of the middle or lower Trenton limestone ('01, p. 551). Later the discovery of Normanskill graptolites in association with other fossils in Virginia led to the assignment of the Normanskill to still older periods; it was first placed by Ulrich ('11, p. 512) below the Lowville and above the Chazy and then by Raymond ('16) correlated with the Upper Chazy. If the typical Normanskill corresponds to the Upper Chazy, the upper Normanskill zone (Magog shale) may be of Lowville and Leray age. It thus closes the upper gap to the Snake Hill beds of Trenton age, and the Normanskill closes the gap in the Chazy above the uppermost Deep Kill zone which we considered of lower and middle Chazy age.

25 **Rysedorph conglomerate.** Two of the most interesting rocks of the capital district are a conglomerate and a fault breccia. The conglomerate was fully described by the writer in 1901 and termed the Rysedorph conglomerate, from its exposure on Rysedorph hill, a prominent eminence two miles southeast of Rensselaer (figure 61). The hill is not known locally under the name given it on the topographic map, but is called the Pinnacle or Sugar Loaf hill. It is a triangulation station with a bench mark and can be recommended to the geologists not only as a fine collecting ground for Rysedorph fossils, but also for its magnificent view, which sweeps the country to the Adirondacks in the north, the Green mountains in the east, the Catskills in the south and the Helderbergs in the west, thereby affording a most complete survey of the topography of the capital district.

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 identical with the Burden conglomerate described by Grabau from Becraft mountain near Hudson.

The typical outcrop on top of Rysedorph hill is a vertical ledge; the main bed is two and one-half feet thick. It is distinctly underlain by black and green shales on the west side. This

condition led Emmons ('55, pt II, p. 72), in his endeavor to establish the Taconic system, to cite this hill as one of his critical localities. As his section indicates, Emmons believed he had the "Calciferous sandstone" (Beekmantown), resting uncomformably on the "green Taconic slates," thereby proving the primordial age of the latter. The writer has fully described the later history and interpretations of this interesting locality, ('01, p. 4 ff.). It may here be mentioned that Hall ('47, p. 35) disputed the Beekmantown age of the rock which Emmons had based on a cephalopod, and declared the mass to be "the Trenton limestone thrust through the Hudson River slates." Walcott ('88, p. 319) had also studied the outcrop and considered it a block of Trenton conglomerate caught on the line of the great fault which passes through the hill and which separates the Cambrian and Ordovician strata. The writer has in the past 20 years taken many geologists, both from this country and from Europe, to the well-known locality and all have returned with interesting fossils and facts from this historic point.

A study of the conglomerate by the writer was carried out with a wagonload of pebbles, most of which being composed of intensely hard siliceous limestone which broke through the fossils, had to be baked in the kitchen range and dumped into cold water, to assure breaking along the fossils. The material proved fully worthy of the work spent on it. There were found seven kinds of pebbles which furnished an amazingly rich and strange fauna. The writer ('01) described 84 species from this small locality, a prodigious number for Paleozoic outcrops; and 25 of these were new, among them six new trilobites. Later collecting has added still new forms. These will be published later in a revision of the fauna.

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 farther 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 fully revealed to science.

The following are the groups of pebbles from the Rysedorph hill conglomerate and their faunas:

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

The pebbles of this group are considered the most valuable and interesting portion of the Rysedorph Hill conglomerate. Unfortunately they are rare and mostly small; they are intensely black when fresh, but very soft and of brownish tint when weathered. It was these pebbles that furnished the rare brachiopods, gastropods and trilobites. Altogether, 45 species were listed by the writer from these pebbles, as follows:

Corals:	Streptelasma corniculum *Hall*	c
Graptolites:	Diplograptus foliaceus *Murch*	r
	Climacograptus scharenbergi *Lapworth*	r
Bryozoans:	Corynotrypa (Stomatopora) inflata (*Hall*)	c
	Stictopora cf. elegantula *Hall*	r
	Callopora multitabulata *Ulrich*	cc
Brachiopods:	Siphonotreta minnesotensis *Hall & Clarke*	rr
	Crania trentonensis *Hall*	r
	Rafinesquina alternata (*Emmons*)	c
	Leptaena rhomboidalis *Wilckens*	c
	Plectambonites sericeus (*Sowerby*)	c
	P. pisum *Rued*	cc
	Christiania trentonensis *Rued*	c
	Orthis tricenaria *Hall*	c
	Platystrophia biforata (*Schlotheim*)	c
	Dalmanella testudinaria (*Dalman*)	c
Pelecypods:	Whitella ventricosa (*Hall*)	rr
	Ctenodonta *sp. ind*	rr
	C. *cf.* astartaeformis *Salter*	r

Gastropods:	Sinuites cancellatus (*Hall*)	r
	Conradella compressa (*Conrad*)	r
	Carinaropsis carinata *Hall*	r
	Lophospira bicincta (*Hall*)	r
	Liospira americana (*Billings*)	rr
	Eccyliopterus spiralis *Rued*	rr
	Holopea paludiniformis *Hall*	rr
Conularids:	Conularia cf. trentonensis *Hall*	rr
Cephalopods:	Zitteloceras hallianum *d'Orbigny*	rr
Trilobites:	Tretaspis reticulata *Rued*	cc
	T. diademata *Rued*	rr
	Ampyx (Lonchodomas) hastatus *Rued*	cc
	Remopleurides linguatus *Rued*	cc
	Isotelus maximus *Locke*	c
	Illaenus americanus *Billings*	c
	Cyphaspis matutina *Rued*	r
	Bronteus lunatus *Billings*	rr
	Calymmene senaria *Conrad*	rr
	Pterygometopus callicephalus (*Hall*)	c
	Ceraurus pleurexanthemus (*Green*)	c
	Cybele *sp*	rr
	Sphaerocoryphe major *Rued*	r
Ostracods:	Isochilina armata *Walcott var.* pygmaea *Rued*	r
	Primitia mundula *Miller var.* jonesi *Rued*	r
	Aparchites minutissimus *Hall var.* robustus *Rued*	c
	Bythocypris cylindrica *Hall*	r

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 hastatus* 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 (see below), and in association with *Christiania 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.

6 Reddish gray compact limestone

These pebbles are composed of very hard, compact, fine-grained, dark gray limestone, that weathers into a reddish gray rock. It is most remarkable for its ostracods, which are the most common fossils, appearing with their tiny, black, glossy shells in wonderful distinctness. Besides these some trilobites of the rare genera Ampyx and Remopleurides also were found in these pebbles. The fauna is the following:

Brachiopods:	Rafinesquina alternata (*Conrad*)	r
	Dalmanella testudinaria (*Dalman*)	r
	Triplecia nucleus *Hall*	r
	Protozyga exigua *Hall*	c
Gastropods:	Carinaropsis carinata *Hall*	r
Trilobites:	Gerasaphes ulrichana *Clarke*	rr
	Ampyx hastatus *Rued*	r
	Remopleurides linguatus *Rued*	r
	R. tumidulus *Rued*	rr
	Pterygometopus callicephalus (*Green*)	r
Ostracods:	Leperditia resplendens *Rued*	c
	Isochilina armata *Walcott var.* pygmaea *Rued*	r
	Schmidtella crassimarginata *Ulrich, var.* ventrilabiata *Rued*	cc
	Eurychilina reticulata *Ulrich*	c
	E. bulbifera *Rued*	c
	E (?) solida *Rued*	rr
	E. subradiata *Ulrich var.* rensselaerica *Rued*	c
	Bythocypris cylindrica (*Hall*)	cc

The pebbles of this group are by their fauna and lithologic transition in some pebbles closely connected with those of the next group.

7 Gray crystalline limestone, which often changes into a veritable shell rock. This is by far the most common group of pebbles on Rysedorph Hill. Most of the pebbles are made up of shells of *Plectambonites sericea* and *Rafinesquina alternata* or parts of the trilobite *Isotelus gigas*. The fauna is the following:

Bryozoans:	Prasopora simulatrix *Ulrich var.* orientalis *Ulrich.*	r
Brachiopods:	Rafinesquina alternata (*Conrad*)	cc
	R. deltoidea (*Conrad*)	r
	Leptaena rhomboidalis *Wilckens*	r

	Plectambonites ruedemanni *Raymond*	cc
	(in original list cited as P. sericeus jasper *James*)	
	P. pisum *Rued*	r
	Triplecia nucleus *Hall*	c
	Orthis tricenaria *Conrad*	c
	Plectorthis plicatella *Hall*	c
	Dalmanella testudinaria (*Dalman*)	c
	D. subaequata Conrad *var.* pervetus *Conrad*	c
	Dinorthis pectinella (*Emmons*)	r
	Parastrophia hemiplicata *Hall*	r
	Protozyga exigua *Hall*	c
	Zygospira recurvirostris *Hall*	c
Pelecypods:	Modiolopsis *cf.* aviculoides *Hall*	r
Gastropods:	Conradella compressa *Conrad*	r
	Carinaropsis carinata *Hall*	c
	Lophospira bicincta (*Hall*)	c
	L. perangulata (*Hall*)	c
	Liospira subtilistriata (*Hall*)	cc
	Clathrospira subconica *Hall*	c
	Trochonema umbilicatum (*Hall*)	c
	Cyrtospira attenuata *Rued*	rr
Hyolithids:	Hyolithus rhine *Rued*	rr
Cephalopods:	Cyrtoceras subannulatum *Hall*	rr
	Spyroceras bilineatum (*Hall*)	rr
	S. *cf.* annellus (*Conrad*)	r
Trilobites:	Remopleurides linguatus *Rued*	rr
	Isotelus maximus *Locke*	cc
	Illaenus americanus *Billings*	c
	Thaleops ovata *Conrad*	r
	Pterygometopus eboraceus *Clarke*	r
	P. callicephalus (*Hall*)	c
	Dalmanites achates *Billings*	c
	Ceraurus pleurexanthemus *Green*	c
Ostracods:	Leperditia fabulites *Conrad*	c
	L. resplendens Rued	cc
	Eurychilina bulbifera *Rued*	r
	E. obliqua *Rued*	rr
	E. subradiata *Ulrich var.* rensselaerica *Rued*	c
	E. dianthus *Rued*	c
	Primitia mundula Miller *var.* jonesi *Rued*	r

Bollia cornucopiae *Rued*..... rr
Macronotella ulrichi *Rued*..... c
M. fragaria *Rued*..... rr
Bythocypris cylindrica (*Hall*)..... c

The pebble groups 6 and 7 belong to adjoining beds and their faunas have also the principal forms in common. This is the most common and principal fauna of the Rysedorph conglomerate. It is a lower Trenton fauna. As this is the youngest fauna obtained in the Rysedorph conglomerate, the latter must be of younger than lower Trenton age.

The Rysedorph conglomerate is exposed in a number of other localities in the capital district. It appears in a five-foot bed at the upper falls in a ravine just east of Papskanee island and thence south in a series of outcrops on top of the Van Denburg ridge. Another interesting outcrop is on Papskanee island on the shore of the Hudson river. Here it forms a hill and cliff on the river bank, on which the clubhouse of the Papskanee Boat Club stands. The writer has picked up there Ordovician brachiopods, as *Plectambonites sericeus,* alongside of recent fresh water gastropods at the edge of the water. An excellent exposure of the conglomerate is seen in the big cut of the Boston and Albany Railroad on the hillside south of Rensselaer. Here it is involved with Normanskill shale, grit and chert.

A fine series of outcrops of the Rysedorph conglomerate is exposed in the lower Moordener kill near Castleton. Dale ('04, p. 34) describes five different outcrops of conglomerate from the Moordener kill from Prindle's observations, the fifth being 50 feet thick, and the third 12 feet thick.

We consider all these outcrops as belonging to the same bed, repeated by folding and doubled in places upon itself. The matrix and pebbles, as well as the fossils, are the same in all outcrops. The first outcrop is below the lower falls, about 200 feet upstream from an outcrop with Normanskill graptolites.

Another conglomerate bed, five feet thick, forms the top of the lower falls, containing boulders two feet in diameter (composed of the brownish sandy calcareous matrix of the Rysedorph conglomerate and squeezed off the main body). The conglomerate here contains also white and brown quartz pebbles and black chert pebbles. Two hundred paces farther up the conglomerate appears again, 12 feet thick, another is below the upper falls and 500 feet above the upper falls is a fifth outcrop. The conglomerate is here folded in with

Normanskill shale, grit beds and white-weathering chert beds composed of alternating limestone (one inch thick) and shale, suggesting Deep Kill. At the lower falls the conglomerate is part of an overturned anticline.

Also farther up the Moordener kill, half a mile above the Schodack depot, is an outcrop of a breccia or conglomerate containing pebbles of black chert and limestone with crinoid stems and bryozoans. This conglomerate is closely associated with Normanskill grit.

Two further outcrops of brecciated conglomerate are found in the Vlockie kill, the next creek south of the Moordener kill, one of these six and one-half feet thick, and both closely associated with the black white-weathering Normanskill chert and black Normanskill graptolite shale.

The Moordener kill conglomerate (see Ruedemann, '01, p. 544) contains Lowville limestone boulders with "bird's-eyes" (*Phytopsis tubulosa*) and *Tetradium cellulosum,* and still larger boulders (two and one-half feet in diameter) of dark gray Trenton limestone. The latter contained (Ruedemann, '01):

Streptelasma corniculum *Hall*	r
Callopora *cf.* ampla *Ulrich*	c
Plectambonites ruedemanni *Raymond*	cc
Strophomena incurvata (*Shepard*)	c
Rhynchotrema increbescens *Hall*	r
Conradella compressa (*Hall*)	r
Pterygometopus callicephalus *Hall*	r
Isotelus *cf.* gigas *Dekay*	c
Macronotella ulrichi *Rued*	r
Bollia *sp.*	

Also pebbles of dull black, very fine-grained limestone were found which contained (Ruedemann, '01):

Callopora ampla *Ulrich*	c
C. multitabulata *Ulrich*	c
Dalmanella testudinaria (*Dalman*)	c
Platystrophia biforata (*Schlotheim*)	c
Plectambonites pisum *Rued*	cc
Christiania trentonensis *Rued*	r
Eccyliopterus *sp. nov*	r
Ceraurus pleurexanthemus *Hall*	
Conularia trentonensis *Hall*	

This black limestone is quite obviously identical with that of Rysedorph Hill containing the Black River—Chambersburg fauna.

An interesting feature of the Moordener conglomerate is that it furnishes a number of fossils in the matrix, namely: *Pachydictya* sp., *Stromatocerium* sp., *Rafinesquina alternata, Strophomena incurvata, Plectambonites ruedemanni, P. pisum, Pterygometopus callicephalus.* An outcrop south of the capital district, back of the village inn at Schodack Landing, has also afforded fossils in the matrix, namely: *Streptelasma corniculum, Plectambonites ruedemanni, P. pisum* and *Orthis tricenaria.* The matrix in the Rysedorph cliff, which is more sandy than in the outcrops farther south, contains only comminuted fragments of Rafinesquina Plectambonites etc. Even if we assume that some of these fossils were broken off pebbles, the number and preservation of those at the Moordener kill mark them as probable elements of the fauna of the matrix.

Northward of Rysedorph hill the conglomerate is very little exposed. An excellent exposure was, however, found as far north as Bald mountain, northeast of Schuylerville, where it forms the northern point of the wedge of Bald Mountain limestone, and lies between the Snake Hill shale and Lower Cambrian, separated from both by overthrust planes. Several geologists whom I took to this outcrop, declared it to be a breccia and not a conglomerate. The blocks are indeed very angular, suggesting a crush breccia of one kind of rock to these visitors. More careful search by the writer ('14, p. 80), has furnished, however, a variety of pebbles from Lower Cambrian to Trenton age and the following fossils:

Lingula *sp.*
Siphonotreta *cf.* minnesotensis *Hall & Clarke.*
Rafinesquina *sp.*
Plectambonites pisum *Rued.*
Ceraurus *cf.* pleurexanthemus *Green*
Bythocypris cylindrica (*Hall*).
Isochilina armata *Walcott var.* pygmaea *Rued.*

The matrix has also furnished specimens of *Plectambonites pisum.* There is, from the facts here given, no doubt in our mind that at this northern locality, there is an outcrop of the Rysedorph conglomerate.

The origin of this strange rock has been the subject of animated discussion, whenever it has been studied by geologists. The writer ('01, p. 109) has fully discussed the earlier views and will here but

briefly mention them. Walcott, in his well known paper on intraformational conglomerates ('93, p. 191), suggested that the sea bed was raised in ridges or domes above the sea-level, and thus subjected to the action of seashore ice, and the aerial agents of erosion. It was the writer's opinion that the erosion of anticlinal ridges would be best suited to furnish the variety of materials of different ages, such as is found in the Rysedorph conglomerate. Others have suggested flood-plain deposits and others glacial beds or sea-ice transportation. To the writer, the presence of fossils in the calcareous matrix is of decisive importance in proving the submarine origin of the conglomerate either along a shore swept by currents of an advancing sea that deposited the coarse material derived from promontories and rivers, or on the flanks of an anticline that was being eroded. The extension of the conglomerate in a north-south direction, as well as the crude assortment of the material, shown by strings of pebbles, especially on Rysedorph Hill, and the fact that in some places the pebbles are still angular and appear to belong to a continuous bed broken up and at once recemented, all these observations suggest the deposition of the bed in the sea and the derivation of the material from exposures along an anticline. There are certain features in the conglomerate which suggest to us a derivation of much of the material of the pebbles from rocks outcropping farther north. These are especially the rare Chazy and the more common pebbles of typical Lowville limestone. There is no Lowville limestone known in the East at all, and west of the Rysedorph conglomerate not until the upper Mohawk valley is reached.

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 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.

26 The Poestenkill fault breccia. A rock that is similar to the Rysedorph conglomerate and that occurs in the same region is the

fault breccia found below the plane of the great overthrust separating the overlying Cambrian from the subjacent Ordovician. This fault breccia has been very fully described by the writer ('12, p. 83) from the Schuylerville quadrangle, where it is splendidly shown in the quarries at Bald mountain, resting upon the Bald mountain limestone. It reaches there 30 feet in thickness in one place and is composed of black soft mud, carrying a variety of small pebbles. It is a typical mylonite, that is, a rock produced by the grinding up of rocks (mostly shales in this case), along the fault plane. Where great masses of Trenton limestone have been worked into the mylonite, it becomes similar to the Rysedorph conglomerate and may even contain fossils. As an illustration of this we have drawn in the diagram of the Bald mountain quarry ('12) accompanying the geologic map of the Saratoga-Schuylerville quadrangles, a large block in the quarry as Rysedorph conglomerate which later turned out to be composed of mylonite.

The capital district furnishes excellent exposures of the fault breccia on the campus of the Rensselaer Polytechnic Institute (figure 64), where it is exposed in a small cliff back of the fence close to the north side entrance on Sage avenue, and especially in the ravine of the Poestenkill below the fall, as well as along Congress street, Troy, below Ida Park. The fault breccia on the campus is overlain by green Lower Cambrian slate and underlain by gray and black Snake Hill shale, showing in a road metal pit on the other side of the street. The breccia, a coarse mylonite, is largely composed of black Normanskill chert, Normanskill grit and Bald mountain limestone. It will be noted that the composition of this fault breccia is entirely different from that of the Rysedorph conglomerate. The breccia at Congress street is almost entirely composed of Normanskill grit, some boulders showing fine "mud-flow" structure and many well-rounded by strong abrasion. The outcrop in the bed of the Poestenkill (figures 26, 62 and 63), after which we name the rock, is the most instructive. It is 150 feet wide, largely composed of Normanskill grit, some of the blocks being ten feet in diameter and mostly well rounded. It rests on Normanskill grit and is overlain by Lower Cambrian green slate.

The principal difference between the Rysedorph conglomerate and the Poestenkill fault breccia is that the former is composed of rocks foreign to the capital district while the Poestenkill fault breccia consists of the rocks of the immediately adjoining formations, mostly the Lower Cambrian and Normanskill. Furthermore, the Rysedorph conglomerate appears to be continuous over a large area and of

fairly uniform thickness, while the Poestenkill fault breccia is probably discontinuous and of very irregular thickness, swelling up locally, as at the Poestenkill and disappearing in other places.

It has lately been pointed out by Cornelius ('27) that polymikt tectonic breccias never have any large extension, and this quite clearly also is true of the Poestenkill fault breccia. Although the fault itself may pass through a very large area and be of great length, the breccia has accumulated only in certain favorable localities, while in others the contact is free of all brecciated and ground-up material.

27 Tackawasick limestone and shale. Along the southern edge of the Rensselaer grit in the capital district there appears a narrow belt of calcareous shale with Trenton fossils. This belt appears entirely out of place both in its location as well as in its character. It is situated between Lower Cambrian shale on one side and Rensselaer grit on the other and it is a limestone where all other formations are represented mainly by shales and quartzites (figure 7).

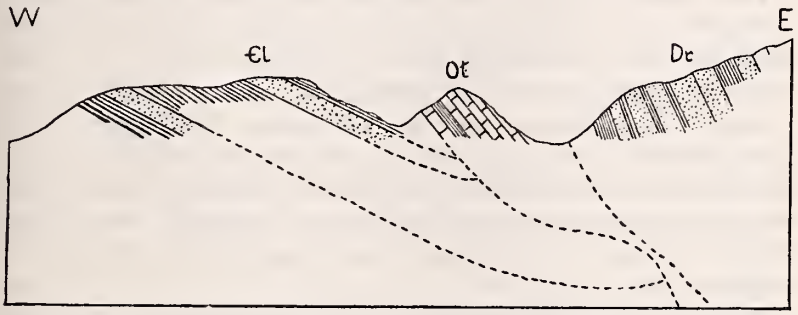


Figure 7 Diagram section by Dale (U. S. Geol. Surv. Bul. 212) across the western edge of the Rensselaer plateau and the second ridge east of Tackawasick pond, in Nassau, showing the surface relations and the probable structural relations of the Lower Cambrian quartzite and shale (*Cl*), the Tackawasick limestone (*Ot*) and the Rensselaer grit (*Dr*). *Dotted beds* (*Cl*), quartzite; lined beds red and green shale with small quartzite beds

We are aware of only three outcrops of this formation in the capital district. The principal one is one-half of a mile east of the north end of Tackawasick pond, on top of the ridge paralleling the road on the east. An old quarry marks the outcrop. The Trenton outcrop, altogether 70 feet wide, with an easterly dip of 50°–55°, consists of thin-bedded shaly gray limestone, the beds about one inch thick with interbedded one-fourth inch dolomitic layers, and some 20 feet of interbedded greenish argillite. There is also a limestone bed two to three feet thick. Toward the east is a swampy and

wooded land and the contact with the Rensselaer grit is not shown, nor is a direct contact observable with the greenish gray and red Cambrian shale which, however, is close by on the west. There is another smaller outcrop three-quarters of a mile farther north, one south of Pike hill, and similar gray calcareous shale is seen also farther south.

Dale ('90, p. 311), in his excellent paper on the Rensselaer Grit Plateau in New York, has carefully described these occurrences of Trenton limestone. He reports that Dr A. F. Foerste in 1890 found Trenton fossils at the locality south of Hoags Corners (east of Tackawasick pond), on what is known as the Coonradt farm, namely: "Monticulipora (under old interpretation Lycoperdon), a Murchisonia, a Calymene, an Orthis of *O. plicatella* type, and crinoid stems." The writer could find only the Monticulipora, which is not rare and the crinoid stems. The bryozoan has been determined by Doctor Ulrich as a Prasopora suggesting Eden age.

Dale concluded that the disconnected occurrences of the limestone are "parts of a narrow limestone belt, anticlinal in structure, underlying the grit and belonging either to the upper part of the Stockbridge limestone, and thus of Trenton age, or else belonging to the Berkshire schist horizon, and then of Hudson River age." In his later publication ('09, p. 35) he connects this belt with the outcrops of limestone about Chatham (on the next quadrangle south of the Troy quadrangle, that is, the Kinderhook quadrangle) from which Bishop ('86 and '90) and Foerste have reported the occurrence of Trenton fossils.

The belt of Trenton limestone in the capital district has no connection whatever with the other Trenton rocks of the belt, either the Rysedorph conglomerate or the Snake Hill beds (see p. 130). It is entirely isolated, as is well brought out by the diagram, furnished by Dale and Prindle. In the south, however, it connects with the "Hudson schist," a broad belt of metamorphosed shales and grits, possibly of Normanskill and Snake Hill ages. Likewise the Trenton area north of Chatham is connected eastward with the Hudson schist, and separated westward by the Lower Cambrian rocks from the Normanskill and other Ordovician rocks.

It is likewise worth noting that the gray limestone of this belt is not clearly recognizable as a constituent of the Rysedorph conglomerate; we believe, because it is younger than the Rysedorph conglomerate. Nor is it clearly referable to the Stockbridge limestone, although by its connection with the Hudson schist it might seem to have relation to it, for the Stockbridge limestone is not only

a thicker formation, but also undoubtedly older and rather to be correlated with the Bald Mountain limestone.

There are, however, outcrops of thin belts of similar limestone, farther south, as James O. Kimball ('90) finds such thin belts of limestone intercalated with argillaceous shales and continuous with calcareous grits overlying conformably the "Hudson River shales" at Burden, Columbia county, and they may continue intermittently as far as the Poughkeepsie quadrangle.

We propose to term this isolated limestone formation of Trenton age the "Tackawasick limestone and shale," to make it amenable to correlation and discussion as a unit.

28 Snake Hill beds. This formation was first distinguished by the writer from the "Hudson River formation" in the neighborhood of Albany ('01) and referred to partly as middle Trenton shale and partly as Utica shale and later correlated with the Magog shale of Canada. Mainly on account of the large and distinctive faunas obtained around Albany, Green Island and Cohoes (figure 67), and especially at Snake hill on the shore of Saratoga lake, these beds have more recently ('12) been considered as a separate formation by the writer and named the "Snake Hill beds" from the most fossiliferous outcrop.

Lithologically, the formation is similar to the Normanskill beds but it lacks the strong development of the grits and white-weathering chert beds as distinct divisions, although both are present in thinner intercalations. Besides, it possesses a conglomerate with characters peculiar to itself. The preponderating portions of the formation, however, are dark gray to black, bluish and greenish gray argillaceous shales which are difficult of separation from the Normanskill shales, save by the inclosed faunas.

The argillaceous shales prevail so much in the Snake Hill formation that we have not observed in the capital district any thick grit beds.

Black, carbonaceous, graptolitiferous bands or seams are more frequently found than in the Normanskill shale, but they contain a much impoverished graptolite fauna as compared with that of the Normanskill formation. On the other hand, small lamellibranchs, gastropods, brachiopods and trilobites are frequently seen in the shale, while but only traces of such have been observed as yet in the Normanskill shale of New York.

The dark shales not infrequently contain thin, sandy bands and still oftener intercalations of sandy limestones and also gray crystal-

line limestone, reaching half a foot in thickness. These bands frequently contain a faunule of brachiopods, crinoid joints etc., and they have furnished the great number of fossils, other than graptolites, recorded by the writer in New York State Museum Bulletin 42. Frequently concretions of both limestone and clay are found scattered or more or less obscurely arranged in layers. Lines of such projecting concretions are well seen traversing the gorge at Cohoes.

Owing to the extreme pliability of the argillaceous shales and the lack of strengthening intercalations of grits etc., the Snake Hill beds are, as a rule, intricately contorted and crumpled and cut by cleavage planes and smoothed slip planes until they have the character of the shales which were termed by the geologists of the first survey "glazed" and "semimetamorphic" shales. These shales so designated were Snake Hill shales of the Hudson valley.

There seems to be a gradual change in lithologic characters southward from the Saratoga and Schuylerville quadrangles, whence the formation was first fully described. It is obvious that also in the capital district the bluish gray, argillaceous, often sandy and slightly micaceous shales greatly prevail. Still occasional grit beds, several feet thick are seen, but more characteristic of the formation are thin (two to three inches thick) layers of cross-bedded reddish and pink micaceous sandstones, that weather yellow and are sometimes associated with rusty-weathering shale. These beds are especially seen in the uppermost division of the thick formation south of Ballston. On the surface the grit beds are most liable to appear, because of their greater resistance, although but widely scattered in the shales.

The thickness of the formation is obviously great. As it is much folded and crumpled almost throughout the belt, it is hard to get estimates. There is, however, a continuous outcrop of Snake Hill shales exposed along Anthony kill from the little hamlet of East Line to Round lake. The distance is three miles and the dip 11° E. 20° S. Disregarding the slight divergence of the section from the dip direction and the grade of the creek (only 60 feet in the whole distance), the thickness of the section appears to be above 3000 feet. Extending this rate of thickness to the whole width, we would obtain a still greater thickness, but it is obvious that the folded portion east of the section should be discounted. There remains still another mile from East Line to the Schenectady beds, which may add another 1000 feet. We therefore consider 3000 as a minimum measurement.

The Snake Hill shales form the broad belt of shales between the Normanskill and Wappinger limestone at the Hudson river bank and

the Skunnemunk mountains, a fact which in itself already indicates a considerable thickness. Ries ('95, p. 401), and more recently Holzwasser ('26, p. 65), have computed a thickness of 1500 to 2000 feet for these shales in Orange county, mainly by comparison with the Trenton limestone. Although the belt is much folded, we consider this a minimum figure in view of the width of the belt, which is over 20 miles.

The fauna of the Snake Hill beds is a fairly large one, and the beds have afforded a number of strange fossils not found elsewhere. The principal localities that have furnished fossils north of the capital district are: Snake hill on the east shore of Saratoga Lake and the shales along the shore, especially north of Snake hill (Ruedemann, '14, p. 96ff). In the capital district are a number of localities that at times have afforded excellent opportunities for collecting, but are not any more accessible. Others still available are the following: Waterford (Ruedemann, '01, p. 514); Block Island, Cohoes (*ibid,* p. 516); Hudson Light and Power Co., two miles below Mechanicville (*ibid,* p. 519); North shore of Green Island (*ibid,* p. 525); East shore of Green Island (*ibid,* p. 526); Railroad cut at Menands (*ibid,* p. 527); Black rock cut on New York Central at North Albany (Beecher, '89, p. 502); Foundations for penitentiary, Albany (Ruedemann, '01, p. 530); Watervliet arsenal (Whitfield, '75); Fitzgerald's quarry, Port Schuyler (Ruedemann, '01, p. 534); Brothers quarry, South Troy, (*ibid,* p. 536). The writer was also able to collect very fine material when the ground was graded for the Delaware and Hudson shops at Colonie, south of Watervliet and for the felt mill in North Albany. Such temporary collecting fields may be opened at any time by building operations in the neighborhood of Albany.

The combined list of fossils obtained at these localities with the identifications brought up to date is as follows:

Graptolites:
Dicranograptus nicholsoni *Hopkinson*
Corynoides gracilis *Hopkinson*
C. calicularis *Nicholson*
C. curtus comma *Rued.*
Diplograptus (Glyptograptus) amplexicaulis (*Hall*)
D. amplexicaulis *var.* pertenuis *Rued.*
Climacograptus typicalis *Hall*
C. spiniferus *Rued.*
C. caudatus *Lapworth*
C. strictus *Rued.* (putillus *auct.*)
Cryptograptus tricornis insectiformis *Rued.*

	Lasiograptus eucharis (*Hall*)
	Glossograptus quadrimucronatus *mut.* pertenuis *Rued*
	Dawsonia campanulata *Nicholson*
Cystoids:	Edrioaster saratogensis *Rued.*
Machaeridia:	Lepidocoleus jamesi *Hall & Whitfield*
	Turrilepas (?) filosus *Rued.*
	(Pollicipes) silurícus *Rued.*
Crinoids:	Glyptocrinus *sp.* cf. decadactylus *Hall.* (joints)
	Heterocrinus (?) gracilis *Hall*
	Cremacrinus *sp.*
	Carabocrinus *cf.* radiatus *Billings* (plates)
	cf. Schizocrinus nodosus *Hall* (joints)
Worms:	Pontobdellopsis cometa *Rued.*
	Serpulites magnus *Rued.* ('16, p. 88)
Bryozoans:	Paleschara ulrichi *Rued.*
	Pachydictya acuta *Hall*
	Prasopora *sp.*
	Escharopora *cf.* angularis *Ulrich*
Brachiopods:	Leptobolus *cf.* insignis *Hall*
	Lingula curta *Conrad*
	Trematis terminalis (*Emmons*)
	T. punctostriata *Hall var.* minor *Rued.* ('19, p. 103)
	Schizambon albaniensis *Rued.* ('19, p. 105)
	Pholidops *sp. aff.* subtruncata *Hall*
	Schizocrania filosa (*Hall*)
	Plectorthis *cf.* whitfieldi (*Winchell*)
	P. plicatella Hall (probably *var.* trentonensis *Foerste*)
	Dalmanella rogata *Sardeson*
	Plectambonites sericeus (*Sowerby*)
	Rafinesquina alternata (*Emmons*)
	R. deltoidea (*Conrad*)
	Plaesiomys retrorsa *auct.*
	Clitambonites americanus (*Whitfield*)
	Rhynchotrema increbescens (*Hall*)
	Platystrophia *sp.*
	Parastrophia hemiplicata *Hall*
	Triplecia nucleus (*Hall*)
	Zygospira recurvirostris (*Hall*)
Pelecypods:	Colpomya faba (*Emmons*)
	Clionychia undata (*Emmons*)
	Whiteavesia cincta *Rued.*
	W. cumingsi *Rued.*

Orthodesma ? subcarinatum *Rued.*
Whitella elongata *Rued.*
Clidophorus ventricosus *Rued.*
C. foerstei *Rued.*
Ctenodonta levata (*Hall*)
C. declivis *Rued.*
C. prosseri *Rued.*
C. recta *Rued.*
C. radiata *Rued.*
C. subcuneata *Rued.*
Lyrodesma schucherti *Rued.*
Solenomya ? insperata *Rued.*
Cuneamya acutifrons *Ulrich*

Gastropods: Archinacella orbiculata (*Hall*)
A. patelliformis (*Hall*)
Sinuites cancellatus (*Hall*)
Tetranota bidorsata (*Hall*)
Kokenospira rara *Rued.* ('19, p. 106)
Cyrtolites *cf.* retrorsus *Ulrich & Schofield*
Cyclonema montrealense *Billings*
C. cushingi *Rued.*
Clathrospira subconica *Hall*
Liospira americana *Billings*
(Pleurotomaria lenticularis *auct.*)
Lophospira bicincta (*Hall*)
L. uniangulata Hall *var.* abbreviata *Hall*
Cyclora *cf.* minuta *Hall*
Cyclospira bisulcata (*Emmons*)
Pterotheca *cf.* canaliculata (*Hall*)

Pteropods (supposed): Conularia trentonensis *Hall*

Cephalopods: Spyroceras bilineatum (*Hall*)
S. subannulatum (*D'Orbigny*)
Endoceras proteiforme *Hall*

Crustaceans (mostly trilobites and ostracods): Eoharpes ottawaensis *Billings*
Trinucleus concentricus (*Eaton*)
Cryptolithus tesselatus *Green*
Proëtus undulostriatus (*Hall*)
Calymmene senaria *Conrad*
Bronteus *sp. nov.*
Isotelus gigas *Dekay*

Pterygometopus callicephalus (*Hall*)
Ceratocephala (Acidaspis) trentonensis *Hall*
Ctenobolbina ciliata (*Emmons*)
C. ciliata *var.* cornuta *Rued.*
C. subrotunda *Rued.*
Technophorus cancellatus *Rued.*

No one seeing the great masses of barren shales of the Snake Hill beds would expect to find a fauna of almost a hundred species in them. It is true that, aside from the graptolites which are more widely distributed, the fossils are mostly found only in restricted layers or in small areas or "nests." It is further notable that the fauna consists everywhere of small forms, or small individuals of larger species. It is a pronounced "microfauna" like that of the Utica shale, and the cause of this is quite clearly to be sought in the unfavorable conditions produced by the rapid deposition in a relatively narrow basin of great quantities of mud, argillaceous and sandy. Under these conditions it is no wonder that this fauna, right under the feet of the most active geologic state survey of the United states remained practically unnoticed for 70 years.

The most common graptolites are *Dicranograptus nicholsoni, Diplograptus amplexicaulis* and its variety *pertenuis, Climacograptus spiniferus* and the species of *Corynoides.* It is, however, to be noted that few of these are found associated, but practically each is in certain localities present to the exclusion of others. Thus *Dicranograptus nicholsoni* is extremely common north of Snake hill, *Diplograptus amplexicaulis* var. *pertenuis* was found in great number at the site of the Watervliet arsenal, *Glossograptus quadrimucronatus pertenuis* on Van Schaick island, *Corynoides curtus comma* at Mechanicville, etc.

The Snake hill beds have in common with the Canajoharie shale the occurrence of *Diplograptus amplexicaulis* and *Corynoides calicularis,* but otherwise bear in both the graptolite and nongraptolitic biota a more distinctly easterly, Atlantic aspect. Here belong the shale on Van Schaick island with *Cryptograptus tricornis insectiformis* and the shale of Mechanicville with *Climacograptus caudatus and Corynoides curtus comma.* There is no doubt in our mind that these occurrences represent a zone that is older than any of the Canajoharie shale zones and that is equivalent or directly follows upon the shale exposed at Magog, for *Climacograptus caudatus* is found in Sweden only in the lowest of the three subzones of *Dicranograptus clingani* and it is also in Great Britain restricted to the zone

of *Dicranograptus clingani.* Not only do *Climacograptus caudatus* and *Cryptograptus tricornis insectiformis* indicate a low horizon and nearness to the Normanskill horizons, but also the outcrops where these fossils occur are close to the Normanskill belt. We have distinguished this earlier zone of the Snake Hill beds as the zone of *Cryptograptus tricornis insectiformis* and *Climacograptus caudatus* (Ruedemann, '19, p. 124).

In the large nongraptolitic portion of the fauna, the brachiopods, especially *Dalmanella rogata* and *Plectambonites sericeus,* and the pelecypods are the most commonly found. As the list shows, a large proportion of the pelecypods proved to be new species.

The fauna is undoubtedly a Trenton one and proves the early Trenton age of the Snake Hill beds (Ruedemann, '14, p. 99). It roughly corresponds to the lower, and perhaps part of the middle Trenton. It contains, however, a large independent biota of its own. The writer has described 26 new forms from this fauna; three others (*Archinacella orbiculata, Proëtus undulostriatus* and *Triarthrus becki*) are also restricted to or peculiar to this formation. The well-known fossil *Triarthrus becki,* which is currently credited to the Utica shale, was described by Green in 1832 from the "glazed shales" at Waterford, and is restricted to the Snake Hill and Canajoharie beds. The Utica form is the *Triarthrus eatoni* Hall. Besides, it has furnished such unique fossils as: (*Pollicipes*) *siluricus, Edrioaster saratogensis, Kokenospira rara, Eoharpes ottawaensis, Bronteus* sp. nov., and *Technophorus cancellatus.* This strange aspect of the Trenton fauna, quite different from that of the Trenton limestone, is undoubtedly due partly to the different facies and partly to the different marine connections, the Snake Hill fauna having lived in the Levis trough (see p. 163) that was more or less separated from the interior Trenton sea.

The possible occurrence of a thin shale intercalation with a Canajoharie shale fauna in the Snake Hill beds has been dealt with on page 31.

29 Rensselaer grit (figures 68–70). The only post-Ordovician formation that is found in the capital district resting upon the deposits of the eastern trough is the Rensselaer grit. Only the western margin, about two and one-half miles wide, of the Rensselaer grit area, that reaches a width of nine miles, extends into the capital district.

The Rensselaer grit has been fully described by T. Nelson Dale in 1893 in his paper on The Rensselaer Grit Plateau in New York, and again in 1904 (Dale, p. 39). Dale also proposed the name Rensselaer grit ('93) for the formation.

Since the Rensselaer grit plateau with its sharp escarpment on the west and north sides is a striking topographic feature and the extremely hard grit projects everywhere in cliffs on the hilltops, the rock formation was early noted. Eaton ('30, p. 73) noticed this great mass, called it "the greywacke of Rensselaer" and stated: "This coarse grey rock forms the basis of more than half the county. It is perfectly insulated, and lies upon the argillite like a huge turtle upon the beach; its back forming the middle and elevated part of the county." It appears from Eaton's further notes that he considered this mass as resting unconformably on the "argillite" (shales). Mather ('43, p. 384) stated later, however, that while it appeared from Eaton's statements that the graywacke of Rensselaer was "superimposed on the slate rocks *unconformably,*" his inference is, "It *may* be so situated, but I have seen no evidence that would lead to that conclusion." Also, other authors failed to separate this great mass that Eaton had recognized. Emmons ('43, '55) included it in his Taconic formation; Logan and Hall placed it in the "Quebec group," and Walcott in the Lower Cambrian or Georgian ('88, pl. III).

It was Dale ('93) who clearly recognized that the mass of Rensselaer grit rests uncomformably in the east on Berkshire schist and in the west on "Hudson River shale and limestone" and Cambrian rocks, the terrane forming a broad, much folded syncline.

As contacts between the Rensselaer grit and the subjacent formations are hard to observe, owing to the fact that they are usually buried under the talus slope, Dale ('04, p. 41) has carefully described two contacts, both in the capital district. One of these is a half mile north of Hoag Corners, in Nassau, about 400 feet east of the road to Alps. Here the red and green shale and Rensselaer grit are separated by an interval of only 150 feet from the typical red Cambrian shale with small quartzites. The other contact is in the town of Brunswick, where the road from Eagle Mills toward Davitt pond crosses the geologic boundary. Here a direct contact is observable, with a one-foot bed of roundish quartz grains in a cement of chlorite on the boundary.

Dale ('04, p. 43) describes the formation as being about 1400 feet thick and consisting of "dark green metamorphic grit with interbedded reddish and greenish shale or slate and conglomerate, containing pebbles of quartzite, marble, black silicious shale, grit, phyllite, all of Lower Cambrian age, some of them possibly of Ordovician age; also pebbles of gneiss and granite of pre-Cambrian origin." To

this may be added the following petrographic notes by the same author (Dale, '04, p. 39):

Its petrographic characteristics, in brief, are as follows: A dark green, tough, generally thick-bedded, often calcareous, crystalline, granular rock, with visible quartz and feldspar grains, and traversed by veins of quartz, in places of epidote and calcite. This rock alternates with beds of purplish, reddish or greenish slate or shale. . . . In some places the grit contains beds of conglomerate up to four feet in thickness, with pebbles of quartz, orthoclase, plagioclase, microcline, granitoid gneiss or granite (with the same feldspars), fine grained gneiss, and rarely chloritized diabase or gabbro, together with pebbles of the following sedimentary rocks: Quartzite (white, black or red), greenish phyllite, siliceous shale and fine grit . . . . granular and crystalline limestone, and cryptocrystalline quartz . . . the diameter of these pebbles does not usually exceed an inch, but the quartzite sometimes attains two inches, the limestone four, and the gneiss in one case measured 12 by 8 by 3.[1]

We have little to add to this excellent description. There are several belts of red and green shale or slate exposed in the capital district, some reaching a thickness of almost 50 feet. The red slate is well exposed in the Poestenkill fall at Barberville, as well as along the north trending road just east of Davitt pond. It also appears in a road metal pit by the side of the state road at Quackenkill. A dull purple slate in this locality is, or has been used for making paint. The conglomerate, with its greenish groundmass and partly rounded, partly angular pebbles of reddish brown, purplish and white quartzite, cream-colored, reddish brown and deep red feldspars, forms a beautiful "pudding-stone" (figures by Dale, '93, pl. *C*). It is well exposed in the abandoned quarry south of East Nassau, in the southeast corner of the map, where also the red shale is well shown, and in less prominent development on the roadside a quarter of a mile below the hamlet of Quackenkill. The State Museum contains a magnificent block of this rock, which on its polished surface brings out the full beauty of the colored minerals.

The Rensselaer grit itself is shown in picturesque cliffs to the north of the Grafton road along the Quackenkill, and appears almost everywhere in the plateau either along the roads, or as low, rounded rocks in the fields and woods.

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[1] East of Quackenkill, near the road to Grafton, we also found pebbles of white-weathering Normanskill chert, up to three inches in diameter, in the conglomerate.

The rocks of the Rensselaer grit formation are distinctly metamorphosed, that is, changed considerably from their original mineral constitution. It is especially the groundmass or cement that contains minerals formed secondarily by crystallization under the influence of pressure and heat (regional metamorphism). These minerals are especially chlorite (giving the green color to the groundmass of the conglomerate), sericite, mica (muscovite), feldspar grains, epidote, secondary quartz and calcite.

Barrell, following a suggestion by Gilbert, has considered it probable that the strong metamorphism of the Taconic region is due to injected masses of granite that have not yet been exposed by erosion. Also the Ordovician and Cambrian rocks are strongly metamorphosed, south and east of the capital district, into schists (Hudson schists and Berkshire schists).

The Rensselaer grit no doubt once covered a larger area. This is indicated not only by its abrupt termination by erosion at the edge of the plateau, but also by outliers, one of which is situated southwest of the plateau at North Nassau. Others are beyond our map; one at Austerlitz (east-northeast of Hudson) is 12 miles south of the plateau. The origin and age of the Rensselaer grit are still in doubt. No fossils, except faint worm-trails (Dale, '04, p. 38) were found in the formation. Hence its correlation is entirely a matter of conjecture.

Eaton thought that the eastern portion of the terrane, which he termed the "Millstone grit and grey rubble," might be equivalent to the Shawangunk grit, a suggestion that was cited and not contradicted by Mather ('43, p. 382). Dale recognized that the Rensselaer grit, resting unconformably on folded Cambrian and Ordovician rocks, must be younger than Ordovician in age, assuming that it was the Taconic revolution at the end of the Ordovician that folded the rocks. Since it is itself folded, "to the post-Devonian or Carboniferous movement, which folded both Devonian and Silurian beds at Becraft mountain in Columbia county, must be assigned the folding and the metamorphism of the Silurian grit of the Rensselaer plateau." He assigned the grit to the Silurian, correlating it with the Oneida conglomerate and Medina. This important conclusion is best stated in his own words ('04, p. 53):

The geographical relations of the Rensselaer grit to the Silurian formations west of the Hudson river are shown on the Lower Hudson, the Hudson-Mohawk, and the central sheets of Merrill's geologic map of New York, It will be noticed that the northern edge

of the Rensselaer plateau is in nearly the same latitude as the boundary between the Silurian (Oneida-Medina) and the Ordovician (Hudson) in Herkimer county, and that its southern part is in line with the southern continuation of the same boundary along the Kittatinny mountain. The plateau thus lies at the apex of the angle formed by the receding shore line of Silurian and Devonian time, as indicated by the outcrops. The west-northwest and east-northeast strikes at the north end of the plateau and the east-northeast one in the Hudson shale on Mount Rafinesque are either related to the general movement which resulted in the general east-west course of the boundary between the Ordovician and Silurian across the State of New York, or else are due to transverse folding. For all these reasons it may be assumed that the grit mass now forming the plateau was near the end of the Silurian bay; but in the Taconic range, in the northern half of Rutland county, Vt., about 57 miles north-northeast of the northern edge of the plateau, lies another mass of grit and conglomerate, also containing pebbles of Cambrian quartzite and overlying the Hudson schist, but only about 500 feet in thickness, and covering not quite four square miles. The bay of Silurian time may thus possibly have sent an arm up the Champlain valley.

Hartnagel ('07, p. 51), in his study of the formations of the Skunnemunk mountain region, came to the conclusion that the Rensselaer grit must be younger than the Oneida conglomerate and that the sea did not cover the region "after the Green mountain uplift until later Upper Siluric or Devonic time." He bases his conclusion on the following arguments: (1) The extensive gap by nondeposition between the eastern terminus of the Oneida conglomerate in Herkimer county, and the Rensselaer grit plateau; (2) the long time interval which must be postulated to account for the Taconic folding and the erosion that preceded the deposition of the grit; (3) the gradual transgression northward of arenaceous sediments over the eroded folds, the Shawangunk grit being a more southerly and hence earlier representative of such transgression. (Clarke, '08, p. 159, from report submitted by this writer).

In preparation of his great memoir on the Devonian of New York and Eastern North America, Doctor Clarke became interested in the Rensselaer grit problem, and asked the writer in 1906 to make a cursory study of the Rensselaer grit for evidence as to its age. The writer was as little successful in finding fossils other than worm-trails as his predecessors in the field had been. Some supposed plant remains turned out to be of inorganic origin. No beds younger than the Trenton were found underlying the Rensselaer grit, nor were there any traces of outliers found bridging the gap between the Austerlitz outlier and Becraft mountain, the well-known Devonian

outlier near Hudson, Columbia county. The crucial locality for the correlation of the Rensselaer grit, however, was seen on top of the Austerlitz outlier; for here the writer found the Rensselaer grit on the mountain height, high above the Becraft Silurian and Devonian outlier only nine miles away and down in the Hudson valley, and across the river the mounting heights of the Catskills, only 30 miles away, and composed of Upper Devonian. It is obvious at this locality that not any of the Silurian, Lower and Middle Devonian formations exposed in the Becraft outlier could grade in this short distance into the thick Rensselaer grit mass, while on the other hand, the conclusion is forced upon the viewer of the situation, that the Rensselaer grit must have reached across and over these buried lower formations to the Catskill formation. Doctor Clarke published the writer's conclusion ('09, p. 159) as follows:

The region of the Rensselaer grit has recently been carefully searched for fossils but though this evidence still fails and its absence can not be explained by secondary changes in the rocks, the stratigraphic considerations indicate the propriety of assigning a distinctly later than Medina age to this formation.

Near the edge of this plateau no beds of later than Trenton age have been observed and there are apparently no outliers to bridge the gap between the later Siluric and early Devonic outliers of Becraft mountain, Mount Bob and the southernmost outliers of Rensselaer grit in the town of Austerlitz, Columbia county. This last-named outlier is of especial interest as it lies but 20 miles northeast of Becraft mountain and is a considerable distance south of the main Rensselaer grit plateau. For these reasons it has been closely studied but found to be in no way lithologically different from the grit of Rensselaer county at the north containing the same alternations of grit with red and greenish slates.

From the presence of only the closing stage of the Upper Siluric at Becraft mountain and in the Helderberg near Albany, (Countryman hill)—the two places where the deposits of the Siluro-Devonic basin of New York approach nearest to the Rensselaer grit plateau—it may be properly inferred that the Upper Siluric sea of New York did not extend into the present area of the Rensselaer grit plateau at any time except possibly in the latest (Manlius) stage of that period. In regard to the latter, the problem is the same as in regard to the Helderberg limestones in general which are exposed at Becraft mountain and of which the Rensselaer grit might be conceived as representing the littoral facies. In favor of this view it may be said that both formations rest on the same basis (Cambric and Lower Siluric slate) and that on account of the rising of the Taconic mountains in early Siluric time, there may have existed a littoral facies of the Helderberg rocks to the east. But this view is strongly opposed by the fact that the Helderberg rocks do not show

any indications of approach to a littoral region at Becraft mountain, but retain the same lithologic characters over a vast area. There would hence have to be assumed an extremely abrupt and improbable change in facies in the short distance of 20 miles from Becraft mountain to the outlier at Austerlitz. A somewhat different case is presented by the Oriskany sandstone, Esopus grit and Schoharie grit which in some places, as at Whiteport and Kingston, contain conglomerate beds. It is altogether probable that the material of these conglomerates was derived from the south and the Oriskany sandstone is too thin a layer (30 feet) at Becraft mountain, to be correlated with the thick mass of the Rensselaer grit (1400 feet). It is, however, possible that the Esopus and Schoharie grits which at Becraft mountain have a combined thickness of 300 feet and are similarly barren in fossils, once continued northeastward into the Rensselaer grit trough. It must further be considered that the Rensselaer grit plateau represents a deposit in a long submeridional Appalachian trough. Its pebbles of coarse and fine gneiss came from a short distance and the numerous Lower Cambric pebbles probably came from places north of the plateau. Its deposits suggest those of an embayment receiving its materials from the north. The entire absence of the fossils occurring in the nearby Becraft mountain formations favors this conception of estuarine conditions.

The evidence compels us to grant that the Rensselaer grit is of later than Siluric age; there is some good reason for regarding it an eastern deposit contemporary with the early Devonic, but the alternative proposition stands open, that its estuarine character and great thickness suggest identity with the Catskill beds which stand sheer on the other side of the Hudson river in heights of several thousand feet and only 30 miles away from the outlier at Austerlitz.

The fact that the generally barren Catskill beds with their freshwater pelecypods (*Amnigenia* (*Archanodon*) *catskillensis*), late eurypterids (*Stylonurus excelsior*) and plants are undoubtedly fresh-water or brackish delta or estuarine deposits, that grade west and southward into marine beds, while northeast of them we find the still more barren Rensselaer grit, extending in a rather narrow belt far north (see Dale's exposure in Vermont and his suggestion that the Rensselaer grit extended into the Champlain Valley), together with the coarseness of the grit, its frequent plunge structure and oblique bedding, and the occurrence of conglomerate, interbedded in the grit in layers or only in nests and streaks—all these facts lead to the conclusion that the Rensselaer grit was deposited in a narrow north-south running trough, probably emptying into the Catskill bay and that the deposits are largely river and delta deposits.

The occurrence of fresh large feldspars in the conglomerate, as well as a variety of minerals in the grit, according to Dale ('04, p.

39), microscopic grains of quartz, orthoclase, plagioclase, and microcline feldspar, biotite, garnet, tourmaline, zircon, magnetite, ilmenite and epidote, all of which indicate an origin from plutonic rocks such as granite, that are found in the Adirondacks and Green mountains, clearly points to a northern derivation of the components of the grit. The freshness and the angularity of many of the feldspars further indicate a not very long or rapid transportation[1], and the irregularity of bedding in many of the grit beds suggests current action. Likewise the red shales indicate oxidation by exposure to air of the muds and hence shallow waters. All these facts mean to us that the Rensselaer grit is the product of a large river flowing from the north into the Catskill embayment.

STRUCTURAL GEOLOGY

The capital district in its structural geology is distinctly a segment of the Hudson valley-Lake Champlain depression, that extends from north to south between the Green mountain-Taconic folds in the east and the Adirondacks and Helderbergs in the west. It therefore shares its principal structural features with the whole physiographic unit.

Cushing and Ruedemann ('14) have fully described the structural geology of the Saratoga and Schuylerville quadrangles. The present chapter is largely only an application of the results obtained there to the southerly adjoining capital district.

In the structural history of the district we have to distinguish between three periods of folding and two of faulting, which formed the last phases of the two last periods of folding.

The first period of folding was Precambrian in age. It produced several long barriers, running in north-northeast to south-southwest direction across the district, and forming two or more troughs. Two of these troughs we have positively recognized and designated as the eastern and western troughs. They are characterized by their entirely different geologic series of formations, as we have fully set forth in the preceding chapter. The eastern trough is the one which

[1] Large, angular feldspars in sedimentary beds have been attributed to several causes. W. von Leszinski ('13, p. 501), has argued that they indicate periods of cool climate, because in another climate they would not remain undecomposed. He cites the arkoses of the Rotliegende, Lower Devonian arkoses of the Ardennes, and Lower Lias and Cretaceous rocks as instances. On the other hand, T. C. Chamberlin has repeatedly pointed to the preservation of feldspar in sediments as proving a lack of vegetation in Precambrian time and finally it is usually considered as explainable by close vicinity of disintegrating granitic rocks.

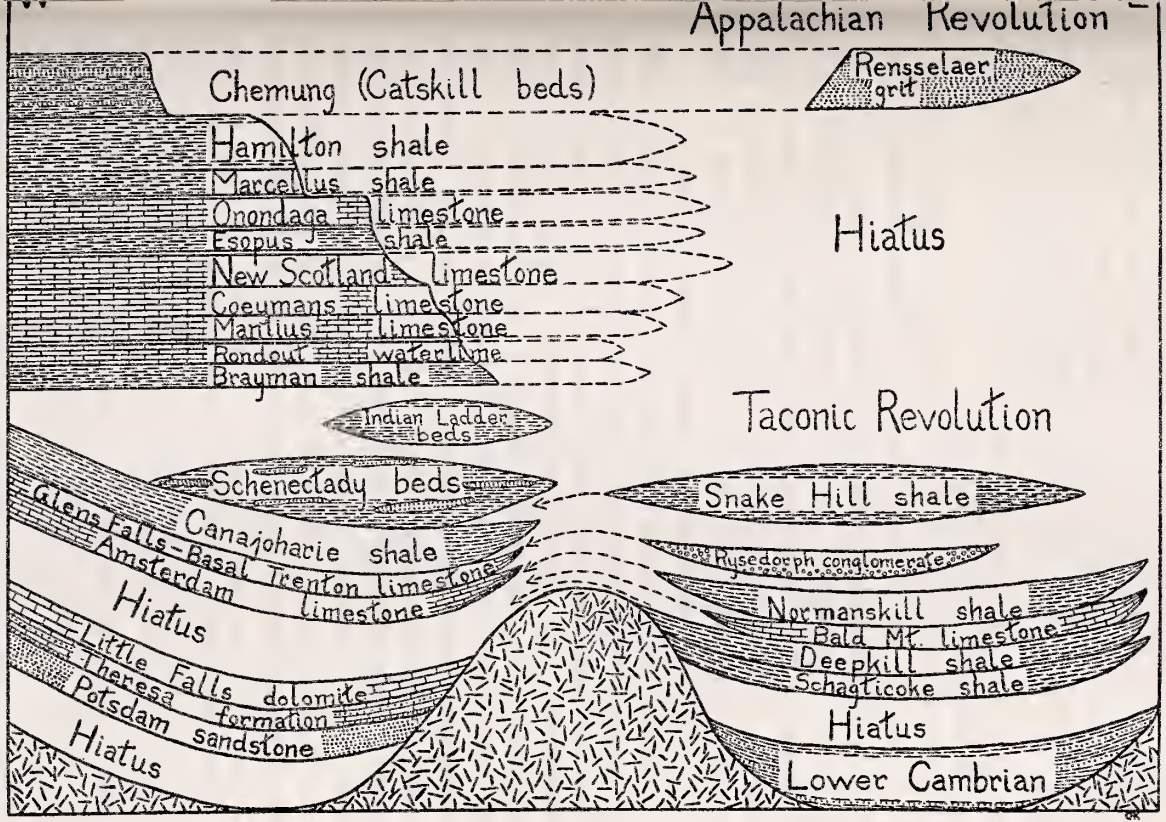

Figure 8 Diagram of successive events in geologic history of capital district, showing the eastern and western troughs of Cambrian-Ordovician age with the Precambrian barrier and their deposits, the hiatuses of nondeposition, the Silurian and Devonian deposits and their probable extension and the time of the orogenic revolutions

contains the Lower Cambrian beds and the long series of graptolite shales, the Schaghticoke, Deep Kill and Normanskill shales and the Snake Hill beds. Ulrich and Schuchert ('01) have termed this the Levis trough, from Point Levis in Canada, where the graptolite shales and other rocks of the trough are well exposed. It is bounded on the east by the Green mountain barrier, and on the west by the Quebec barrier. The latter separates it from the Chazy basin and its southern continuation which we have termed the western or Lower Mohawk trough ('14, p. 140).

The western trough (figure 8) contains the "normal series" of beds, namely: the Potsdam sandstone, Theresa formation, Little Falls limestone, Beekmantown and Chazy beds farther north, the Amsterdam limestone, Glens Falls limestone, Canajoharie shale, Schenectady shale, Indian Ladder beds and the Helderberg series of Silurian and Devonian formations. 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.

The Green mountain and Quebec barriers, delimiting the Lower Cambrian sedimentation, must have been present at the beginning of Lower Cambrian time and arisen, probably as low folds, in Precambrian time. 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 proterozoic 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 Scotis in the north, Appalachis in the south), which furnished the material for the great thicknesses of formations in the eastern trough.

These two troughs persisted through Cambrian and Ordovician time according to the record they have left in the sediments and fossils. They were, however, more or less independent from each other, so that one could be drained while the other was inundated; and a study of the diagram (figure 37) shows that they were drained in fairly regular alternation (see chapter on Historical Geology, p. 163, for details).

The second folding that affected the rocks of the capital district was the Taconic folding, named after the Taconic mountains on the New York-Massachusetts boundary line. This folding took place at

the end of the Ordovician period according to general assumption. It was believed to have extended over such a wide area in eastern North America that Dana termed it the Taconic Revolution. It has more recently been claimed by Clark ('21) that the Taconic folding, at the close of the Ordovician, was localized in eastern and northeastern New York State. 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 (see p. 151) 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 found, and often well shown. Dale (figures 10–15) has given excellent diagrams of a number of synclines from the Cambrian belt of the capital district that permit the making out of the succession of the beds, and we have inserted them here. The Snake Hill shales, which are much less competent than either the Cambrian or Normanskill beds, are uniformly thrown into a mass of closely packed, small, closed folds that are asymmetric and uniformly overturned or inverted to the west, so that on the surface and in sections where the tops of the anticlines are eroded away, the entire mass has an isoclinal structure, most beds dipping to the east with varying angles, averaging about 70°. This condition is, for instance, well seen in the Cohoes gorge. In places these shales are so contorted that they have the appearance of having yielded to the pushing by simply crumpling up. Open folds, however, occur here also, when heavier beds are present, as at Snake hill (figured by Mather, '43, pl. 11, figs. 10–12).

The folding dies out gradually towards the west (figure 7 and section *BB*). While Albany stands on steeply inclined and intensely

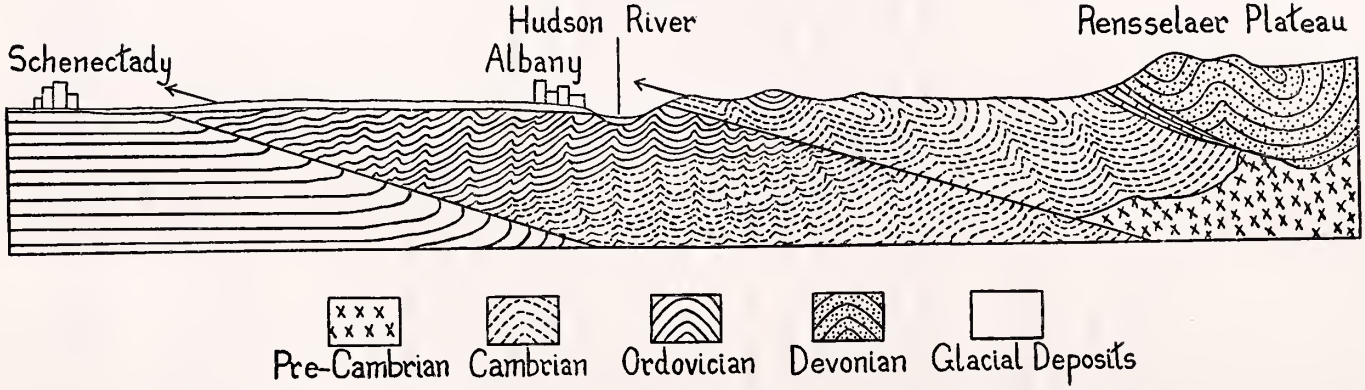

Figure 9 Generalized section through capital district to show folding and principal overthrusts (see section *A-A, B-B* and *C-C in folder*)

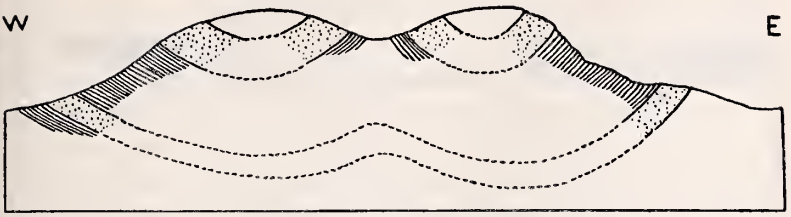

Figure 10

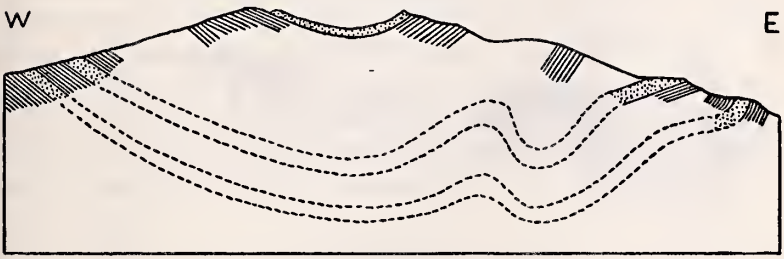

Figure 11

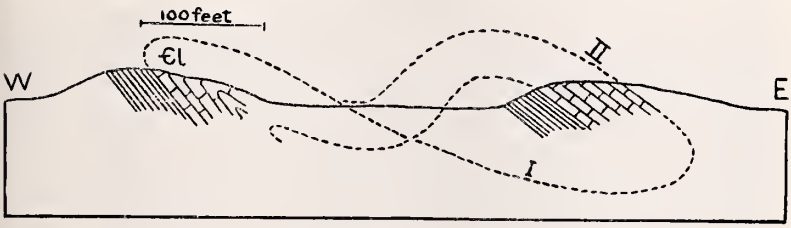

Figure 12

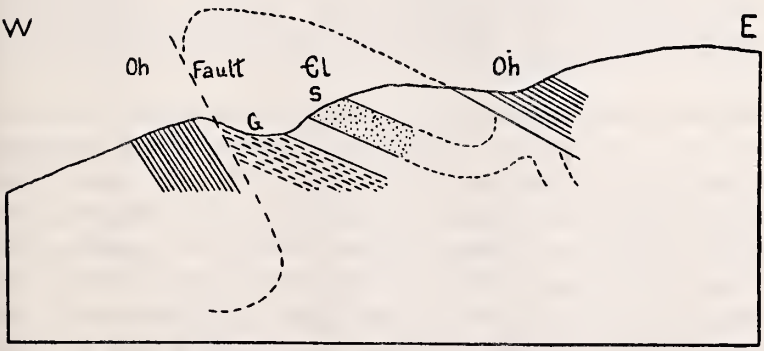

Figure 13
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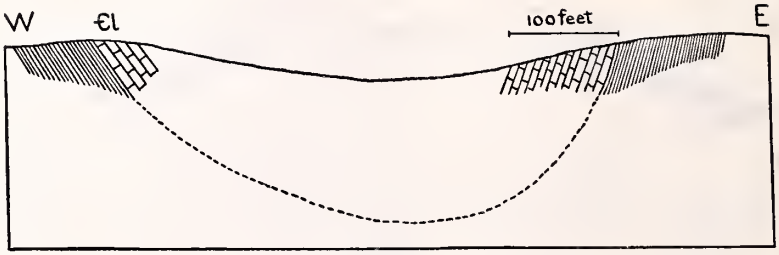

Figure 14

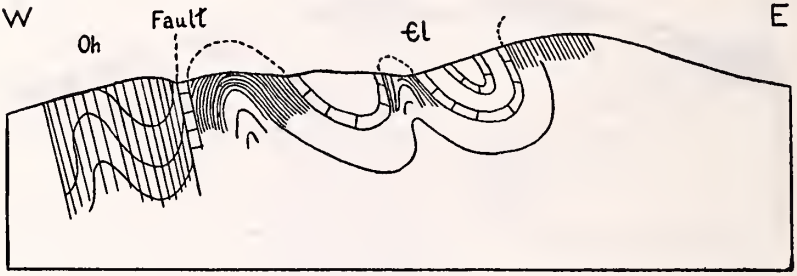

Figure 15

Figures 10-15 Series of folds observed by Dale, of Lower Cambrain rocks on Troy quadrangle (U. S. Geol. Surv. Bul. 242). Figure 10 Diagram section showing the general structure of the ridge between Tackawasick creek and pond and the Rensselaer plateau, in Nassau. Dotted beds quartzite; lined beds, shales. Height, about 200 feet. Figure 11 Diagram section through the southern part of Curtis mountain (Dusenbery ridge) in Nassau. Height, about 400 feet. Figure 12 Diagram section two miles east of Defreestville, in North Greenbush, showing two interpretations of the relations of the greenish shale to the Lower Cambrian fossiliferous limestone (*Cl*). Figure 13 Diagram section near Speigletown in Lansingburg, showing the general relations of the olive grit (*G*) to the Lower Cambrian sandstone (*Cl*) and the Ordovician shale (*Oh*). Figure 14 Diagram section two miles southwest of West Sand Lake, in East Greenbush, showing the relation of the Lower Cambrian limestone (*Cl*) and gray shale. Figure 15 Diagram section by Foerste, slightly modified by Dale, showing the probable general relations of the Lower Cambrian fossiliferous limestone (*Cl*) at Troy to the red and green shale (lined beds) and to the Ordovician shale (*Oh*).

folded beds, the shales along the Vly below Voorheesville are for the most part in flat position, but there are still fault-lines and small anticlines and synclines but a few feet high seen at the upper rapids below the mill. An excellent section from the folded into the unfolded region was formerly displayed along the canal and the Mohawk river between Cohoes and Rexford (figures 16–24). The damming of the river for the barge canal has unfortunately submerged many of the best outcrops. 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 (figure 16). West of this zone the Schenectady beds are undisturbed. It can therefore be stated as a general proposition that the rocks of the eastern trough are completely folded, while those of the western trough are in their natural position. In the Saratoga region Cushing and Ruedemann found that the rocks of the western trough were much disturbed by normal faults, as the ones at Saratoga, along which the springs come to the surface. If there are such faults in the capital district, where blocks through the action of gravity have sunk down along more or less vertical fault planes, they are buried under the glacial drift and not recognizable. Small normal faults were, however, observed in the Helderbergs (see p. 159).

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, both of which were already fully described by the writer from the Saratoga-Schuylerville regions in 1914 (p. 109 ff.) (see figure 9).

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. It is only by this movement that the deposits of the two different troughs could come in direct contact, as they do along the line. A considerable portion of the crumpling of the shales may be due also to this overthrust movement. The barrier which once separated the two troughs has been completely overridden.

This overthrust plane has nowhere been directly observed, not even in the section along the Mohawk river, where it would be most liable to appear. In its place appear a number of small overthrust planes. It is therefore our conviction that the overthrust is dissolved into a multitude of smaller overthrusts. We had already found clear evidence of this structure on the Schuylerville quadrangle

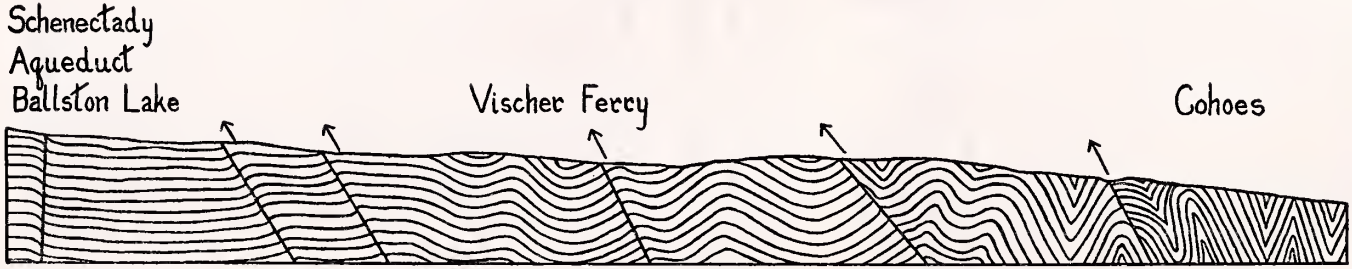

Figure 16 Diagrammatic section of the folding exposed along the Mohawk river and canal from Cohoes to Schenectady. From sketches by Mather ('43, pl. 2) and the author, made along the old canal.

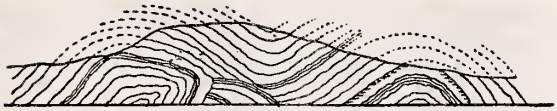

Figure 17

Figure 18

Figure 19

Figure 20

Figure 21

Figure 22

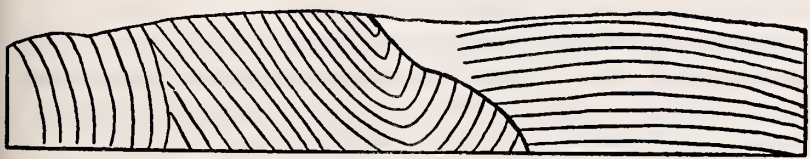

Figure 23
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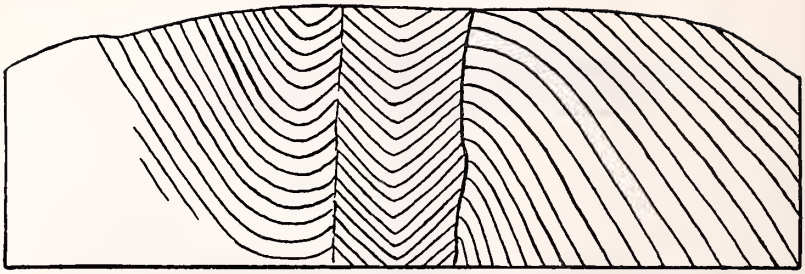


Figure 24

Figures 17–24 Sketches of structures along Mohawk between Cohoes and Schenectady, by Mather and Ruedemann. Figure 17 Section one and one-half miles northwest of Cohoes Falls (Mather). Figure 18 Section from the Island one-half mile west of Vischer's Ferry (Mather). Figure 19 Section one-half mile northwest of Vischer's Ferry (Mather). Figure 20 Two miles from Alexanders Bridge (Rexford), by Mather. Figure 21 Two miles west of Vischer's Ferry (Mather). Figures 22–24 Sections north and south of Mohawk river and in railroad cut, three miles northwest of Niskayuna (Ruedemann). The folds are flatter where competent beds (sandstone) prevail, and closely folded where shale predominates.

(Ruedemann, '14, p. 103). In a good east-west section through the Snake Hill shale along the Batten kill at Clark Mills, a whole series of such faults, about 10 to 20 feet distant from each other, were observed in the north wall and traced across the river bed. They all rise toward the west at angles varying from 20° to 45° and many are made conspicuous by calcite veins. The throw is always small, but the upthrow side is always pushed a little to the west.

While the throw of each of these overthrust faults is small, their accumulative effect, going from west to east, owing to their great number and uniform direction of throw, must be quite large. If we assume a throw of six inches for each fault and that they are 20 feet apart, we obtain for the belt measured from the foot of Willard mountain (on the Schuylerville quadrangle) normal to the strike, with a width of ten miles, a compound throw of 1320 feet. The effect of this accumulative throw would be to bring progressively older beds to the surface as one goes east. It is therefore possible that the position of the Normanskill belts to the east of the Snake Hill belts is due largely to this effect of the small overthrust faults which might be termed "multiple overthrusts."

Likewise the rather indistinct boundary of the Snake Hill and Schenectady beds is probably caused by the presence of numerous small overthrust planes at the boundary instead of one large one.

We have cited (Ruedemann, '14, p. 103) instances on the Saratoga quadrangle where the slickensides upon the thrust planes, and especially the direction of the slickenside scales, leave no doubt that the upthrow side had moved from east to west upon that plane. Some of these overthrust faults have clearly resulted from overturned folds (fold thrusts). The upper leg is seen in such cases to have been pushed westward beyond the lower. Some instructive examples of these were seen about Saratoga lake, especially on Snake hill. Most of these small faults ran with the general strike (north-northeast direction) of the beds or are *strike faults;* there were observed, however, some which cut the beds obliquely, as one at Victory Mills, striking N. 60° E. These deviations from the general north-northeast direction are probably connected with local irregularities in the general trend of the folds.

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 Hall and Normanskill on the other.

While our first observations on this progressive mode of overthrust were made on the Schuylerville and Saratoga quadrangles, the capital district also furnishes evidence that supports it. There is an overthrust plane that is nearly horizontal exposed on the west shore of Saratoga lake, a little north of the edge of the capital district. In the cliffs on the southwest shore of the same lake (on the Schenectady quadrangle) many such overthrust faults were observed, in one place four, each above the preceding. They all dip southeast, mostly at an angle of about 25° (figure 25). Another place where the small overthrusts were well seen, is the Brothers quarry in South Troy. Here they appeared in part as mere slickensided slip planes between the harder beds, and in part as slight excessive movement of the upper legs of the overturned anticlines.

A distinct belt of faults extends from Ballston Spa to Ballston lake. The Saratoga fault has been considered by Cushing and Ruedemann ('14) to continue through Ballston Spa, producing there the springs, inclusive of the well-known iron spring. This is a normal or gravity fault, one of the step faults of the Saratoga region, by which the country has sunk down in steps to the east of the Adiron-

Figure 25 Four small overthrust faults in Snake Hill shale in cliff on southwest shore of Saratoga lake.

dack massif. These faults are characteristic of the unfolded region to the west of the folded belt. On the other hand, the overthrust line separating the rocks of the eastern trough, with the Snake Hill on top, from those of the western trough, with the Canajoharie shale on top, was drawn by us to pass a mile east of Ballston Spa. A temporary outcrop in the village later showed us that the Snake Hill beds come into the village, and the boundary line should run farther west, as now continued on the map of the capital district. In that case the Saratoga normal fault and the Canajoharie-Snake Hill overthrust boundary come together at Ballston Spa; that is, the much younger Saratoga fault intersects the older overthrust line. A series of small faults can be seen south of Ballston Spa in the capital district, in evident continuation of the Saratoga fault. Two such small faults, striking N. 50° E., are found in the bed of the Mourning kill under the bridge of the Delaware and Hudson Railroad (Schenectady branch), one and one-half miles south of Ballston Spa. Another distinct fault line is seen a quarter of a mile east, where the Mourning kill turns north. All these faults are in the Snake Hill beds, possibly of small throw and normal faults. Another distinct fault line is seen 250 feet west of Ballston lake, in Forest Park, where the grit beds of the Snake hill stand vertical. Farther north it is seen that the beds on the east side are dragged and dip east, the rock having dropped on the east side of the fault. This fault was known to Emmons, who claimed that it had a great length and importance and was the cause of Ballston lake. Stoller ('11, p. 10) has also noted the fault line on the west side of the lake and inferred that "a preglacial stream heading to the north followed the course of the present Ballston channel, finding its bed in the line of vertical out-

crops of rock, and joined the Mohawk near Schenectady." He concluded that in glacial times the valley made by this creek was scoured out and enlarged by ice erosion and thus the Ballston channel produced. It is our opinion that the entire depression extending from Ballston southwest to Schenectady, and occupied by the Mourning kill in the north, Ballston lake and the Anthony kill in the middle and the Alplaus creek in the south, and furnishing an even grade for the Schenectady branch of the Delaware and Hudson Railroad, is caused by this zone of weakness, where the Saratoga fault has been divided into a "horsetail," or a number of secondary faults, which finally die out southward. The Schenectady-Snake Hill overthrust line, which is older than this group of normal faults, diverges from them at Ballston Lake.

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. While the continuity of this line is still doubtful and it is certain that it is of Paleozoic age, and long ago became inactive, after every earthquake in the East it is still revived by the press and even by geologists as the seat of the disturbance. After an earthquake the first question newspaper men ask geologists, at least in eastern New York, is, "Is it Logan's line?" It is not, and never will be.

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, how-

ever, 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. It has been described on page 113 as the *Poestenkill breccia.*

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 overthrust ('01, '09, p. 191), while Dale ('04, p. 293) 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. In 1913 the writer took the late Professor Rothpletz of Munich, a leading authority on the alpine "Decken" or "charriage" structures, to Bald mountain and was assured that the exposure had all the earmarks of an overthrust of the first order of magnitude. 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. The same observations can be made in Troy, as readily seen on the map, where Normanskill, Snake Hill and again Normanskill pass under the Cambrian rocks.

Another exposure of crucial importance in this connection is that at Grant hollow, where the Deep Kill section described by the writer is found at the bottom of the gorge, while the hills both north and south of the gorge are composed of fossiliferous Lower Cambrian. This occurrence is further of great interest because it connects the Ordovician shale belt, west of the overthrust line, with the large Mount Rafinesque-Rice mountain "outlier." If the Georgian rocks overlie the Beekmantown graptolite shale at Grant hollow, it is probable that this outlier is really a "fenster," or a portion of the Ordovician rocks underlying here the Cambrian mass that is exposed by erosion (see p. 145ff).

The exposure at Schaghticoke is also very instructive. There the Schaghticoke shale is exposed at the bottom of the river and in the river bank, but the hills to the north and south of the gorge, in the general strike of the rocks, consist of Cambrian beds. These oldest graptolite shales here lie clearly under the Cambrian.

An exceedingly fine exposure of the Cambrian-Ordovician overthrust is afforded in the gorge of the Poestenkill (figure 26), where a mass of fault breccia, more than 50 feet thick, and containing Normanskill grit blocks 20 feet in diameter, separates the overlying

Cambrian rocks from the subjacent Normanskill beds (figures 62, 63 and 65).

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.

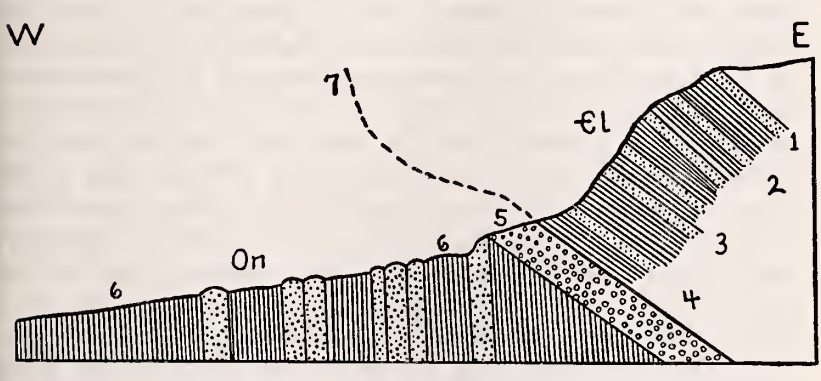


Figure 26 Section of the Poestenkill at the fall in Troy, showing the position of Logan's line (7) as seen on north wall overlain by the Cambrian red, purple and green slate with intercalated beds of sandstone (1–4), the one at 1 fossiliferous (Hyolithes, Hyolithellus); 5 is the mylonite (fault-breccia) bed; 6 the Normanskill shale with interbedded Normanskill grit.

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 which is considered responsible for the principal folding and overthrusting of this region. Such later folding, probably of Carboniferous age, is shown by the folded condition of the Rensselaer grit (see p. 148), and by the remnants of the folded and overthrust Devonian limestones still found farther down along the Hudson river, as at the Vlightberg at Kingston and Canoehill at Saugerties.

A problem that is closely connected with the extent of the great eastern overthrust is whether the "outliers" in the Cambrian east of the river are regular outliers, that is, masses of Ordovician rocks

normally resting upon the Cambrian and left by erosion of the continuous Ordovician cover, or "fensters" (windows), that is, exposures of the Ordovician, buried by overthrusting under the Cambrian and exposed by the erosion of the Cambrian. There are two such areas, the large one, already mentioned, of the Mount Rafinesque and Rice Mountain stocks, and a smaller one, west and south of Lake Aries (Snyder's lake). We have failed to find convincing evidence for either possibility in the structural conditions, owing to the complexity of the structures and the lack of sufficient outcrops. It is apparently an important fact in the understanding of both outliers, that they are more or less connected with cross folds; that is, while the general strike of the folds is N. 20° E., there are found in these areas east-west striking folds. The largest of them is that which gives Mount Rafinesque, east of Lansingburg, its form and direction. The strike of the rocks (E. N. E. to W. S. W.) is also on the map indicated by the east-west strike of the Beekmantown belt on the south slope of Mount Rafinesque. Also the Snyder's lake outlier is connected with a cross fold that just south of Wynantskill has thrown the Beekmantown beds, as well as the Lower Cambrian beds, into east-west strikes. Another cross fold is south of Albany, forming the ridge south of The Abbey (Glenmont), where the state road crosses the West Shore Railroad. Here the Normanskill beds (mostly white-weathering chert) strike east and west. Traces of this cross fold can still be noted across the river.

Whether these cross folds are due to local obstacles that threw the folds of the Taconian revolution into a secondary direction, as happens in folding, or are the result of the last folding of Carboniferous time, we do not know. If they are caused in the first manner, it is probable that the "outliers" are due to the projection upward of the Ordovician stocks into the Cambrian and are "fensters"; in the second case, they were folded long after the overthrusting and are merely erosion remnants, or true outliers. E. Kayser ('21, p. 238, footnote) has pointed out that in the Hartz mountains as in other mountain ranges local influences have produced oblique stresses and torsions of the rocks to such an extent that in places the strike has been turned by 90°. It is easily understood that such closely folded, incompetent beds as the shales of the eastern belt, would be readily turned aside by local obstacles, and this would therefore seem to be the most acceptable explanation of the cross folds in the belt.

There should be mentioned here one fact that appears to have a direct bearing on the question of these outliers. That is their

position in the upper part of the Lower Cambrian. We have shown before that in the Lower Cambrian of the capital district at least two belts could be discerned, one of the older divisions (Nassau beds) to the east, and one of the younger formations to the west. These have been marked on the map by different colors. It so happens that both of the outliers in question are found in the belt of the younger Lower Cambrian formations. It is obvious that this fact does not militate against their being outliers, while, on the other hand, if they were "fensters," they would have had to pierce both the lower and upper divisions, or the entire lower Cambrian, a rather improbable performance.

A fact of the greatest significance in regard to the structural relations between the Lower Cambrian and Ordovician near the overthrust line and in the direct continuation of the Mount Rafinesque-Mount Rice outlier or fenster, was observed by the writer when in 1903 the tunnel for the Troy waterworks was drilled from the Tomhannock reservoir west paralleling the Tomhannock-Melrose road on the south. The writer had occasion to study the tunnel in connection with some engineering problems and found that while the surface rock was greenish gray Lower Cambrian shale (and has been mapped as such by Dale), the rock in the bottom of the shafts was fossiliferous Normanskill shale. In shaft 1 (at *A* on map) the writer found at a depth of about 64 feet in the tunnels both east and west of the shaft black shale with large concretions, the shale containing Normanskill graptolites (*Climacograptus parvus, Corynoides curtus* etc.); west of the shaft the fossils were found in two places 50 and 108 feet from the shaft. Also shaft 4 (at *D* on map) furnished at a depth of 50 feet black Normanskill shale with graptolites (*Diplograptus* sp. *Climacograptus parvus, Dicellograptus sextans, Glossogr. whitfieldi*); and shaft 2 (at *B* on map) contained rocks of the lithologic character of the Schaghticoke and Deep kill shales, but afforded no fossils. Shaft 3 (at *C* on map) and the tunnels leading from it were drilled in greenish gray shale probably of Lower Cambrian age.

We have marked the site of the shafts on the map by the symbols *A, B, C* and *D,* a mile northeast of Melrose. The picture one obtains from the distribution and character of the rocks in the shafts and tunnel is that the Ordovician rocks continue from the outlier northward below the Cambrian surface rocks except perhaps for a narrow tongue of Lower Cambrian rocks, at shaft 3, pressed in between the "outlier" in the east and the belt of

Normanskill shale in the west. This observation, as well as that of the position of the Deep Kill shale at Grant hollow, are certainly very suggestive of a partial overriding, at least, of the Ordovician rocks of the outlier by Cambrian rocks.

The last folding is that which is typically displayed in the Rensselaer grit plateau. We have already seen that the Rensselaer grit is probably of late Devonian age. It is strongly folded, and this folding must be of later than Devonian age. There is little doubt that it is a manifestation of the late Carboniferous to Permian Appalachian revolution that folded the Appalachian system and whose influence is widely felt through New England and lower Canada, as well as in the Taconic and Green mountains. It has long been recognized that the Appalachian folding is markedly displayed in the much disturbed Lower Devonian rocks of the Hudson valley, as about Kingston, Catskill and, in lesser degree, the Becraft mountain. Weaker manifestations of the same force are seen in the capital district in slight folds and small faults in the Helderbergs (see p. 151). No doubt the Cambrian and Ordovician rocks, already strongly folded by the Taconic revolution, again felt the compressing and lifting force of the Appalachian revolution, but the effects are hard to recognize. We have already attributed to this cause the folding of the great overthrust plane and possibly the cross folds observed in the capital district.

The structure of the Rensselaer grit plateau has been carefully worked out by Dale ('93, p. 324), from whom we quote here freely. After showing that the Greylock mass, the Taconic range proper and the connecting East and Potter mountains are synclinoria, that is, compound synclines, composed of many smaller synclines, and the Berlin-Lebanon valley an anticline, formed of Stockbridge limestone (fig. 27), the grit plateau is described as a broad compound syncline. It is shown from the strikes that a syncline occurs a little west of the east edge of the plateau, that seems to continue northward into the schists. "In the hill of Grafton Center is an anticline, and at least one anticline occurs also in the slates and shales between Pittstown Corners and Hoosick Falls. Therefore at least one anticline probably runs through the center of the plateau." These localities are just beyond the eastern margin of the capital district map.

At one locality only (loc. 191, Bowman pond) were horizontal strata found, but others probably exist. It is quite probable that several gentle folds occur between the central anticline and the west edge. In the southwest corner conflicting pressures have

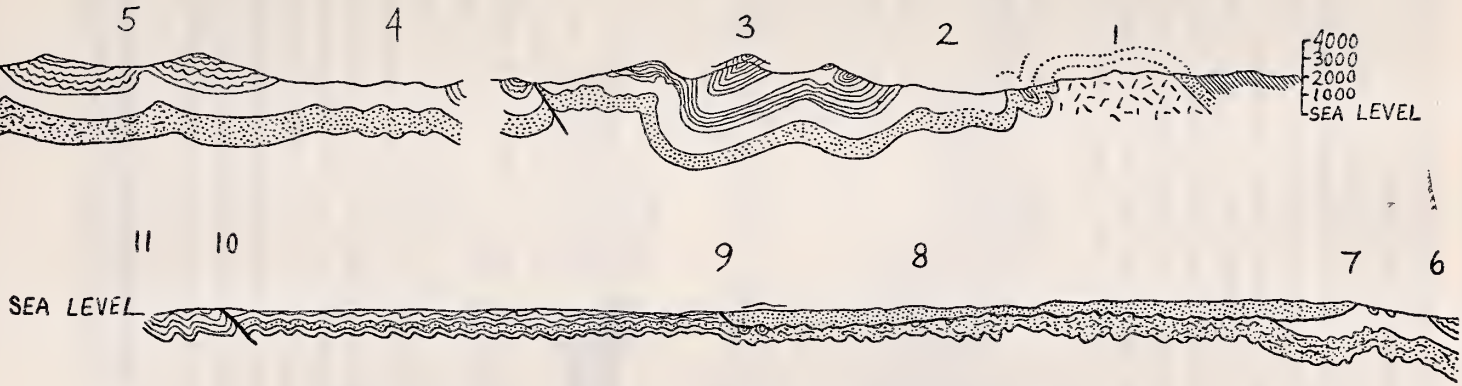


Figure 27 Cross section along line 1 of map, Hoosac mountain to Troy, N. Y. From Monograph U. S. Geological Survey, v. 23, Thirteenth Annual Report U. S. Geological Survey, and later observations, showing the relations of the granitic, granular, calcareous, schistose and shaly rocks. 1 Hoosac mountain; 2 Hoosic valley; 3 Mount Greylock with Ragged mountain on east and Mount Prospect on west; 4 South Williamstown valley; 5 Taconic range; 6 valley of the Little Hoosic; 7–8 Rensselaer grit plateau; 9–10 Cambrian shales of Hudson valley; 10 Ordovician shale; 11 the Hudson at Troy. The beds without symbols are limestone, dolomite, and marble. The granular beds pass westward into slaty and granular ones and these into shales and grits, west of plateau (from Dale).

operated [as shown by the confused strikes]. At the northeast end there are also abrupt changes in the strike.

The structure of the west edge of the plateau, as shown in the general section, was taken from between Barberville and Poestenkill, at the falls and in the gorge of the Poestenkill, and on Snake hill, loc. 202. The river at Barberville flows south for a space along the west side of a small anticline of grit and purple slate, and then making a sudden easterly turn, cuts through the top of the anticline [figure 68], flows into the adjoining syncline and then plunges down some 70 feet, cutting off the east flank of a low anticline, the layers of which dip at a small angle east [figure 28].

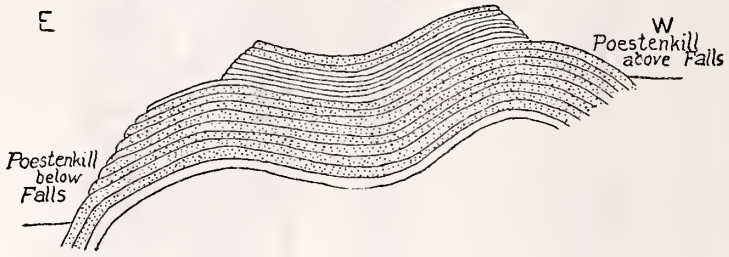


Figure 28 Section through the anticline at Poestenkill falls (see figure 68). Height between water levels about 150 feet. From Dale (U. S. Geol. Surv. 13th Ann. Rep't, 1891–92, pt 2).

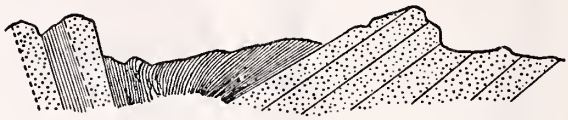


Figure 29 Syncline in Poestenkill gorge. Length, 150 feet. From Dale (U. S. Geol. Surv. 13th Ann. Rep't, 1891-92, pt 2).

. . . . . About 1000 feet west of Poestenkill falls, the grits and slates dip 15° E. and then 70° to 75° W., forming another anticline, which is closely followed by a sharp syncline, possibly accompanied by more folding [figure 37]. . . . The structure of the west edge of the plateau consists therefore plainly of at least two synclines and two anticlines, i.e., of several folds. Such folds have also been shown to exist east of Tackawasick pond (Pl. XCIX, G.), and the topography about Quacken kill points to a like structure [figure 68].

The general structure of the plateau consists therefore of a well marked syncline along its east side, a compound syncline along its

west side, and certainly one and probably several folds in the intervening area. It is a synclinorium six to nine miles wide and about 20 miles long, mainly of hard dense rocks with softer rocks underlying it on all sides. This synclinal structure is apparent in its narrower southwest portion.

We have little to add to Dale's exhaustive description of the structure, but wish to mention that more recent quarrying operations have in one case, the East Nassau quarry, (figures 69 and 70) exposed a fine recumbent fold and in another quarry, directly at the western margin of the grit plateau, at Poestenkill, beds that are practically flat, dipping but slightly east.

This last observation, which brings out a strong difference in dip with the adjoining Cambrian rocks, suggests the possibility of slipping along the boundary line, amounting in places to a fault. This would seem especially true of the southwestern edge, where the belt of Tackawasick limestone and shale appears from below the Rensselaer grit. It is hardly possible to assume there any other structure than faults on both sides of the limestone, making it a wedge brought out along a fault-movement. Dale's figure (copied here in figure 7) also suggests the same condition, and he has furthermore ('93, p. 314, 327) mentioned the possibility of a fault along the foot of the west side, which, however, is not great enough to bring up anything older than the Berkshire schist into contact with the grit.

Actual faults in the Rensselaer grit can be seen in the above-mentioned East Nassau quarry. One, an overthrust fault, of small throw, cuts the recumbent fold. Besides these, there are several normal faults of small throw seen in the quarry wall. In fact, the fold and faults and slipping along bedding planes and joints have broken up the rock into a mass of blocks.

Helderberg Folds and Faults

(Figures 71–77)

The Appalachian folding and thrusting which has affected the Rensselaer grit plateau and the Helderberg rocks of the middle Hudson valley, is but feebly displayed in the southernmost part of the Helderberg rocks of the capital district. It has already been well described from that region by Darton ('94, p. 447). He writes:

As the formations of the Helderberg mountains are brought down to the general country level, they extend to the east and south into a flexed region. The first features noticeable are a series of gentle

undulations which broaden the outcrop areas of the limestones and indent their edges into a series of *en echelon* offsets. These undulations enter the Helderberg area in succession from west to east, as it extends southward, along axes striking south ten degrees west, approximately, and pitching slightly in the same direction, which is diagonal to the general inclination of the monocline. In figures 4 and 5 [our figures 30 and 32] I have attempted to illustrate the nature of these features in the limestone area, for they are an interesting example of the beginning of the series of flexures and they explain the singular distribution of the Helderberg rocks in this portion of Albany county.

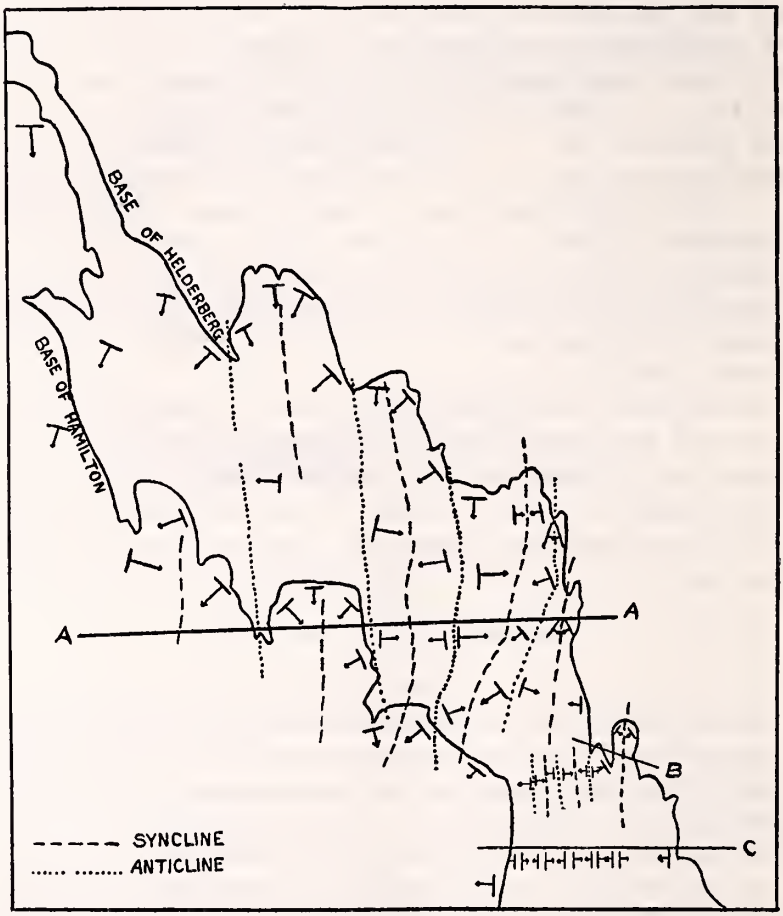


Figure 30

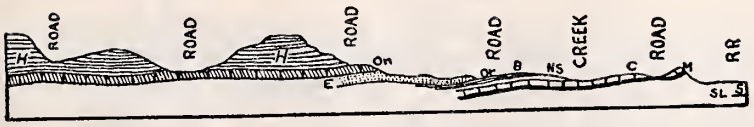


Figure 31

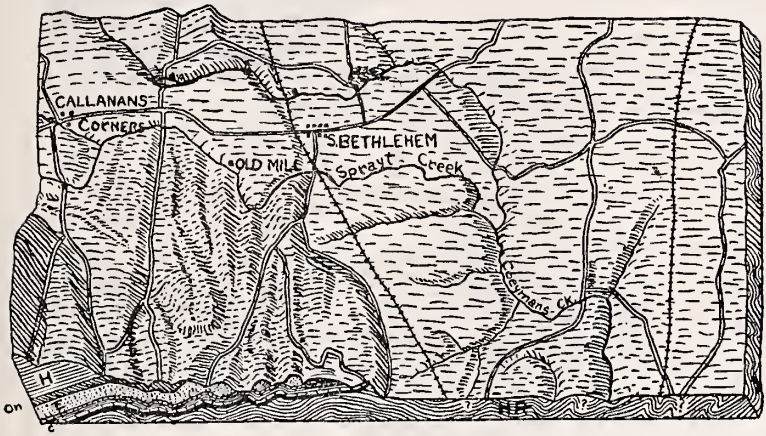


Figure 32

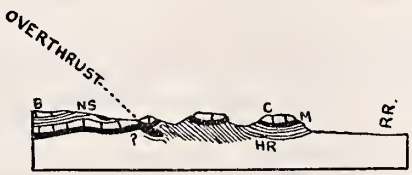


Figure 33

Figures 30–33 Figure 30 Diagram of a portion of Albany county to illustrate the undulations at the edge of the folded region, from New Salem southward. The length of the stems of the dip marks is inversely proportional to the amount of dip. *A-A,* section is given in figure 31; *B,* section in figure 32; *C,* section in figure 33. Figures from N. H. Darton (47th Rep't N. Y. State Mus., 1894). The anticlinal and synclinal lines in figure 30 have been added by the author.

It will be seen in these figures that the undulations increase in steepness to the eastward and finally become a succession of steep parallel folds which are of true Appalachian type.

One of the most noteworthy details of structure in southern Albany county is an overthrust of small amount, but with most interesting features. It is among the gentle flexures near the northern edge of the disturbed area in the Helderberg rocks. Its general relations are represented in the following section:

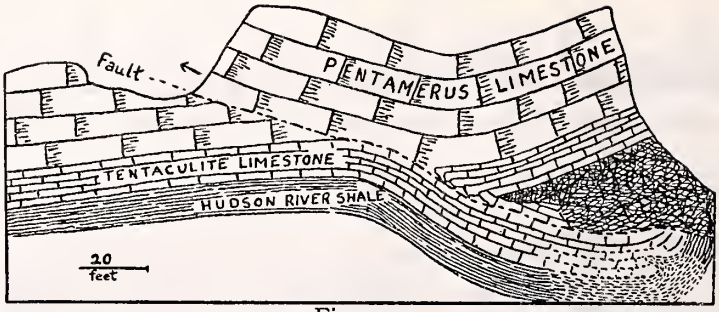
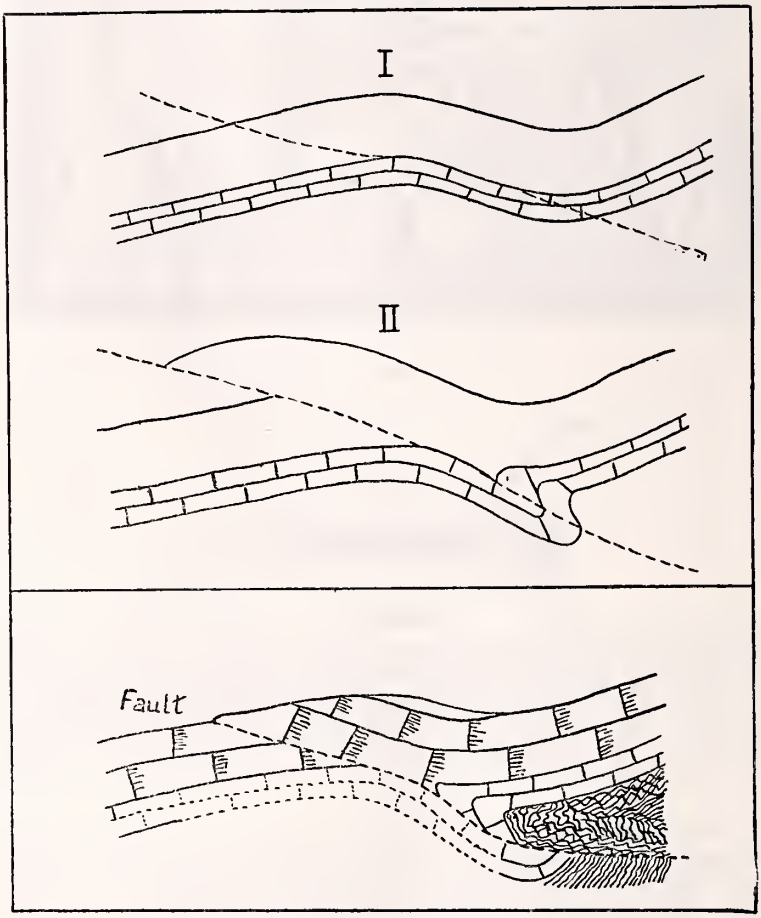


Figure 34



Figures 36 and 35

Figures 34–36 Figure 34 Cross section of overthrust west of South Bethlehem. Exposure on south bank of Sprayt creek. Looking north (reversed). Figure 36 Same overthrust, cross section seen on north bank. Looking north. Figure 35 *I-II*, Hypothetical sections to illustrate stages of development of the overthrust. All figures from N. H. Darton (47th Rep't N. Y. State Mus., 1894).

The characteristics of this overthrust are an "underturned" flexure in the thin-bedded underlying limestones, also involving the soft slate of the Hudson river formation, and a fault which offsets the flexure and traverses the hard, massive overlying beds of Pentamerus limestone. The overthrust is exposed only on Sprayt creek, which it crosses at an old mill about three-quarters of a mile west-southwest of the village. Its trend is north and south, but it does not appear to extend for any great distance. The principal features of the exposure at the mill are shown in plate 6, in which the inclosed wedge of slate is shown in the lower left-hand corner, the flat arch of the inclosing limestones in the middle of the view, mainly far to the right. The massive overlying series is the Pentamerus bed.

The relations of the mill and their interpretation are further illustrated in the following figures, in which the features above the broken-line portion of the sections are exposed in the bed and banks of the creek.

I discovered these overthrusts in the autumn of 1892 and sent a brief account of their relations to the Geological Society of America. [Published in the Bulletin, 4:436–39.] In 1893 I again visited the locality and on careful reexamination, under much more favorable conditions, found that the features were somewhat more complicated than I had first supposed.

It is unfortunate that the exposures are not more complete, but sufficient is seen, I believe, to substantiate the interpretation given in the figure. Only the upper portion of the "underturned" fold is exposed in the limestone, but the greater part of the fault plane is visible on the south bank of the creek above the dam. The enfolded slate is seen to be excessively crumpled and its original bedding planes obliterated, but the lower limestones bend over the arch with but little fracture. There has been considerable slipping along the contact of the slate, and the portion of the limestone which is folded under is considerably broken and contorted. At several points, as shown in the figure, fragments of the limestones have been torn off and are more or less surrounded by the slate.

In the north bank of the creek, under the mill, the exposure is less extensive, but the general relations are similar to those on the south side. The principal features in this exposure are shown in the following figure.

The mechanism of the overthrust is, I think, not difficult to understand, and I have represented the hypothesis of its development in the diagram in the above figure, I, being the first stage, II, the second stage and the present conditions the third stage. The broken line on I indicates the plane of weakness, the arrow the direction of thrust. The fault, sheared diagonally through the massive beds of Pentamerus limestone but the softer, thin-bedded underlying limestones in moving forward with the thrust were buckled downward and backward under the soft shales, as indicated by the arrows in II before they were also fractured. The lower limestones were also considerably broken and cross-faulted, as shown in the figures. The

amount of displacement of the overthrust is about 100 feet. The force was exerted from the eastward and almost horizontally in direction, unless the present low angle between fault line and axial planes is due to subsequent tilting.

This interesting little overthrust is, on a small scale, a duplication of the greater overthrusts described by Davis ('84) from Catskill; by Van Ingen and Clark ('03) from the Vlightberg at Rondout; and by Chadwick from Canoe hill at Saugerties ('10). Chadwick, in his paper (p. 160) infers that these "instances must at least appertain to the same set of movements, the same rift, extending along the entire eastern edge of the folded Appalachians as a constant and normal feature."

There is no doubt that small overthrusts are more frequent in the southern part of the capital district in connection with the folding than can be observed on the surface. For instance, two small overthrusts are well exposed in Callanan's quarry in South Bethlehem. Both fault planes dip eastward, the eastern portion being pushed over the western. The larger and more distinct one (figure 76) is seen in the western part of the quarry. It strikes about N. 50° E. and the hade or amount of movement is about 25 feet; the other, farther east, has led only to a slip of a few feet.

Two very distinct overthrust planes are now seen in the face of the South Albany quarry. These follow in the middle, where they are exposed in their strike, a low anticline. On the sides they are seen to rise westward and cut across the formations. Robert Jones, consulting geologist, advises that the quarries along the entire eastern Helderberg front exhibit these small overthrust planes striking as a rule true north 10° east and rising to the west. He finds that they appear to be mostly developed on the intersection of the low east-west folds with the regular north-south folds, these intersections being as a rule the sites of quarries.

Other small folds in the Helderbergs have been observed by Prosser at Clarksville (figure 75). He states ('99, p. 343):

Along the base of Bennett hill immediately south of the village are seen the northernmost traces of those flexures which are so apparent in these formations farther south (Appalachia 1884, 3: 20–33, plate). They consist of two slight folds and a small overthrust. The overthrust is in the gorge through the Onondaga above the village and may be plainly seen on its eastern side. There is a layer of Schoharie grit with Onondaga limestone dipping under it, eight or ten feet of the limestone being exposed, while above the Schoharie lies the regular thickness of Onondaga. A number of fissures filled with calcite, made no doubt when the overthrust occurred, may be

seen in the gorge. One of the folds consisting of a broad, low anticline, is very evident in the sides of the gorge through the Esopus shales below the village. The other fold is between the two gorges east of the home of Mr W. H. Rowe.

A further effect of these structures is the inlier of Esopus in the Onondaga limestone just south of Clarksville. The last and northernmost fold, a low anticline, is seen in the town of New Scotland quarry east of Wolf Hill. A little to the south of the capital district, as in the "High Cliff" near Coxsackie, the folds have already become so sharp that the beds approach in places a vertical position and the folds are of the type of closed folds, perhaps in connection with strike faults.

Three Stories of Folding in Capital District

In summarizing the orogenic revolutions of the past in the capital district, it can be stated that we have here distinctly three stories of folded rocks one above the other and each separated from the preceding by a distinct plane of unconformity and erosion. The oldest is that of the Precambrian rocks now deeply buried here but exposed in the Adirondacks to the north and the Highlands to the south. Its folding runs in NE-SW direction. Upon this first story rests the second, that of the Taconic folding, seen in the Cambrian-Ordovician rocks. It strikes N. 20° E. As the Precambrian rocks were stiffened by their folded conditions, they were little affected by the later folding. This second story is again cut off by a great plane of unconformity and erosion that is now seen at the base of the Helderberg cliff. Upon this rests the third story of folding, that of the Appalachian revolution, shown in the Helderberg and the Rensselaer plateaus. This folding probably also had but little effect upon the already closely folded underlying rocks. It strikes nearly north and south (see figure 30).

In other words, we have here the remains of three worn-down mountain systems, each erected upon the deeply eroded roots of the preceding, and each running in a somewhat different direction.

Cleavage

Connected with the folding of the shale belt of the capital district is the cleavage found everywhere in the rocks. Cleavage, or the parting of the rocks into thin plates, independent of the bedding, results from "a rearrangement of the particles of a deposit by pressure and a simultaneous arrangement of any new crystalline par-

ticles formed during that pressure. This arrangement of old and new particles is related to the directions of pressure and of resistance" (Dale, '99, p. 205).

As the cleavage is much more strongly developed in the shales than the bedding, it is often difficult to recognize the position of the beds, unless quartzite layers or differently colored beds or sandy streaks indicate the direction of the beds. As a rule, the cleavage dips toward the east, under various angles, indicating a pressure from that direction as is also indicated by the folds that are overturned to the west. Where shale alternates with heavy grit beds, as in the Rensselaer grit, only the shale possesses cleavage, the grit having been folded by the same compressive force that spent its energy in cleaving the shale.

A remarkable vertical fracture cleavage in the Coeymans limestone has been developed along the small fault, south of the Indian Ladder (see p. 160).

Strike and Dip

The folded and overthrust rocks of the eastern trough show a general strike to north-northeast (N. 20° E.), and, of course, a great variety of dips. As the folding dies out toward the west, the dip becomes more regular, and finally along the western margin of the capital district it can be considered as fairly steady.

It was found by Cumings ('00, p. 462) that the rocks west of the capital district dip south at the rate of 140 feet a mile. Farther east, approaching the Helderbergs in Albany county, the dip gradually changes to the southwestward, changing the east-west direction of the Helderberg escarpment, west of Albany, to a southeast direction east of Altamont. This southwest dip (amounting to 1° to 2°) is also found in the Schenectady beds of the district. Darton ('94, p. 446) found the dip in the Helderbergs, west of the capital district, on the Berne sheet, to be not more than 100 feet to a mile. About Thompson's lake and Indian Ladder it is reduced to an amount not over 35 feet a mile; it is, however, somewhat variable in that region by reason of the slight faults described below (p. 159). Darton shows that the dip, which averages 112 feet a mile, S. 10° W. in direction, "carries the outcropping edges of the (Coeymans) formation gradually downward along the face of the mountain, from an altitude of 1100 feet above tide south of Altamont to about 1000 feet at Indian Ladder and 660 feet a mile south of New Salem. To the southward, about Clarksville, the rate of dip gradually

decreases to 60 feet a mile, and its direction changes to due west. As the formations of the Helderberg mountains are brought down to the general country level, they extend to the east and south into a flexed region."

We have seen that the structural elements of the capital region are a system of folds in the east of three different ages, Precambrian, late Ordovician and late Carboniferous. Both the late Ordovician and the Carboniferous foldings of the region led to extensive overthrusts, by which portions of the folded regions were carried westward over unknown but possibly considerable distances. The Ordovician system of folds, produced by the Taconic revolution, may not extend far beyond the New York slate belt. It also produced, however, the two great overthrusts which (1) brought the formations of the eastern trough (Snake Hill-Normanskill beds) into contact with those of the western trough, the Canajoharie and Schenectady formations along the overthrust line, running from Ballston Spa to the Helderbergs, west of Feura Bush, and (2) pushed the Lower Cambrian beds over the Normanskill and Snake Hill beds along "Logan's line" east of the Hudson river. The last folding was that of the Appalachian revolution. Its effect is mainly seen in the strong folding of the Rensselaer grit, the gentle folds of the eastern Helderberg plateau and the final overthrusting of the Helderberg rocks, but feebly displayed in the capital district, and well shown in the middle Hudson region, from Saugerties to Rondout.

Normal Faults of Western Trough

We finally have as a last manifestation of the unrest of the crust in this region the normal or gravity faults in the western or otherwise undisturbed belt. We have already described the Saratoga fault, which enters the capital district at Ballston Spa. There are undoubtedly others in the belt of the Schenectady formation, but the monotony and thickness of the formation, as well as the scarcity of exposures, serve to hide them effectually.

Into this group, however, fall several normal faults that we have observed in the Helderbergs. Several of these escaped notice until the new state road to the Indian Ladder exposed them.

The first of these (no. 1 of map) is about one and one-half miles from the Indian Ladder not more than one-quarter of a mile from the edge of the capital district. This fault runs in a little ravine. It is distinctly seen at the edge of the cliff, where on the east side of the fault the top of the Coeymans is at 1155 feet, while at the west it

is at 1095 feet. There is thus a drop of 55 to 60 feet, the western side having been dropped. The fault runs about N. 30°–40° E. (magnetic). The fault line can be seen in the cliff, where about a decade ago a long section of the cliff broke off along a joint plane, producing a bare exposure and a long talus slope or rock slide, now visible from the roads in the plain. An interesting feature of this fault is the strong vertical cleavage that has developed in the Coeymans limestone and New Scotland beds along the fault and that is especially well seen in small cliffs in the woods a little ways back of the edge of the escarpment and to the east of the ravine.

Another small disturbance that is visible directly from the road, is situated three-quarters of a mile from the preceding locality in the direction towards New Salem. Here a block of Becraft limestone, about 90 feet wide, and bounded by two faults, running in northeast direction, has dropped 20 feet into the New Scotland beds on either side. At the edge of the cliff, where there is a reentrant distinctly visible from the plain and situated under Daniel O'Connell's house, one can also see the New Scotland dropped 20 feet into the Coeymans.

A third fault, already mapped by Darton, produces an offset in the Helderberg cliff one and one-quarter miles southeast of Feura Bush and only a quarter mile north of the South Albany Railroad quarry. The fault itself is expressed by a deep wooded ravine leading up through the cliff, in which sink holes and small vertical outcrops of Coeymans and Manlius are found, indicating the drag along the fault. The contact was not observed and the drop not established. This fault strikes about N. 30° E.

A small fault, with a drop of about 20 feet, is directly visible in the east end of the quarry, the eastern side having dropped there. To the right of it a low syncline, followed by an anticline, was excellently exposed in the summer of 1927.

Another zone of disturbance is located in the depression south of the quarry, where the road from Feura Bush leads onto the plateau. This road runs along, or just to the west of the bottom of a syncline, for in the depression to the east of the road the New Scotland beds are present, while the Coeymans to the east and west dips steeply toward the trough of the syncline (at 21°, resp. 11°). In the bed of the Oniskethau creek, a quarter of a mile to the southwest, a great mass of very large upper Manlius boulders (the thick-bedded, fine-grained limestone) is exposed, indicating that here the top of the Manlius in the anticline, adjoining the syncline on the west, has been cut into by the creek.

A series of small structural disturbances is exposed about Clarksville. There is an elongated outlier of Onondaga limestone, half a mile east of Clarksville, forming a ridge. The eastern boundary of this has the appearance of a fault-scarp. A very fine overthrust plane (figure 78) is now exposed at the south end of this outlier in the north bank of the state road. The Esopus shale is here pushed over Onondaga limestone in a westerly rising plane. The same fault is well exposed on the south bank of the Oniskethau creek, where it brings the Onondaga and Esopus into lateral contact.

Another small overthrust has been described and figured by Prosser ('99, p. 343), in connection with small folds (see p. 156). It is exposed in the bed of the Oniskethau creek south of the village, just below the bridge.

The age of these small faults is not known. They may be contemporaneous with the Carboniferous folding of the Helderbergs, but are more probably of much younger age and connected with adjustments that took place in Mesozoic time to the east and west of the Appalachian fold system, as shown by the sunken fault blocks in the Champlain basin and the Connecticut valley.

There is no doubt that faulting on a small scale takes place to this day. This is shown by the observation by Woodworth ('07) of series of small step faults, each with a throw of about a few inches, in the Snake Hill and Normanskill rocks of South Troy (Brothers quarry), Defreestville (along road), Rensselaer, and other localities in the Hudson Valley. As these small faults appear in glaciated rock surfaces, they must be of postglacial age. It is the opinion of Woodworth that these small faults indicate a continuation of the ancient pressure that elevated the Appalachian system; because (in the Brothers quarry) "the situation of the postglacial faults along the eastern border of the sandstone core of the overturned syncline, in the plane of the reversed dip of the stratification, is precisely where overthrust planes would be expected to arise in mountain building from a continuation of the ancient pressure."

Nevertheless Professor John H. Cook has suggested to me that some at least of the postglacial faults are connected with the postglacial differential elevation of the country. Such a fault, with a throw of about one foot, was discovered by him in the lower reaches of the Oniskethau in the Oriskany sandstone, about two miles east of Clarksville. The fault forms a step of about a foot in the stream bed, so recent that it has not even been channeled by the stream. Smaller postglacial faults have been found by him just outside of

John Boyd Thacher Park, three-quarters of a mile west of the Indian Ladder, also in the Oriskany. It is believed by Professor Cook that there are numerous such small postglacial faults which if studied in detail might give important clues to the postglacial doming of the country.

Volcanic Rocks

Although one might expect that a great amount of volcanic activity would have developed in connection with the widespread folding and elevation and the overthrusting of the country, thus far no volcanic rocks have been found in the capital district.

There occurs, however, only a few miles from the eastern margin of the capital district, between Babcock pond and Kantsville, an eruptive rock described by Wolff as "a surface volcanic flow" (Dale, '93, p. 327). And further, the Northumberland volcanic plug, popularly known as the "Schuylerville volcano," is an outcrop of volcanic rock not very far north of the capital district. It is therefore quite possible that volcanic rocks occur in the capital district and may be exposed some day through building or engineering operations.

HISTORICAL GEOLOGY

The geological history of the capital district is a very complex one as the region has been part of a very unstable area, that existed from Precambrian time.

There are at present no Precambrian rocks exposed in the capital district, but we have not far to go for the granites and gneisses of the Adirondacks, which come down to the northern outskirts of Saratoga Springs. Dale ('04, p. 57) has suggested that the Precambrian rocks come to the surface in the Rensselaer grit plateau and recommended a minute exploration of the plateau for a Precambrian mass.

There is no doubt that the Precambrian granites and gneisses underlie our district at a depth of 4000 to 5000 feet (counting the thicknesses of the formations of the eastern trough at Albany). Regarding these Precambrian rocks of the Saratoga region, Cushing ('14, p. 135) has stated:

Our direct knowledge of the events of Precambrian time in the region commences with the deposition of the Grenville series. These rocks are very widespread and very thick, with great amounts of shales and limestones and a lesser amount of sandstone. They must have been deposited on some floor of older rocks which has since been entirely destroyed by igneous action, or else yet remains to be discovered. Judging by their extent and thickness the series was

probably deposited under marine conditions, but, lacking fossils, there can be no certainty in the matter.

Following the deposit of the Grenville sediments the region was repeatedly invaded from beneath by great masses of igneous rock. The earliest and most widespread of these invasions was that of the Laurentian granite. Subsequently came invasions of anorthosite, syenite, granite and gabbro. These broke up the Grenville rocks into groups of fragments, apparently ate away and digested much of the basal portion of the sediments and caused the complete disappearance of their old floor of deposit.

Then followed a very long period of erosion of the region during which it was above sea level. A great thickness of rock was worn away from the surface, bringing to daylight the tops of the great igneous masses which originally solidified much below the surface. The final effect of the long erosion period was to have reduced the entire region to one of low altitude and small relief.

In the Adirondacks, or in fact wherever they are known, the Precambrian rocks are intensely folded. It was generally held that these folds are irregular in direction and hence of no structural significance. The writer ('22) has shown that the folds are all arranged in orderly fashion, and that this order is 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. Thus in the Adirondacks the Precambrian folds strike in northeast direction and the same is undoubtedly true of the folding deep under the capital district. Recent researches by Schuchert ('23) indicate that in the last division of the Precambrian era, in the Proterozoic time, distinct geosynclines can be made out in North America. One of these long depressions, which became submerged and sank as they were filled with sediments from the neighboring mountain ranges, and which finally were themselves folded again into long mountain ranges, extended the whole length of the continent inside of the borderland from Newfoundland or even beyond to Alabama. The capital district formed just a small sector of this great Precambrian geosyncline.

The first indication of mountain ranges that appeared in this geosyncline were the bars or ridges that separated the troughs which we find in early Cambrian time. The western basin, comprising the Champlain-Hudson trough, has been called the "Chazy basin," the eastern the Levis basin. There were others still beyond the latter, which do not concern us here.

These basins were sometimes inundated partly or wholly from the northern Atlantic and sometimes the sea came in from the south, and

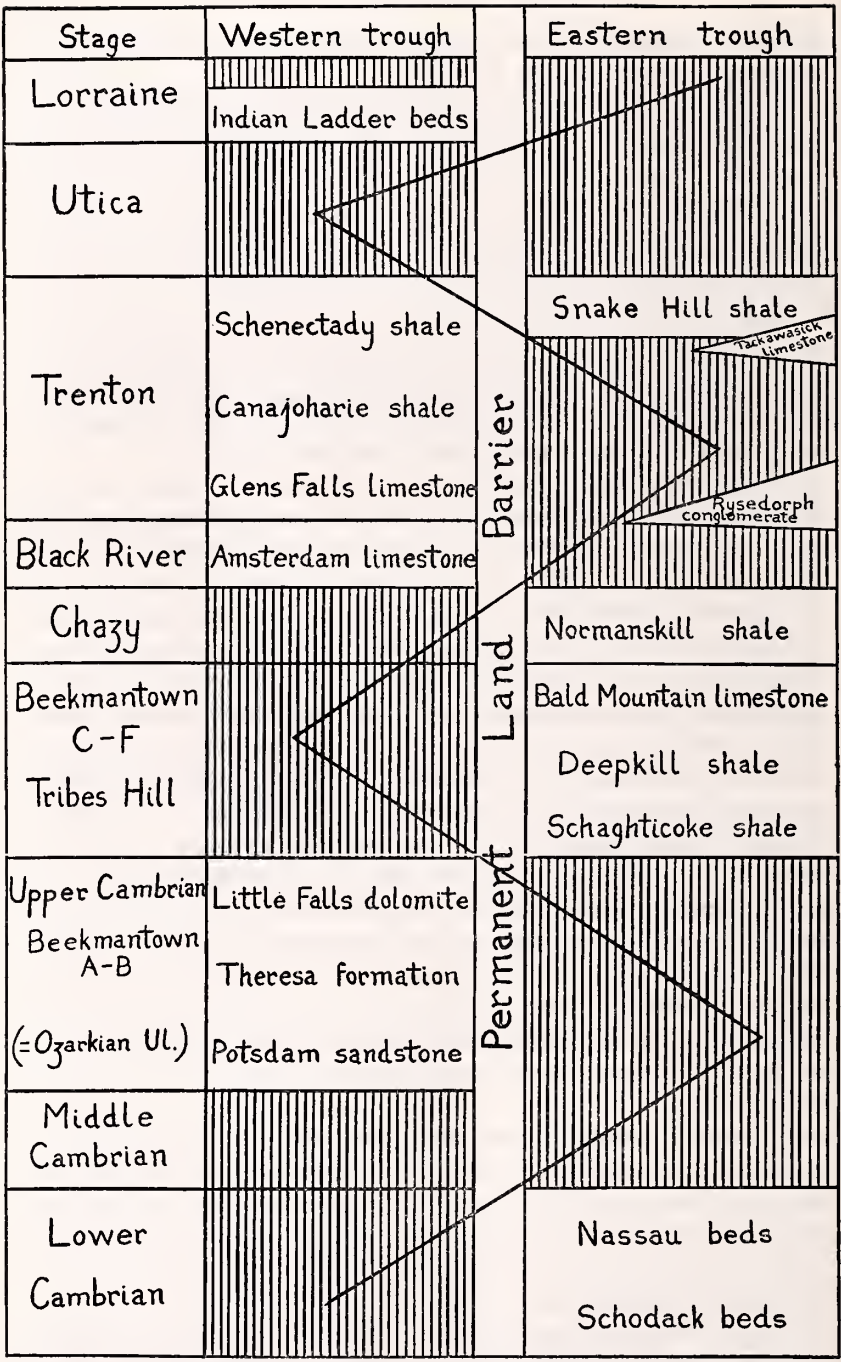


Figure 37 Diagram of emergences and submergences in the eastern and western troughs of the Appalachian geosyncline in capital district. The lined intervals are those of emergences and the zigzag line indicates the shifting of the alternate movement from one trough to the other.

sometimes the sea spread beyond them into the interior of the continent.

We have represented in figure 37 the events going on in the two troughs, during Cambrian and Ordovician times, where the shaded periods represent emergences and the unshaded the submergences. It is seen at once that frequent oscillations took place in both basins and that the invasions of the sea and withdrawals did not take place simultaneously in both basins, but at very different times and apparently independently of each other. The most interesting feature that the diagram clearly brings out is that there was a regular alternation of the sea in the two basins, indicating an east-west shifting of the seas in the troughs, such as has been observed in more complete development by Ulrich ('11, p. 547) in the Ordovician seas of the Appalachian valley troughs in east Tennessee.

Cambrian and Ozarkian History

The Lower and Middle Cambrian time finds the western trough entirely drained of the sea, while at the same time a great mass of sediments was deposited to the east, the Lower Cambrian rocks in the Levis trough, and the middle Cambrian or Acadian beds in still more easterly troughs, and possibly also to a limited extent in the Levis trough. This invasion came from the north. It brought with it a fauna of trilobites, brachiopods and pteropods, and a flora abounding in the calcareous alga Oldhamia. The sea was, for the most part, quite shallow, as is indicated by the oblique sedimentation and plunge structure in the quartzite beds and the conglomerates. The beds deposited were alternately sandy, clayey, and calcareous organic, the clayey beds predominating in the capital district and especially in the upper divisions of the Lower Cambrian. The abundant red and purple beds may indicate subtropical conditions on the land or exposure and thorough oxidation of the muds in flats. At the close of Lower Cambrian time the sea retreated northward and a crustal movement folded these sediments. The new land surface was exposed to atmospheric erosion during the long intervals of Middle and Upper Cambrian time and considerably leveled. At the close or shortly before the close of the Cambrian time, the basin became again submerged and the Schaghticoke graptolite shales were deposited.

Meanwhile the western trough remained dry until Ozarkian time, when the Potsdam sandstone was deposited. This is an accumulation of coarse quartzose sands and gravels. The accumula-

tion began first on the northeast, in Clinton county, and extended itself progressively to the west and to the south. Only the upper portion of the formation is found in the Saratoga region and enters more or less into the capital district.

This upper portion contains marine fossils and must have been laid down in shallow marine waters. The climate was arid and the land a desert without any vegetation. The land to the west and south had strong relief, and vigorous currents transported the coarse sands and gravels into the basin.

The sands of the Potsdam sandstone are succeeded in the Saratoga region by the alternating sands and dolomites of the Theresa formation without any sign of a break between them. Erosion had lowered the bordering lands and the Potsdam sea extended around and over the Adirondack plateau in the north and south. As a result less and less sand was brought down from the heights and dolomite began to be deposited. The sands steadily diminish in frequence and thickness, and thus the Theresa formation grades upward into the Little Falls dolomite. Both these formations are marine, but in both of them fossils are very rare, especially in the dolomite. The great reefs of the calcareous alga Cryptozoon which occur at many horizons in the neighborhood of Saratoga, especially at the "Cryptozoon Park" seem to indicate the likelihood of a congenial climate and abundant life.

The Hoyt limestone is a local upper phase of the Theresa formation about Saratoga. It seems to represent a more offshore phase of the formation, and fossils are much more abundant than in the ordinary Theresa or the Little Falls formation. There is especially an abundant fauna of trilobites.

These three formations are of extreme upper Cambrian age, or belong to the era separated as Ozarkian by Ulrich, and are the only Cambrian (or Ozarkian) deposits that were laid down in the Chazy or Champlain trough. Following their deposit mild uplift occurred and the troughs came above sea level, existed as land for a time, and were somewhat eroded. This erosion gently beveled off the surface instead of deeply cutting into it, which suggests that the land was of low altitude.

Ordovician History

The uplift just mentioned forms for the geologist the dividing line between the New York Cambrian formations and those classed as of Ordovician age. No one has any clear idea in regard to the length of elapsed time which this uplift represents. Eventually the

western trough became again depressed and occupied by marine waters, and in these, on all four sides of the Adirondack region, the various dolomite and limestone formations of the Beekmantown group were laid down. These are thickest and most complete in the Champlain trough, which sagged more and more to the east of the Adirondacks, and for a longer time, than on the other three sides of the Adirondacks. But the deposits of the Beekmantown of the northern Champlain trough do not occur in the southern continuation, in the Saratoga region and in the capital district. Apparently the Beekmantown submergence fell just short of covering this district. It is barely possible that the formation was thinly deposited and subsequently entirely worn away.

It was entirely different in the eastern or Levis trough. Here the sea spread in Beekmantown time from north as far as the capital district and beyond, for an unknown distance. It deposited the Schaghticoke shale, at the base of the Ordovician according to many authors (others still place it at the top of the Cambrian, especially in Great Britain), and the Deep Kill shales. These thick masses of shales and grit carry no other faunas but graptolites and but rarely stragglers from other classes. The writer has recently discussed ('25, p. 78) very fully the conditions under which graptolite shales were formed, and in agreement with Lapworth and Marr ('25) in England, arrived at the conclusion that they were deposited in the dead grounds, or as Marr expressed it, in the "poisonous" waters of depths where lack of circulation does not provide sufficient oxygen to permit life. The graptolites which were planktonic or pseudo-planktonic (attached to floating seaweeds) in habit, dropped into these depths from the higher regions after death, or when they were torn from the seaweeds by storms. They were brought into the trough from the open ocean, which was their home and it seems that the rich graptolite zones of the Beekmantown and Normanskill would require channels with exits at both ends, to allow strong surface currents to bring in the graptolite faunas. In the case of the Normanskill shale there is little doubt that the Levis basin extended the full length of the Appalachian geosyncline and that the sea could freely sweep through it.

It appears that the conditions were at least once congenial for organic bottom life in the eastern trough in late Beekmantown time. That was when the Bald Mountain limestone was deposited north of the capital district. We do not know for a certainty whether this extended as far south as Albany, but similar limestone appears again farther south, as on the Poughkeepsie quadrangle.

The graptolite-bearing marine invasions continued through Chazy time (uppermost Deep Kill zone and Normanskill shale), the sea withdrawing for shorter intervals, as between the Deep Kill and Normanskill invasions, and possibly between the lower and upper Normanskill invasions, the latter probably of Black River age. The Rysedorph conglomerate indicates a period of great erosion or working up of various rock formations by an advancing sea with strong currents, for some of the pebbles, as those of Chazy and Lowville limestone, must have been brought considerable distances from the north. This happened in early Trenton time; then followed throughout the rest of Trenton time the Snake Hill invasion, which deposited a great mass of shale with some grit, probably the full length of the eastern or Levis channel, for the Snake Hill shale can be traced from Vermont at least, but probably from the St Lawrence river through New York and farther south it merges into the Martinsburg shale of Pennsylvania. The eastern trough must have been rapidly sinking, to allow the accumulation of 3000 feet of shale and grits. While the fauna consists largely of graptolites, brought in from the ocean by the currents sweeping through the trough, there was also enough circulation on the bottom to allow a fauna other than graptolites to exist, for the most part consisting of small forms and appearing impoverished, as if overwhelmed by too great accumulation of mud. It is for this reason that the mud-loving pelecypods or lamellibranchs prevail in the Snake Hill fauna.

In this time, however, there were also places in the Levis channel where better conditions existed and calcareous Trenton beds could be formed, as is shown by the Tackawasick limestone and shale. This may have formed in protected regions of the eastern part of the trough, unless the limestone has not been pushed over by overthrusting from a still more easterly situated basin; for it is not without significance that the Tackawasick limestone has nowhere been seen in the western portion of the basin and that it is nowhere in contact with the Snake Hill shale, but appears between the Lower Cambrian and the Devonian Rensselaer grit, separated from both by thrust planes.

The Snake Hill closes the Ordovician series and the Eastern basin was apparently completely drained during Utica and Lorraine time.

Returning to the Western or Chazy trough, we have already seen that the Beekmantown sea advancing from north, just missed reaching the Saratoga and capital districts. Also the Chazy fell short

of advancing into this region. In Black River time the Amsterdam limestone was deposited in the Saratoga region and it undoubtedly also extended into the capital district. This is a pure limestone with an abundance of life, indicating favorable conditions, due to the absence of a great influx of mud and sand, which means that the neighboring country had a low altitude.

There came a slight uplift of the region above sea-level and then the Trenton sea invaded the western trough through its full length. Its first deposit is the Glens Falls limestone in the Saratoga region. There is no doubt that this limestone extends into the capital district and is now deeply buried there under the Schenectady beds. Conditions were at first favorable and the water clear, but the Glens Falls limestone shows in its middle and upper parts much intercalation of blackish shale, some of it containing graptolites and indicating the beginning of an influx of mud. It is followed by the Canajoharie shale of Trenton age. The sea that deposited this great mass of black shale, containing graptolites and small cephalopods and lamellibranchs that could exist under the unfavorable conditions, extended all through the Champlain basin, down through the whole Chazy channel, and it also spread westward beyond the trough over the southern slopes of the Adirondack plateau. Toward the west the Canajoharie shale is replaced by the Trenton limestone, which indicates the clear marine conditions farther out in the shallow epicontinental Trenton sea.

The Canajoharie shale has its greatest thickness, over 1000 feet, in exposures in the Amsterdam quadrangle, directly west of the capital district. This great thickness is undoubtedly continued eastward into the capital district. It was the result of the continuous sinking of the Chazy trough and the influx of much fine detritus, probably from the north.

The Canajoharie shale grades upward into the still thicker Schenectady beds, also mainly of Trenton age, a great mass of mostly grayish and more or less sandy shale, alternating with sandstone beds, many of the latter of considerable thickness, especially toward the top. The formation, more than 2000 feet thick, shows a persistent hundredfold alternation of shales and sandstones, as along the Schoharie creek below Esperance and in the neighborhood of Altamont and Delanson, as well as at Schenectady. The rocks are for the most part barren, but they have furnished in some localities seaweeds, marine brachiopods, pelecypods, trilobites and eurypterids. It seems, therefore, that these beds were formed in a fast sinking

basin that was rapidly filled with sediment. Shifting currents deposited sands along the coast in times of greater velocity and muds in such of lesser velocity. The formation is not known to extend far north or west and it disappears under the Helderbergs in the south. We therefore do not know whence the invasion came or how far it extended. There is no doubt that owing to a long interval of emergence, the greater part of the Schenectady beds was eroded again, at least in the north. The Schenectady is a distinctly clastic shore formation that may pass westward and northward into upper Canajoharie shale and finally into Trenton limestone; or in other words, the same Trenton sea may have deposited Schenectady beds in the capital district, black shales in the near north and west and Trenton limestone farther away. This deposition may have continued even into early Utica time. The principal portion of Utica time is, however, not represented in either the eastern or western basin, and the true Utica shale is found only in the middle and upper Mohawk valley. If there was any coarser shore deposit of the Utica other than the upper Schenectady, it has been entirely eroded away.

The last Ordovician formation of the western trough is the Indian Ladder beds. This formation, consisting of shales and alternating thin sandstone slabs, in the lower part calcareous, is exposed only in a narrow belt under the Helderbergs, extending from Altamont to New Salem. It reaches, however, considerable thickness in the neighborhood of the Indian Ladder. The formation was evidently deposited in a narrow trough that sagged rather rapidly in the middle and that extended for an unknown distance from north to south. It is connected by its fauna, a pronounced microfauna indicating unfavorable life conditions, more closely with the Eden shale of Cincinnati and the middle division of the Martinsburg shale in Pennsylvania and more remotely with the Frankfort shale in New York. It was therefore undoubtedly formed by an invasion advancing from the south in the western trough, to an unknown distance north beyond the Indian Ladder. Whatever there was of it north of the Indian Ladder has long ago been carried off to the ocean, for there followed an exceedingly long interval of emergence in both the eastern and western basins, comprising all the upper Ordovician time, as well as the Ordovician-Silurian intersystemic interval of general emergence and the earlier Silurian time.

It was in this long interval that the Taconic revolution took place, which first threw the rocks of the eastern trough into a system of

complicated folds and then overthrust the folded mass successively in a number of plates westward, so that finally the Snake Hill beds of the eastern trough came to rest against the Schenectady beds of the western trough and the Lower Cambrian beds came to rest, in part at least, upon rocks of Ordovician age, notably the Normanskill and Snake Hill formations. This revolution took place at the end of the Ordovician era, or in the Ordovician-Silurian interval of continental emergence. Then followed again a long interval of exposure to the atmosphere and intense erosion of the elevated region. As a result it was reduced to a peneplane, when the sea in Silurian time advanced again. Not only were both troughs completely obliterated and filled up by the Cambrian and Ordovician formations, but the material was after the folding and thrusting so far eroded that a broad belt of Normanskill shale came to the surface from under the heavy cover of Snake Hill beds that had been totally carried away, and the great cover of Normanskill beds and Snake Hill beds, at least 4000 feet thick that once covered the Cambrian beds, had been eroded away, with the exception of a few outliers, exposing the very oldest fossiliferous formations that rest upon the Precambrian rocks in the capital district. The Devonian Rensselaer grit rests even on the lower division of the Lower Cambrian, the Nassau beds, so that it may well be deposited in places even on Precambrian rocks, as Dale suspects.

As a further result of the folding, overthrusting and great erosion, the Silurian and Devonian rocks of the Helderbergs rest partly on the Schenectady beds and Indian Ladder beds of the western trough, partly on the Snake Hill and Normanskill rocks of the eastern trough. The contact of the Helderberg formations especially with the Normanskill rocks is a very unconformable one, that is, the Helderberg rocks rest more or less undisturbed and horizontally on highly folded and tilted beds, as is seen for instance on the Sprayt kill (figure 72). It is evident that during the Silurian and Devonian invasions of the sea, the old Levis and Chazy troughs had entirely ceased to function as depressions that received sediments, and the Silurian and Devonian invasions extended more or less far east over them. Becraft mountain, a small outlier of Silurian and Devonian rocks east of Hudson, affords the best evidence of the distance to which the Helderberg rocks extended eastward, some farther, some not so far. 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.

Silurian History

The long interval of emergence and erosion that followed the small Indian Ladder invasion was finally terminated by a sea that came in from the southeast, where the Atlantic ocean, or its predecessor, the Poseidon, had closely approached to the present coast line. The thin bed of pyritiferous Brayman shale, may, as we have pointed out before, be a residual soil of the long era of weathering, reworked and redeposited by the advancing shallow Salina sea. The following Rondout waterlime deposited after another emergence, is clearly a marine sediment, formed by chemical deposition in a shallow epicontinental sea that extended from the Atlantic to Michigan and in a narrower embayment southward into Virginia. The greater thickness and development of the Salina formations eastward and especially westward seem to indicate that there was a barrier in the capital district and its neighborhood, which frequently interrupted the ingress of the sea, from the southwest, about where New Jersey is today. As a result of this very incomplete connection with the ocean, the Salina beds are very unfossiliferous and great deposits of salt and gypsum have formed in the shifting salt pans from western New York to Michigan. The climate was evidently an arid one, so that this more or less land-locked sea received but irregular drainage.

The next or Manlius sea, of similar extent, had, however, free connection with the ocean and a marine fauna of corals, pteropods, brachiopods, pelecypods and trilobites flourished in a broad expanse of sea that spread westward to Michigan and southward in a narrow trough to Tennessee. How far this, as well as all the following Helderberg formations, extended, we do not know. There is, however, no doubt that they reached not far up onto the southern slopes of the Adirondack massif. They have weathered back over the broad inner lowland to the present escarpment (also called cuesta) of the Helderbergs, the "Helderberg Cliff" exposing the Ordovician rocks at the bottom.

In the capital district the Manlius sea was extremely shallow. We have described before the evidence of tide flat conditions seen in the New Salem quarry and elsewhere. The thin-bedded Manlius limestones with their tentaculites, ostracods, small spirifers and lamellibranchs, mud cracks and mud pebbles, and their association

with the Stromatopora beds, suggest that these limestones are principally lagoon deposits on tide flats, formed between and behind the coral reefs.

Devonian History

The Manlius sea in the capital district seems to have changed gradually into the Coeymans sea, as is indicated by the transition beds, although locally there is an unconformable contact with pebbles, as at the Indian Ladder, caused by local elevation or stronger erosion by currents. It is thus seen that the boundary between the Silurian and Devonian systems is not so distinctly marked as we would expect to find it.

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 Coeymans beds are again connected by transition beds with the overlying New Scotland beds, proving a gradual change of conditions. The New Scotland sea lacked the westward extension of the Coeymans and Manlius seas, but it extended southward in the Appalachian region and it found a passage eastward across the Taconic region into a narrow area that extended to the St Lawrence country and beyond the Newfoundland region to the Atlantic. The condition had changed in the capital district in that there was a much greater influx of mud, so that the New Scotland beds are impure shaly limestones and calcareous shales. On the other hand, a much richer fauna than before flourished in this sea, a fauna that consists of 184 species in the capital district, comprising sponges, corals, bryozoans (71 species), brachiopods (62 species), lamellibranchs, gastropods and trilobites. It is a fauna of the littoral region, but not of the tide flats, the preponderant bryozoans indicating deeper and quieter waters.

The Becraft limestone is so well set off from the subjacent New Scotland beds that there may have taken place a brief elevation of the region above sea-level, or at least a shifting of barriers and currents, that produced a mud-free clear sea in which a limestone, largely composed of crinoid stems and plates and brachiopods, could form. This sea formed but 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.

The Oriskany-Esopus beds are separated from the Becraft limestone by a break, during which the Port Ewen, Connelley and Glenerie beds were deposited farther south in the Kingston region. It is therefore probable that the sea withdrew during that time from the capital district and the country to the west of it. The Oriskany sandstone is characterized by its thick-shelled fossils and sandy limestone, changing to pure quartz-rock at Oriskany; there is no doubt that the turbulent sea near the northern shore line deposited these beds. The Oriskany sea, that like all the preceding seas had an oceanic connection in New Jersey, spread westward in a narrow embayment into Ontario and like the preceding seas over the Taconic region into Massachusetts and thence northward into the Gaspé country, where thick calcareous beds (Grand Grève beds) were deposited. The broad access of the northern Atlantic in the Gaspé region and in Nova Scotia brought in the North Atlantic fauna with European relations (Clarke's Coblenzian invasion), that furnishes the typical Oriskany brachiopods, in contrast to the preceding faunas that had southern Atlantic characters. The thick mass of the blackish, gritty or sandy Esopus shale is but a different facies of the upper Oriskany beds, or later Oriskany sea. These barren beds, containing only the spiral worm trails, known as *Taonurus cauda galli,* indicate such an influx of mud, that organic life was almost impossible. These conditions did not extend far west beyond the capital district (to Otsego county), but southward to Pennsylvania.

The Schoharie grit is but a local development or sandy facies of the lower Onondaga limestone, indicating a great influx of sandy material in the region from Albany county to Otsego county. In spite of this sandy admixture to the calcareous mud, the formation has furnished a large fauna (of 123 species), indicating congenial conditions, especially for brachiopods (33 species), cephalopods (44 species) and trilobites (16 species). It is a distinct cephalopod facies, many of which, as the Trochoceras and Gyroceras forms were undoubtedly bottom-crawlers. It was altogether the rich benthonic life of the zone below the tides. This cephalopod facies of the Schoharie grit marked only a restricted area in the great Onondaga sea, that spread far to the west to the Great Lakes region, sending a broad arm north to Hudson bay, and another

south to the Gulf of Mexico, as well as a narrow blind arm through the old eastern trough to the St Lawrence region. The short Schoharie grit episode was followed by the open Onondaga sea, depositing pure lime and harboring widely spread coral reefs, that give evidence of very clear warm water and generally congenial conditions, reflected in brachiopods, large cephalopods and trilobites.

The Onondaga limestone is abruptly followed in the capital district by nearly 200 feet of black fissile shales, the Marcellus beds with a characteristic diminutive fauna. This fauna came from the southeast, having wandered into this region from the southern Atlantic by way of the Appalachian interior sea. Going west from here one finds that the beds become more and more calcareous, and that at least the lower 50 feet correspond to the upper Onondaga of western New York. The Marcellus is therefore, in part at least, a muddy facies of the Onondaga sea. Also the upper Marcellus contains in the west a calcareous intercalation known as the Spafford limestone. This, as well as an earlier smaller calcareous intercalation, beginning just west of the capital district and known as the Cherry Valley limestone, contains a Hamilton fauna. There is still another upper division of the Marcellus beds present westward from Schoharie county that we do not have in the capital district, namely the Cardiff shale. The sea, when these muds were being deposited along the eastern and northeastern shore lines, was already beginning to spread far to the west, even beyond the Onondaga sea. The source of the black muds must be sought in the higher lands, bordering the sea in the east and north.

The Marcellus sea became by transitional stages, as shown in the limestone intercalations with Hamilton faunas, enlarged into the Hamilton sea, which 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 Mackenzie region to the Arctic ocean. In New York this sea deposited several thousand feet of shales and sandstones teeming with life, especially brachiopods and lamellibranchs, adapted to the muddy sediments. In the east the faunas entered from the Atlantic, carrying the characteristic Atlantic brachiopod *Tropidoleptus carinatus,* that is found as far south as South Africa, and the Falkland Islands. In the western portions of the great inland sea, Arctic and Pacific faunas are found. Even if deposition of the beds took place much faster than that of the limestones, the great thickness of the formation and the wide extent of the sea indicate that it must have persisted over a long period of time.

While it is true that the Hamilton beds are the highest that we find now in the capital district, there is not the least doubt that the Devonian beds, that overlie the Hamilton beds in the eastern belt of New York and south of the capital district, once extended entirely over the district to the southern slopes of the Adirondack plateau. They have been entirely eroded away. These formations are the Sherburne sandstone, the Ithaca beds, the Oneonta sandstone and the great mass of the Catskill beds. These several thousands of feet of shales and sandstones indicate at least two floods and emergences of the country. First it appears that there was a withdrawal of the sea in the northeast, for in western New York there are a number of formations, the Genesee beds (with the Tully limestone, Genesee black shale, Gennudewa limestone and West River shale that do not reach eastern New York) and in southeastern New York are the Bellvale flags of the corresponding age. Then the Portage sea advanced from the west, depositing in western and central New York the Cashaqua shale and in eastern central and eastern New York the Sherburne sandstone. In Otsego and Schoharie counties the fossils of this formation are a modified Hamilton fauna, that still lingered from earlier times, but in Albany county, down to Greene and Ulster counties, we find only barren flagstones bearing occasionally a few species of plants. It is quite obvious from this observation that a broad bay, the Albany bay, had been formed in the northeast corner of the Portage sea, where a river, most probably coming down from the north, emptied and brought into the bay the sands and the plant fragments now found in the eastern Sherburne rocks. These conditions continued while in western New York the peculiar foreign Naples fauna flourished, and farther east lived the Ithaca fauna, still a derivative of the Hamilton fauna. This Naples-Ithaca sea deposited in the northeast corner, the Albany bay, Ithaca beds, that are reddish and greenish shales and sandstones, instead of the bluish and grayish marine shales of the west. These reddish shales are again barren and both by this fact as by their color denote their derivation from a near-by land and their deposition in a brackish bay. The Ithaca beds are followed by more than 500 feet of Oneonta beds between the Helderbergs and the Catskills. These are "red and green shales, reddish sandstones and coarse grained grayish to greenish gray sandstones" (Prosser, '99, p. 313). They are unfossiliferous, except for an occasional specimen of the fern Archaeopteris and the fresh-water clam *Archanodon (Amnigenia) catskillensis.* These beds are also correlated with marine

beds holding the Naples fauna, of Portage age. It was in this time that on land to the east and north of the bay, the most ancient forests grew, that we see reproduced in the Gilboa group in the State Museum. Such forests may have grown above the shore lines in the northern part of the capital district or only a short distance beyond it. The northeastern Albany bay was now more sharply separated from the sea than before, probably by a bar projecting southward from the coast line in the north such as Clarke ('04, plate B) has described. And upon the Oneonta beds are piled the thousands of feet of Catskill rocks, shales and sandstones, that are of the same age as the Upper Devonian Chemung rocks of western and central New York, with a profuse organic life that strongly contrasts with the barrenness of the Catskill beds. At this time heavy land drainage had changed the Albany bay into a large fresh-water or brackish lagoon or estuary. As we have already described in another chapter, a great river coming from the north into this bay deposited the Rensselaer grit 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.

This was the end of the marine Paleozoic deposition of which we have a direct record in this part of New York. In southwestern New York and in Pennsylvania a great series of formations of Carbonic age, both of the Mississippian group and the Pennsylvanian group are still found. The rich coal beds of Pennsylvania were formed in this time. There is no doubt that a large portion of these formations, also, once extended into our district, and that for all we know luxuriant swamp forests of the coal period may have flourished here as well as in Pennsylvania, for, if we consider that the capital district was exposed to the gradational work of wind and weather ever since the Carboniferous period, that is, for 300 millions of years as geologic time is figured now, it is readily seen that an enormous amount of material above the Catskill beds must have been removed in this long time.

Toward the end of the Carbonic era the Appalachian revolution began, which again folded eastern New York, throwing the Rensselaer grit into the series of anticlines and synclines that we find now composing the plateau. This folding died out rapidly toward the west. Its last vestiges are the small folds in the Helderbergs, south of Clarksville, described in a former chapter.

And then began the great process of removal of the pile of rocks which from the top of the Catskills to the base of the Cambrian

amounted to over a mile of rock, and at the beginning probably to a mile and a half. Considering that this mass was folded in the eastern portion of the capital district and raised into mountain ranges, it is not too much to say that there were possibly as much as two miles of rock above the site of Albany that have been carried off to the sea since Paleozoic time. The process began in the north on the slope of the rising Adirondack plateau and worked backward and southward in a series of terraces and escarpments, until now everything of Silurian and Devonian age is eroded away north of the Helderberg escarpment, and the older Ordovician and the very oldest Cambrian rocks have come to the surface. Above the receding Helderberg cliff the enormous pile of rock that we see rising farther south in terraces to the top of the Catskills has already been worn away. It is due to this far-reaching erosion that the capital district furnishes a section from the Lower Cambrian to the Upper Devonion rocks.

Cushing and Ruedemann ('14, p. 142 ff.) held, in regard to the Saratoga district, that the Silurian and Devonian seas did not reach it, and that the preservation of the Ordovician rocks in the western trough demonstrates that the region remained near sea-level and as a result was exposed to but little erosion; further that "it is probable that during oscillations which depressed the western trough, continental deposits accumulated in it and were subsequently worn away during the intervening periods of greater altitude." It was also (p. 143) suggested that "much of the overthrusting is of later date (than closing stage of the Paleozoic) and possibly very much later." In the light of the information gathered in the capital district, it appears necessary to qualify these statements, since it is quite certain that the Silurian and Devonian rocks extended into the Saratoga district from the Helderbergs and that continental deposits in the eastern trough are represented only by the Rensselaer grit. The fact that the overthrust planes pass under the Helderberg rocks without producing any far-reaching disturbances in these overlying beds, seems to us to demonstrate that the overthrusting must have taken place before the deposition of the latter. Even if the slight folding in the southeastern portion of the Helderbergs in the capital district and Kingston region is attributed to the influence of the large overthrusts in the shale belt, it would make the latter not older than the Appalachian revolution. If a direct connection between these overthrusts of the Devonian Helderberg rocks and those in the slate belt can be established, it will mean either contemporaneity of the two and late Carboniferous age for both, or that the overthrusting in

the Devonian rocks is a posthumous revival of the older overthrusting activity.

In our opinion, the unconformable relationship of the late Devonian Rensselaer grit to the underlying Cambrian-Ordovician thrust masses must indicate that at least a part of the overthrusting took place before the deposition of the Rensselaer grit. On the other hand, if the Tackawasick limestone and shale is separated from the Rensselaer grit by an overthrust, as seems to be inferred from the structural relations, thrusting has still taken place after the deposition of the Rensselaer grit, and there is no saying when that may have been.

Mesozoic History

For the Mesozoic history of the capital district we have only negative data. There is no trace of deposits of this long era here. It would therefore seem to follow that the region must have been a land area. During the early part of Mesozoic time, in the Triassic period, however, certain troughs along the east margin of the Appalachian region subsided and received a large thickness of continental deposits. If such later troughs had been formed in the capital district, the Helderberg region would preserve a record in some sagging of the beds. The Helderberg rocks, however, exhibit fairly regular strike, with the exception of minor faults and folds. Cushing and Ruedemann ('14, p. 144) have argued that the great normal faults of the Champlain basin and the Saratoga region are the result of repeated dislocations that began with the sagging of the western trough in early Paleozoic time and the tendency of the Adirondacks on the west to rise, and may have well continued into Mesozoic time, for "the faults of the eastern Adirondack region are normal with nearly vertical fault planes, and these certain Mesozoic faults are of similar type" (as for instance those delimiting and transecting the Connecticut Triassic basin). It is quite possible that the Saratoga fault, which enters the capital district and passes along Ballston lake, is of Mesozoic age, and likewise the small faults found in the Helderberg cliff.

Cessation of the continental deposits of early Mesozoic (Triassic) age in the troughs to the east of the Appalachian folds was probably brought about by renewed uplift. Then followed a long period of erosion, the final result of which was a rather thorough wearing down of the region to a comparatively low plain, a so-called peneplane. A peneplane of late Mesozoic (Cretaceous) age was produced quite generally throughout the Appalachian region and eastern

Canada, and it is quite reasonable to assume that it was also produced here.

In reconstructing in the mind the events of this Mesozoic era, we can not help being aroused by the thought of the strange world that during this long era (that began 600 million years and ended 200 million years before our time) existed at the beginning perhaps two miles above the present site and level of Albany; of 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; and of the 40 million years of time, of which we have no record here and during which the country gradually sank to near sea-level.

Cenozoic History

The Cenozoic history of the capital district is the same as that of the Saratoga region, which has been described by Cushing and Ruedemann ('14, p. 145) as follows:

At the close of the Mesozoic the region was again uplifted. The low altitude peneplane which had been produced over the Adirondack region was elevated some 1500 feet or more, and rapid erosion of its surface began. Stream valleys were cut down and broadened. It is the depth of the valley cutting below the old peneplane level which enables us to estimate the amount of the uplift. The divides between the valleys, however, have been but little worn down during the time that has passed since the uplift. These divides rise now to uniform levels, the level of the old peneplane. An observer, standing upon one of these divide summits and looking abroad to the others, receives the impression of standing upon the surface of a plain and has merely to imagine the valleys refilled with material in order to picture the plain as it was at the time of the uplift.

This old peneplane surface is readily made out over most of the Adirondack region. But in the extreme east it seems to fail and the divide summits rise to very discordant levels instead of being uniform. This we take to mean that here renewed slipping along the old faults occurred as a phase of the uplift; that the Champlain trough displayed anew its tendency to sag relative to the district to the west; that it was uplifted much less than the Adirondacks; and that the difference in amount was made possible by additional faulting, the easterly slices being thrown down relative to those west of them. The old fault scarps had been peneplaned along with the rest of the region. These further movements renewed them, and their prominence today is in part due to this late movement. The McGregor and Hoffman fronts of the Saratoga quadrangle would be much less imposing than they are had it not been for this.

It is by no means unlikely that further westward movement of the eastern basin rocks along the thrust fault planes also took place at this time.

During the first part of the Cenozoic, the Tertiary, minor oscillations of level took place in the region, but we lack the precise knowledge of just when and what they were. Later in Tertiary time an additional uplift took place, considerably increasing the altitude of the region, not improbably with renewed faulting. The peneplane that had formed during the preceding Tertiary time and that was now uplifted, is recognized in the Tertiary peneplane of the Helderberg mountains and the Rensselaer plateau, described in another chapter. A still lower peneplane began then to form in the inner lowland of the Helderberg and Rensselaer plateaus; this is the Albany peneplane. It is still growing into the surrounding plateaus.

Finally the region was invaded by the ice sheets of the glacial period. The Pleistocene history, or the fate of our district during the glacial period, will be fully described by my colleague, Professor John H. Cook.

THE GLACIAL GEOLOGY OF THE CAPITAL DISTRICT

BY JOHN H. COOK

In the capital district broad areas of the bedrock are concealed by overlying deposits of laminated clay, sand, gravel and glacial till or boulder clay, all of which are referable to late glacial or recent time. With the exception of certain clayey or sandy residual soils (formed in place by the weathering of exposed rocks), an occasional talus and a moderate amount of alluvium, these unconsolidated materials are products of the action of moving land ice, having been plucked or rubbed from the bedrock by the overriding Wisconsin ice sheet and subsequently more or less sorted and redistributed by water and wind. Wherever the beds accumulated in such manner that they present definite characteristics of form or internal structure, it is possible to infer from them something of the conditions under which they were laid down, and these inferences, supplemented by those which may be drawn from the distribution and relations of the several types of deposit, constitute the evidence to be interpreted in reconstructing the salient phases of this part of the geological history.

During the recent period the familiar processes grouped under the term erosion have altered the topography of the region by removing portions of the ice-derived deposits from their original positions; the wind has deflated the sand plains west of the Hudson river, and streams of water have etched the whole district with valleys. Much

of the fine wind-blown sand has escaped lodgment in the water courses and has piled up in mounds or dunes,[1] but, of the materials excavated by the numerous streams, by far the greater part has been carried out of the district. That part which has remained, notably the coarser elements, has been left as sediment in the Hudson valley and now forms an extensive filling in the channel from Troy southward for a distance of 30 or 40 miles.

This deposit is made up principally of the sand and silt brought down by the river system above Troy (although each small creek discharging into the Hudson below that point has contributed its quota of sediment) and constitutes the sea-level delta of that system at the present attitude of the land with regard to the sea, its higher portion projecting as a series of islands and mud flats as far south as Coxsackie. From Troy to Coxsackie the deltas of the side streams are commingled with the sediments of the Hudson proper, but south of the latter place they may be distinguished as independent deposits.

That the accumulation does not at once suggest its nature is due to its undeltalike form. When free to do so, the constantly shifting distributaries of a river emptying into a lake or the sea spread the sediments into a rude fan; but when, as in the present instance, these distributaries are confined by high ground to a more or less straightened course, the delta will, of necessity, be linear in form.

There is no way of determining how long it has taken to make this recent fill in the channel, but we know that the beginning of sedimentation coincided in time with a subsidence of the land which carried the old valley floor of the Hudson below sea-level and permitted the sea to invade the main trench and the lower portions of the contributary valleys to a point only a few miles south of the Mohawk confluence. This can be shown to have taken place more recently than any other important geological event affecting the region. Not only was the glacial ice gone and the "lakes" in which the clays were deposited drained, but the development of the valleys of the modern drainage system had progressed well toward the condition found today. The proof is as follows:

While the Hudson river itself, from Hudson Falls southward, lies within an older (preglacial) valley, which for convenience we shall continue to call the Hudson valley, practically all of the contributary streams follow new or postglacial courses as they approach

[1] The three principal dune areas lie (1) between Albany and Schenectady; (2) about Clifton Park, Saratoga county; and (3) in the town of Stillwater northeast of Round lake.

this old valley, and they come to the brink of its steep rock wall, on one side or the other, at points not previously breached by the action of flowing water. When these lateral streams began to intrench themselves the land stood higher above sea-level than it does now and the trunk stream (the Hudson) into which they emptied made its way over a bed of rock and boulders, sweeping most of the finer particles of its load along with it. Then the land began to subside and sea water crept into the valley system from the south. But before the crustal movement ceased, with the sea reaching inland as far as Troy and the lower part of the system drowned and dismembered, the greater part of the material washed away by the lateral streams in making their valleys had been removed. This is indicated by the comparatively small amount of sediment which has been dropped by them in the existing estuary; that is to say, the modern delta of any one of the creeks entering the estuary below Coxsackie represents but a small fraction of the total material excavated from the basin which it drains. It would thus appear that the time during which the present stand of the land has determined the location of such sedimentary deposits has been short in comparison with that represented by the erosional work in the basins supplying the sediments.

We may, therefore, divide postglacial or recent time by the criterions given above into a longer and a shorter period, the former measured by stream erosion and the latter by deposition in the estuary. During the earlier and longer period, the land began to subside and continued to do so until the present stand was reached; during the shorter period the earth's crust has been stable. The Hudson's delta was built during the second period which has been, geologically speaking, a very brief time interval.

Geologists are quite generally agreed that the weight of the covering of land ice during the glacial period was sufficient to upset the balance of forces which maintains the subcrustal rocks in a rigid condition; that material some 60 or more miles below the surface moved out from under the ice field to sections of the periphery until equilibrium was reestablished; and that, when the ice melted off, this displaced material slowly returned to something like its former position. Thus both the greater elevation of the land in the capital district at the time of maximum glaciation, and the gradual lowering of the crust after the ice had disappeared, are accounted for. It is interesting and important to note how lately the last movement of readjustment took place.

In attempting to gain a reasonably accurate estimate of the amount of erosion accomplished by the modern stream systems, it is necessary to make allowance for certain channels which were in existence before the ice invasion and for others which appear to have been made by streams of ice water during the final stages of melting of the Wisconsin ice. For example, the Hudson Valley itself is preglacial. Again, the disproportion between Drummond creek from East Line northward (east of Ballston Spa) and the channel which it occupies suggests at once that the latter was cut by a larger stream, probably of ice-derived water. Another channel of similar origin, but carrying no stream, is found about four miles a little west of north from Schenectady. It is a small gorge cut through the rock of the ridge which extends southeasterly from Town House Corners in the town of Glenville, particularly instructive in that it bears no relation to the lines of existing drainage.

Allowance must also be made for certain features along the courses of streams which appear to be erosional expansions of their valleys but which are in reality cavities left by sizable masses of dead ice which have melted. Many of the lake basins of the district were formed in this way and a few of them have been mistaken for excavations made by the modern drainage. They will be mentioned later. The Hudson valley itself appears not to have been filled with glacial deposits and reexcavated, but to have been protected in large measure from such filling by the remnants of a tongue of ice remaining in the gorge.

It will be seen, therefore, that a quantitative estimate of the amount of material removed by the Hudson river system above Troy is difficult if not impossible, but, in view of the criterions furnished by the small valleys southward from Coxsackie, we may be confident that the modern delta is but a small part of it.

The glacial deposits consist of (1) "till," the unassorted mixture of clay and stones of moderate size, dropped from the melting ice; (2) more or less assorted gravels laid down in the presence (frequently banked against the edges) of stagnant remnants of the glacier and distributed in part by the waters of melting ice; (3) thick beds of laminated clay marking the sites of former lakes held up on the rock terraces by unmelted ice, in the Hudson valley especially, but also at other places as for example: the headwater part of the Alplaus kill basin; and (4) quantities of yellow sand rather generally distributed over the surface of the clays and, in large part, to be referred to the stage of temporary lakes. The lacustrine

beds taken as a whole belong to a stage which is later than that shown by the till and gravels.

In dissecting these beds, the streams excavated the softer materials rapidly, until downward cutting was checked by bedrock or till of a resistant character. At each point where such harder material was encountered a rapid or fall was formed and, upstream from each rapid or fall, a reach or comparatively level stretch was developed. In the reaches sediment accumulated and from time to time forced the stream against one side or the other of its valley, thus enabling it to widen the sections between rapids by lateral cutting. As a steep-walled gorge was eroded through each barrier of rock or other resistant material, the reach controlled by that barrier was trenched more deeply and portions of the leveled floor thus abandoned were left above the new high-water mark of the stream as terraces.

It is convenient at this point to note that a body of standing water, as for instance a glacial lake, in the path of one of these modern streams would have acted to hold up the development of its valley to the level of the lake surface, and, as that surface lowered, the abandoned deposits made at each stage of fall would now be represented by terraces, similar to those in a reach but not correlated with any down-stream control. Since such features do not appear along the streams which were clearly formed of meteoric waters alone after the lacustrine beds were exposed to their action, we conclude that *those streams were not in existence during the lake stage.* This can mean only that the climate at that time was much drier than at present. Such physiographic evidence is of considerable importance in the attempt to separate the lines of glacial drainage from those of the modern system. We shall mention the more important of the latter in more detail.

The valley of the Mohawk, within the area of our map, is wholly postglacial although west of Schenectady the river occupies an older valley. This preglacial valley in the bedrock is continued eastward from Schenectady to the Hudson valley which it joins near Albany. This part of the preglacial channel was filled up by sediments, and the modern river, directed by the new slopes so created and possibly also by low places where ice blocks were melting out, has taken a course to the northeast, spilling over a rock barrier at Aqueduct and thence making its way to the Hudson at Cohoes. There is a rather pronounced reach level indicated in the Schenectady district which may be correlated either with the Aqueduct barrier or one

south of Ballston lake, the elevation of both being about the same. The fact that a terrace of this series continues along the west side of the broad channel in which lies the lower course of Alplaus kill has led to the supposition that the glacial equivalent of the Mohawk (the Iro-Mohawk) followed this channel for a time before the present course was established. We shall consider this possibility later.

The Hoosick river is in a preglacial valley from its upper basin to near Schaghticoke, but from this point westward it occupies a postglacial channel cut through a broad delta built by the river during a stage of the glacial lakes. This delta was laid down over a large block of ice anchored in the Hudson gorge, which ice persisted through the earlier phases of the dissection of the deposit and was effective as a barrier, delaying the downward cutting by the river long enough to permit the formation behind it of several successive terraces. As the levels of these terraces are not matched by the equivalent deposits of other, presumably contemporaneous streams, in the vicinity, it seems evident that they were not controlled by the surface of a wide and open body of water covering a considerable area, but are of strictly local origin.

The sites of other large masses of ice which outlasted the lake stage are the basinlike areas in the bottom of which lie Round and Saratoga lakes. The basin of Ballston lake was gouged out of the bedrock by the passage of the glacial ice and it too must have contained ice during this stage, or it would have been filled with sediment, for the upper part of the Alplaus kill system, that is, all that lies west of the trench followed by the Delaware and Hudson Railroad, was the site of a temporary ice-confined lake receiving sediments which today present a surface from 360 to 380 feet above tide. Although the trench fronting this deposit and, farther north, containing Ballston lake, may have been used later by the Mohawk or the Iro-Mohawk, its glacial predecessor, it seems that parts of it were still occupied by ice, or dissection and sedimentation would have left it with the leveled structure of a reach slightly above 300 feet (A. T.) to conform with the normal development behind the barrier at that level, caused by the divide just south of Ballston lake. It is only frank to admit that the drainage lines north of the Mohawk from the Ballston channel to the Hudson present a puzzle which has not as yet been satisfactorily solved.

The valleys appearing west of the Hudson between the Mohawk and the base of the Helderbergs have all developed along courses predetermined by the surface of the lacustrine sands and clays.

East of the Hudson the drainage lines are very largely due to the slope produced by the irregular deposition of glacial materials (sands, till and gravels at the higher elevations, clays below about 260 feet), and the numerous lakes and alluvial flats shown on the map mark the outlines of lingering masses of ice or valleys dammed by glacial drift. The largest and most striking of these is the trough occupied by Tomhannock creek north of Raymertown, which was ice filled while glacial waters were silting up the valley south of that point along the course of the Quacken kill.

The foregoing will serve to introduce to the reader three of the outstanding pictures in the geological record which may be conjured up from the evidence furnished by the unconsolidated deposits: (1) the stage of coarse gravels and sands being laid down as the last stagnant shreds of the glacier were melting off; (2) the stage of clay beds evidencing lacustrine conditions; and (3) the recent subsidence.

To recapitulate: There is a series of deposits made along the edges of remnants of the disappearing cover of ice or pocketed in crevasses and other openings. Next, there may be inferred a transition stage, as the standing waters of a "lake" rose about the remains of the glacier and began to float the fragments while the rock flour and fine sands washed out of the ice settled in horizontal layers over the previously deposited gravels. The ice had not completely melted away when the "lake" waters had reached their maximum depth and the last beds of sand and clay referable to this stage had been laid down. The falling levels of this body of water appear to be vaguely shown by occasional terraces on the bluffs above the estuary and also bordering the river and its larger tributaries above Troy. But it is to be inferred from the absence of such terraces at many critical points that the climate was still deficient in rainfall and we are probably justified in concluding that the water of all the streams feeding the shrinking lake was derived from melting ice.

Then the climate altered to one characterized by greater precipitation, the present-day drainage lines were established, and valley cutting began. After an interval during which many deep trenches were corraded in the glacial deposits and softer rocks, the last important crustal movement in the region took place, drowning part of the Hudson river system and confining erosion to the area left above the level of the newly formed estuary in which deltas began to build.

Before describing the pleistocene deposits in greater detail, we shall repeat briefly the description given in a previous chapter of the topography of the bedrock underlying them.

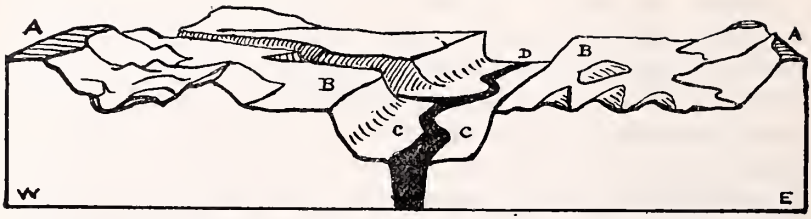


Figure 38 Diagram of the valley now occupied in part by the Hudson river. *A-A*, Cretacic peneplane; *B-B*, 200-foot terrace; *C-C*, floor of outer gorge; *D*, inner gorge.

First, there is an old land level known as the Tertiary peneplane now uplifted to an elevation of some 2000 feet above tide, the much dissected flat top of which can be detected from many high points in the Helderbergs and along the extreme eastern edge of the Troy quadrangle (*A-A* in the ideal diagram, figure 38). Into this plain an ancient drainage system sank its valleys, the principal one of which extends north and south through eastern New York. Most of the area with which we have to do in this discussion lies within this great meridional valley, the much worn sides of which slope down to a flattish floor. This latter comes to the edge of an inner valley as a rock terrace standing, in the vicinity of Albany, at an elevation of some 200 feet above tide (*B-B* of figure 38). The inner valley has steep side walls and is properly to be spoken of as a gorge; its floor now lies some 20 or 30 feet under the waters of the estuary at the southern boundary of the Albany quadrangle and comes above sea-level at Troy (*C-C* of figure 38). This, in turn, is threaded by a much deeper and narrower gorge (*D-D* of figure 38) with which we are not concerned except that it would appear to be this deeper trench to which the now drowned mouths of the lateral valleys were adjusted in the period just preceding the recent subsidence. At the site of the new railroad bridge near Castleton, it coincides in position with the navigable channel.

Probably more or less adjusted to the levels of both the gorges are two deep preglacial valleys (now buried) joining the meridional valley near the point where the city of Albany stands. One is the previously mentioned continuation of the valley now occupied by the Mohawk river as far east as South Schenectady which, borings show, lies approximately parrallel to and not far north of the Normanskill. The other is located under the plains of clay and sand west of the Hudson, passing through the basins of Saratoga and Round lakes, the expansion of the Mohawk valley between

Vischer's Ferry and Dunsbach Ferry, and so to West Albany somewhere near which place the two buried valleys join. This rock surface was subjected to glacial erosion several times, but as none of the local features demand explanation as the results of earlier glaciations, we are concerned only with the last of the great ice sheets, the Wisconsin.

At its maximum extent this ice sheet maintained a front just south of Manhattan island and was thick enough to pass over the highest peaks of the Catskill and Adirondack mountains. The movement of the ice was subject to change in direction both horizontally and vertically as the avenues of least resistance were shifted. We may picture the character of this movement best by assuming the whole mass to lie immovable except as increasing pressure now and again passed the critical point beyond which the deeper ice could no longer maintain its rigidity and moved out radially from under the overload, frequently coming to the upper surface of the ice field some distance away and there leaving a moraine derived from a lower elevation. Such a moraine would be ephemeral in the sense that, being built upon ice, it would not be preserved to reach the ground in recognizable form, if at all.

The record of one such movement is found in the capital district. It took the form of a fan with a more extended branch, running, like a broad stream, westward nearly to Utica, attached to its northern edge. This westerly moving arm would appear to mark the earlier phase of the movement for the northern part of its basal portion is rather abruptly truncated. The fan proper spread over the dissected plateau north of the Catskills among the northern peaks of which mountains the moving ice probably sheared upward over stagnant ice. At any rate there is no moraine marking its periphery or frontal edge as there probably would be if the land to the south and west were uncovered.

This glacial flow in the midst of the ice while it was still very thick carried a large amount of drift from the low basin area up over the Helderbergs and across the intervening valleys to the limits to which its traces on the land can be found. It scored the ground from present sea-level to more than 2000 feet above it before overriding the ice in front; it was the last recorded streaming, obliterating the marks left by all former passages of ice throughout the field which it covered, fluting the land with elongated hills of till (drumlins) and scoring the bedrock with deep furrows, of which latter the basin of Ballston lake is the most striking example.

Figure 39 is intended to show, diagrammatically, by a vertical section through the glacier, the phenomena of a movement in the ice caused by local overloading at a distance behind the periphery, or by a general thickening of the central field of the ice cap. Increased pressure at *N* (and to the right of the diagram) has set the ice crystals of the deeper portion in positions so nearly horizontal that they slide over each other with great freedom, and a forward motion of the superincumbent mass results, which may eventually be transmitted to the bottom of the sliding zone. As the frontal field of the glacier is in a state of equilibrium and, at the time, without motion, it acts as a barrier to be overcome. In consequence, the pressure behind the moving ice will be too weak to rearrange the crystal axes in the position necessary for motion everywhere and to an unlimited distance from its point of origin. When the limit of its power so to do is reached, the front of the area (or the periphery if movement is radially distributed) sheers up over the surrounding motionless ice until a new temporary equilibrium is established.

Figure 39 A north-south section showing ice moving out from under an overload and overthrusting on motionless ice in front. *C,* Catskill mountains; *H,* the Helderbergs. Arrows indicate the direction of movement; the short arrow continues the plane of overthrust.

It is probable that this is a common method of both thickening and advance in an ice sheet of continental proportions. A mountain glacier is dependent for its pressure upon the accumulation of snow in a comparatively small field, but a vast area of land ice receives its snowfall on its surface, is thickened locally and often responds by local adjustments taking the form of saucers, the arcuate edges of which sheer up onto the ice at a distance from the center of pressure created by local increases in the precipitation. At its maximum extension such an ice cap would be apt to have wide sections of its marginal zone in a stagnant condition and, as the snowfall decreased with an amelioration of the climate, the local thrusts from within the field would become less frequent and finally cease altogether, leaving the marginal zone to melt off *in situ.* This is what appears to have occurred in eastern New York and in New England.

In the higher parts of the capital district we find little to mark the form of the large ice masses resulting from the slow melting of the stagnant glacier, but, as the ice thinned and the land surface began to appear through it, streams of ice-derived water distributed sands, gravel and clay beds over the dead ice and here and there left a deposit against a hillside in what was evidently a pocket between the land and a mass of ice. Such accumulations are known as lateral terraces but, where the ice was stagnant the term "marginal" is perhaps more accurate. They are characterized by the partial preservation of the slope where they lay against the ice; if the ice edge was steep, as in *A* of figure 40, the outer boundary of

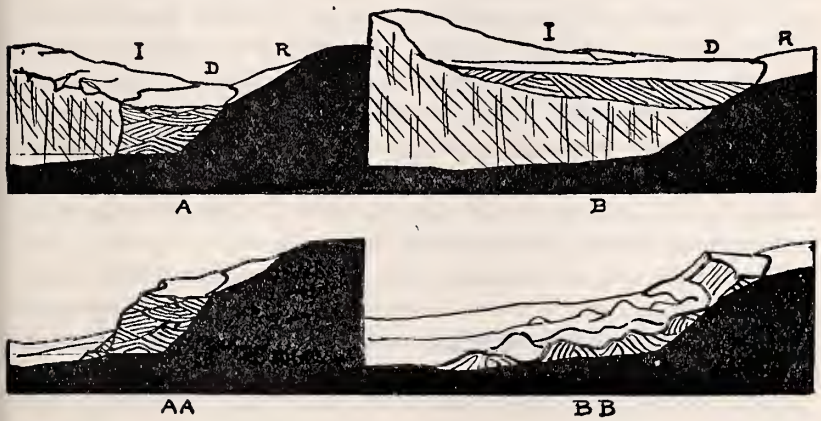


Figure 40 Types of contact with the ice. *I*, the ice; *R*, the land slope; *D*, the deposit which in *A* becomes the steep-faced terrace in *AA* as the ice melts, and in *B* collapses into a field of knobs and hollows *BB*.

the terrace drops off steeply, a comparatively small amount of material having slumped when the supporting ice melted (*AA* of the figure). If, as in *B*, the terrace was built over thin ice, it may have collapsed into a belt of knobs and hollows (kame-kettle terrace) and now retains little more than a hint of its original form (*BB*). One such terrace occurs at the southeastern base of Copeland hill on the Helderbergs, its leveled top just above the 520-foot contour line, and the contact slope as in *AA*.

A second type of deposit which has been preserved by having been built on the ground is illustrated by a rudely conical mound of waterwashed gravels at the north end of Bennet hill three and one-half miles northwest of the terrace just mentioned. Its top rises above the 660-foot contour and it was evidently made in a hole or small crevasse in thin stagnant ice.

So scattered are the isolated deposits at the higher levels that no relations can be established among them, but it is quite evident that, as the ice thinned, the outline of its southern margin became more and more complex. At first its surface was interrupted only by land islands where the hilltops of the dissected plateau came through; these small bared areas spread and joined and became connected with the ice-free district to the south. With each stage of thinning, a thicker insulating blanket of detritus accumulated on the surface of the ice, some of which was transported and deposited by superglacial and subglacial streams; but only as a part of this accumulated débris was carried or dumped from the ice onto a rock surface could it remain sufficiently undisturbed to furnish evidence to the geologist. A topography partly of land and partly of ice and threaded by shifting streams of water of inconstant volume will normally give less opportunity for leaving accumulations in the positions in which they could be preserved when there is a comparatively small land surface exposed. Therefore, while the ice was thick enough to cover the Hudson valley and the lower slopes leading up to the top of the plateau, only the first few scattered terraces were built against those slopes.

Without the action of running water the entire drift content would eventually have come to rest on the ground previously occupied by the land ice as an undifferentiated mantle of "till," but where stream-borne materials have been washed out over thin ice in sufficient quantity, the subsequent melting of the ice, though destroying any form which the deposit may have had and nearly, if not quite, obliterating its stratified or bedded structure, will not alter its character as washed or sorted material. Many of the gravelly beds of the capital district are without an admixture of clay or fine sand and are interpreted as having been partially washed by superglacial streams and marginal streams with little grade or sorting power.

A series of glacial plains in the basins of the Poestenkill and the Wynant kill (Troy quadrangle) presents a congeries of features, including much of this poorly washed gravel, which indicates that the ice which overlay the district was for a time in the path of a major line of superglacial drainage. As the higher rock hills appeared through the lowering surface of the ice, their slopes received deposits, and from about 800 feet A. T. downward plains and kame-kettle terraces built among masses of stagnant ice constitute a notable element of the landscape. At an elevation of about 400 feet the outline of the ice tongue filling the Hudson valley and thinly covering the rock-benches of the basin area can be partly reconstructed

by direct evidence. The stream-borne waste carried over the ice at the earlier stage began to be washed and dumped into cavities created by irregular melting and the two basins mentioned present excellent examples of the topographic characteristics produced under such conditions.

Other openings in the ice reaching to the underlying rock subsequently appeared (1) north of Albany (one-half mile west of Newtonville), and (2) south of Meadowdale along the foot of the Helderbergs. These openings through the thinning glacier remnant were also in the paths of superglacial streams and, as the ice broke up around their margins, and the open spaces were enlarged, they appear to have been filled in rapidly with deposits of gravel (or till, if the amount of available drift on the ice nearby was too great to admit of sorting by the streams handling it). At last a stage was reached where extensive terraces were built on the ground, or partly on the ground and partly over thin ice, and the elevations of their flattish tops give evidence of the levels of down-stream controls. Nearly all of the barriers acting as controls were of dirty basal ice more or less blanketed with débris and, in consequence, there is very little evidence of the action of flowing water (either through the "glacial drift" as it now lies or on the rock surfaces) which can be definitely correlated with the terraces.

The opening which appeared south of Meadowdale (Albany quadrangle, near the western edge) is marked by two conical piles of partly washed materials at the eastern end, rising above the 440-foot contour line, and by a similar though more irregular heap one and one-quarter miles a little north of west from the others. There are also some small crude terraces and one short narrow channel cut in the rock on the steep slope leading up to the limestone cliffs to the southwest, showing that the Helderberg (at least locally) was, at this time, practically free from ice-border drainage. This opening was enlarged southward along the foot of the "mountain," past New Salem; and the waters which governed the upper levels of the group of terraces found here, apparently spilled over the divide south of New Salem into the basin of the Oniskethau creek while it was still partly cumbered with remnant ice. There is, along this creek (west of the railroad, at South Bethlehem) a deltalike terrace built in a pocket between the rock wall and an ice wall along its eastern margin, and it is possible that, for a time at least, the forced drainage contributed to the building of its highest level (at about 300 feet).

A second enlargement of the Meadowdale-New Salem opening took place eastward with terrace levels falling to 350 feet, and

channels cut by ice-water streams below the 340-foot contour. The most marked level is just over 360 feet and extends almost to Voorheesville, where persistent ice prevented the accumulation of any definite terrace. To the southeast the deposit continues to within less than a mile of New Scotland at a somewhat lower elevation and here it ends abruptly.

The enlargement of the cavity south of Newtonville finally permitted the building of a terrace at an elevation of 370 feet A. T. with a few mounds rising above it, marking the slightly earlier stage of somewhat thicker ice and a smaller opening to the bedrock. The highest point reached by any of these kames is about 430 feet. The terrace extends southward into the limits of the city of Albany and would seem to be continued on the opposite side of the river by a broad terrace (named by Woodworth the Schodack terrace) which exhibits a dominant level of 370 feet where it begins at East Greenbush. It slopes southward and at the southern edge of the map is some 20 feet lower. Its contact with the ice tongue which still occupied the lower ground in the Hudson valley is well outlined by the slope running from the 300-foot contour line to that of 360 feet (or, at the south, 340 feet). This belt of gravelly materials can be traced along the margin of the stagnant ice for many miles to the south.

There are a number of smaller deposits of similar origin scattered over the northern part of the district, as at Burnt Hills west of Ballston lake, a mile southeast of Groom Corners and one-half mile northeast of Tomhannock, but they do not throw much light on the outline of the persistent ice mass.

It will be remembered that the lower accumulations of glacial sand and gravel, relied upon to interpret this stage of ice evacuation, are largely buried under later lake sediments and are only occasionally exposed in natural or artificial cuttings or in exceptional situations near ice masses contemporaneous with the lake deposits. In 1905 Professor J. B. Woodworth gave the name "Lake Albany" to that body of water in which the clays of the capital district were laid down, and he regarded all the clay beds southward to Kingston as belonging to the same series. This conception is too simple to account for the very complicated problem presented by high level clays and low level gravel terraces for the former demand standing water and the latter flowing water. Thus, from East Greenbush northeasterly, the Schodack terrace is continued as a strip of mounded, cross-bedded, coarse sands inclosing ice-block kettles, to the east side of Teller hill at an elevation of about 220 feet. From Oak-

wood Cemetery in Troy northward is a gravelly shelf which appears to mark a water level at about 310 feet. There are secondary terrace levels at South Bethlehem at 240 feet and a large cavity left by melting ice in the course of the Sprayt kill. At this point the glacial stream following the Oniskethau valley seems to have found its way *into the ice* at a level below 200 feet (the level to which the clays rise locally).

There are many exposures of water-laid gravels underlying the clays of the Hudson valley within Woodworth's "Lake Albany" district which indicate a free run-off of the glacio-natant waters through the ice at a time preceding the lacustrine conditions. One of the best is that of the North Albany gravels in the northern part of the city of Albany. The deposit has the structure of a short esker and represents crevasse or tunnel filling clearly connected with drainage from the southern end of the Newtonville terrace.

In addition to the coarser gravels which appear always to have been dumped or washed from the dead ice at no great distance from where they lie, there is a large amount of fine yellowish sand (partly redistributed in the lake waters) which is probably best interpreted as a deposit on the stagnant ice. Some of it can be shown to have been brought into the district by way of the Hoosick valley, and some by way of the Adirondack section of the Hudson river's course. In the latter case an ice-water stream was prevented from following the present course of the river from Corinth eastward by thick ice athwart that course; the stream was forced southward over thin ice in an old valley to the vicinity of Ballston Spa, northwest of which place it built a sand plain against an ice margin with a control just above the 400-foot contour line. There is hardly room for doubt that quantities of the sand were washed out over the ice at that level; it forms the topmost layer of the Newtonville terrace and would have been thought to be a wind deposit had it not appeared in two sections exposed in gravel pits more or less involved with the underlying cross-bedded gray sands.

Concerning the glacial lake or lakes we know much less than we would like to know. It has been shown that there was a period of free run-off down the Hudson valley prior to the deposition of the clays, and we are called upon to explain how this could have become so impeded as to create a basin capable of retaining a body of water in which from 100 to 300 feet of sedimentary beds accumulated. For lack of a more satisfactory explanation, the writer will venture to offer his opinions.

It is certain that ice filled the gorge of the Hudson and overlapped the rock terrace east of the river at the time when the 370-foot glacial terraces near Albany were made, and that this east bank drainage was kept out of the deeper part of the valley as far south, at least, as a point opposite Catskill village by a tongue of ice remaining in the gorge and extending southward an unknown distance. Nevertheless there is much to suggest that there were lines of free run-off through or under this tongue *for such streams as had access to them.* The gradual melting of the ice would tend to open these lines still further but the sediments carried into them would tend to close them, and only when the subglacial and other low channels were choked up (as they might easily be more than once to be subsequently partly reopened) would the ice tongue act as an efficient barrier. Such a conception will account for innumerable temporary water levels throughout the district and permit the consideration of an hypothesis of a series of fugitive lakes, some of longer life than others, but all subject to changes of level occasioned by changes in the unstable outlets through the lower valley.

At any rate, there was a lake or a series of lakes in which clays and fine sand accumulated to varying summit levels: 300 feet near Schenectady; 280 feet six miles northwest of Albany; 220 feet in the western parts of that city; and barely 200 feet on the rock terrace above Rensselaer. Along the base of the Helderbergs and southward they maintain a rather uniform level of about 180 feet as far as the mouth of Catskill creek. If the clay beds could be regarded as a continuous series laid down in a single extended lake, we might place the surface of the latter at something above the elevation of the highest clays, that is, about 320 feet, and if necessary, assume that the old water plane is somewhat tilted up at the north or down at the south in consequence of the crustal movement of recent times or one or more earlier movements. In the absence of independent evidence demanding such explanation it does not seem justifiable to postulate these earlier crustal adjustments. We know that after the ice had disappeared from the basin of Lake Champlain the northern part of New York State stood some 600 feet lower than it does now, letting the open waters of the ocean invade that basin as far south as Whitehall. But when we allow for the tilting which accompanied the recent rise of the Champlain basin and the subsidence of the lower Hudson valley, we have not accounted for "Lake Albany" nor have we discovered its shore line. A well-developed shore line would be easy to recognize, but, apart from the deltas built by the Hoosick river and by the outflow from Lake Iroquois, forced down the Mohawk valley, there is

little to suggest the marginal phenomena of a broad open body of water. Except where slowly melting masses of ice, lingering in the smaller drainage basins, gave rise to weak streams, those basins appear to have been dry, indicating a xerothermic climate as previously stated. And when all the deposits which may legitimately be regarded as deltas are mapped, and profiles taken through their theoretic water levels, we do not find ourselves much further advanced toward a solution. Certainly ice lay over the depressions in the bottom of which lie Round, Saratoga and Ballston lakes even after "Lake Albany" was extinct. The large delta of the Hoosick was built over a block of ice in the gorge and it is possible that the level indicated by its flat top represents approximately the surface of a local pond held behind ice not far to the south. The larger deltalike flats east of Troy were built by ice-water streams following the basins of the Wynantskill and the Poestenkill and were laid against masses of ice. (The only free deposit in this locality is a small fan of sand at an elevation of about 300 feet.) At Catskill the head of a delta built in the presence of ice lying to the south of it, is slightly above 180 feet. These levels are confusing and discordant and the deposits do not seem to belong to a single lake with a stable surface. Moreover, it is difficult to regard the present valley of the Hudson, between the clay bluffs mantling the rocky walls of the gorge, as the result of the reexcavation of a formerly clay-filled trench. The character of the terrace from Glenmont southward to Cedar Hill at an elevation of less than 100 feet above the estuary (except for some hills of rock and washed gravel) would appear to be decisive on this point. It is difficult to believe that the river could have removed a fill so completely before shifting into the narrower channel to the east, or could have failed to leave recognizable traces of its scouring action over ground which must have been its bed. The steep-sided knolls of gravel east of Wemple have more the appearance of having been confined in open pockets in the remnant ice, than that of river bars or earlier deposits once covered and now revealed by removal of the cover.

Practically all of the exposures of the lake sediments which are useful for study are furnished by the clay pits which have been dug in the bluffs bordering the Hudson in connection with the manufacture of bricks. The predominant color of the lower clay beds is blue, indicating the derivation of the rock flour composing them to have been from the underlying shales of the region, but a closer examination shows many layers (laminae) of green and red. There are occasional thin partings of fine sand, and many sections exhibit

the succession of varves (alternate finer and coarser deposits) interpreted as annual fluctuations in the conditions of sedimentation, the coarser materials representing summer melting of the ice, the finer representing the winter deposition. The upper clay beds are weathered to a dull yellowish hue and are, as a rule, overlain by yellow sand. There are very few evidences of the presence of the disintegrating ice sheet to be found in these exposures, and the small stones and boulders now and again come upon would appear to have been dropped from floating ice cakes. It is probable that the last important dam of ice in the gorge was far enough south of the capital district to permit the formation of a lake behind it which was comparatively free from ice remnants.

As the level of the ponded water in the Hudson valley lowered toward final draining, any streams entering the lake would cross the exposed sediments, trenching them and building a delta at each halt of the falling surface. As has been stated, there is reason to believe that the only streams of this time were those derived from the melting ice, and of these the Mohawk valley carried the largest. Professor James H. Stoller, who surveyed the Cohoes and Schenectady quadrangles for the State Museum, is of the opinion that this river at first spilled northward through the Ballston channel and was effective in making the rock channels from East Line (1) to Saratoga lake and the Hudson by way of Fish creek, and (2) to Round lake and the Hudson by way of the Anthony kill before finding its way into the course now held from Aqueduct to Cohoes. Doctor Stoller considers some of the sand plain levels of the vicinity as deltas made in the shrinking lake. If this is the correct interpretation of the topography of this part of the district, the Iro-Mohawk must have followed these more northerly courses for a comparatively short time, since the excavations in rock are inconsequential when contrasted with the cutting accomplished along the course of the modern Mohawk after it turns aside from the Ballston channel at Aqueduct.

With the draining of the glacial lakes we come to that part of the history which may be regarded as recent and the principal events of which have been outlined as follows: a period of (probably) xerothermic climate followed by a climatic change bringing more abundant summer rains and a higher temperature. The deflation of the areas of light sand seems to have begun as soon as these appeared above water, probably under the force of strong northwest winds coming off the land ice in the Ontario basin, but the trenching of the land by the modern streams was delayed until the amelioration of

climate which brought with it the meteoric waters to form such streams. Finally came the crustal movement whereby the land locally was depressed, creating the estuary and causing the Hudson's delta to accumulate.

At the present time, the activities of man in grading and tunneling constitute the most notable geologic process bringing about changes in the topography and, were man to forget or be forced to abandon the technology of engineering, his descendants, however familiar they might be with so-called "natural" processes and their results, would be sorely puzzled to account for many of the features of the landscape.

ECONOMIC GEOLOGY

The capital district is not so fortunate as to contain in its rocks any important minerals, such as the salt of the Syracuse region, that would form the foundation of a large industry. There has never been any mining carried on and there is no prospect that valuable minerals ever will be found. It is true that even to this day samples of supposed "coal," in every case slickensided black shale, usually from the Normanskill beds, or of "silver ore," white mica from the Rensselaer grit, and "gold," iron pyrite from the black shale, are brought to the office of the State Survey by excited prospectors. Much money has been lost in the last century in futile prospecting for coal and other minerals.

Still the capital district has one economic product of its geologic resources that is known over the whole country for its excellence, and that is the molding sand. Besides this it furnishes building stone and road metal, as well as clay for the manufacture of brick, a flourishing industry in the district, and gravel and building sand.

Considerable quarrying for dimension stone was formerly carried on in the Schenectady beds. The sandstone of the formation that is used for building is fine-grained and of a light gray or greenish gray or bluish color, weathering to a mellow yellowish tint. The even-bedded and well-marked jointed structure makes the quarrying relatively easy. Large quarries were formerly worked in this rock in Schenectady and Aqueduct and some are still active in Schenectady. Many of the older buildings in the capital district are built of this Schenectady bluestone. Smock ('90, p. 329) says regarding the Albany buildings:

Schenectady bluestone is seen in St Peter's Protestant Episcopal church, on State street; in St Joseph's Roman Catholic church, Ten Broeck street (walls); in the Protestant Episcopal Church of the Holy Innocents, corner of North Pearl and Colonie streets; in the

Second Presbyterian church on Chapel street, and in St John's Roman Catholic church, Ferry street. The stone in the walls of St Peter's church is nearly all natural-face blocks, and many of them have mellowed on exposure, to soft yellowish and light brown tints, which give the building the appearance of age.

Also No. 425 State street is, according to Smock, a noteworthy example of Hudson river bluestone, where the blocks are in course-work and have bush-hammered surfaces.

In Schenectady itself the rock has been used with fine result in the Memorial Hall of Union University, in the East Avenue Presbyterian church, and in the new Armory. It is further seen in the church at Menand's station, and in St Patrick's Roman Catholic church in Watervliet.

The rock has not only been used in ashlar work in the older stone buildings in the capital district, but much is still used in common wall-work and for foundations. The bluestone industry of Schenectady county amounted in 1925 (the last available figure) to $28,640.

In Troy the sandstone has been quarried for many years from the Normanskill and Snake Hill beds (in the Brothers quarry, south of the Poestenkill), but the industry is inactive at present.

More recently the Normanskill sandstone, as also the Schenectady bluestone at Aqueduct, has been used for crushed stone. The quarry at Kenwood was opened in Normanskill sandstone for this purpose. An important stone industry is the quarrying and crushing of limestone for road metal and railroad ballast. There are two great quarries and crushers in operation now at the Helderberg cliff, namely, the quarry of the Albany Crushed Stone Company, one and one-half miles southeast of Feura Bush, and Callanan's quarry at South Bethlehem. The production in 1925 was worth $345,062. The rock used is the Manlius and the Coeymans limestones. There are also smaller quarries, worked only intermittently, like the one above New Salem. The Onondaga limestone is at present quarried by the town of New Scotland on the north side of the New Salem-Wolf hill state road; and smaller quarries, temporarily opened for road metal in the Manlius, Coeymans, Becraft or Onondaga limestones, are scattered through the Helderbergs.

The Rensselaer grit also has been used for crushed stone and railroad ballast. It makes a most excellent material for that purpose. The Rensselaer Quarry Company had a large quarry and crushing plant near Brainard station, in the farthest southeast corner of the capital district. The rock proved too tough on the drills and work stopped some years ago.

The Snake Hill shale is being ground and used for improving sandy soils; the shale containing 4 per cent of potash, 16.5 per cent of aluminum oxide, and 0.15 per cent of phosphoric acid, a small proportion only of which, however, is soluble in distilled water. The plant (Werner's Natural Fertilizer Company) is in Mechanicville.

The other economic products are derivatives of the Pleistocene or Glacial period. Commercially the most important of these are the clays. The clays were deposited in a lake—or lakes—that formed at the end of the Glacial period, according to Woodworth, as the result of a rising of the land above the Highlands. This lake, which is known as Lake Albany, extended from the Kingston region to Schenectady and Saratoga. The well-laminated clays one sees so often exposed in Albany, where streets are cut through or cellars dug out, were deposited in this lake. These often thick deposits of clay, which extend on both sides of the river, have been the foundation of a great industry. The principal use of the clay is for brick-making. There are brickyards in Albany (north end: Murray & Riberdy, Van Woert street; at the south end: E. J. Smith, on First avenue) and in Watervliet, Troy, Crescent, Mechanicville and Stillwater. In Troy, also, hollow building tile and sewer pipe, as well as stove lining are manufactured. The General Electric Company in Schenectady also produces porcelain electric supplies and saggers, mostly from imported material.

The following figures, supplied by C. A. Hartnagel, give an idea of the importance of the industry. The clay products made in Albany county in 1925 were valued at $1,442,923; those in Rensselaer county at $755,744; in Saratoga county, $878,983; and in Schenectady county at $953,641 (General Electric Company).

To this must be added the slip clay, which is dug in Albany near the Dudley Observatory, and which in 1925 had a value of $34,943.

The Clay Products Cyclopedia, 1924, p. 35, describes the slip clay as follows:

> A slip clay is one that contains such a high percentage of fluxing impurities, and is of such texture, that it melts at a low cone to a greenish or brown glass, thus forming a natural glaze. . . . While easily fusible clays are not uncommon, all do not melt to a good glaze.
>
> Several fair slip clays have been found in different parts of the country, but the most thoroughly satisfactory material comes from Albany, N. Y., and is shipped to all parts of the United States for potters' use.

The most interesting economic product of the capital district is the molding sand, which is known all over the United States as "Albany molding sand," or "Albany sands."

D. H. Newland ('16) and C. M. Nevin ('25) have published interesting accounts of their investigations of the Albany sands which they made for the New York State Survey. From these authorities we gather the following facts:

The Albany molding sand consists almost wholly of quartz grains bonded by clay, while the common sand that we see drifting about in the dunes to the west of the city lacks this clay bond. The Albany molding sand has been recognized as being specially adapted for brass, aluminum and the smaller types of iron castings. "These sands," Nevin says, "have been shipped to every part of the United States and have established an enviable reputation for long life and satisfactory performance." Nevin (p. 69) states that certain grades are shipped as far as Tacoma, Wash., for brass and as far as Milwaukee for malleable castings.

The Albany molding sands, which are often sold under the trade name of Selkirk, Crescent and North River sands, are distributed on both banks of the Hudson river over a stretch of about 100 miles from Glens Falls on the north to Kingston on the south. Albany lies near the center of the area that in the south usually does not reach back more than a mile or two from either bank but broadens with the expansion of the valley at Albany through the entrance of the Mohawk, extending to Schenectady.

The molding sand always forms a layer directly below the soil, ranging in thickness from a few inches up to four or five feet; the thickness being not much more than 18 or 20 inches in the usual run of the bank. As one can often observe in driving through the country about Albany, this layer is carefully excavated and the sod replaced on the gray sand below. The mostly buff-colored sand can be seen piled up for shipment or in stock piles in various places, as at Glenmont and at Selkirk.

The origin of the molding sand has been found by the authorities cited above, to consist in the weathering of the easily attacked particles of "Hudson River shales" into a clayey substance which now forms the bond of the molding sand. The weathering takes place only under the soil under the influence of humic and other organic acids. For this reason the sharp gray glacial sand with intermixed particles of Hudson River shale, which everywhere underlies the

molding sand, is, like the dune sand, potential molding sand and may change into it under proper conditions.

The important centers of production in the capital district are: Ballston Spa, Mechanicville, Reynolds, Ushers, Round Lake, Schaghticoke, Elnora, Alplaus, Carmen, Schenectady, Waterford, Van Hoesen, Vischer Ferry, Karners, Crescent, Niskayuna, West Albany, Elsmere, Delmar, Slingerlands, Glenmont, Wemple and Selkirk. Albany county produced in 1925 molding sand worth $328,100; Saratoga county, $515,564; Schenectady county, $53,549; and Rensselaer county $13,206.

There is finally a considerable amount of building sand and gravel obtained in the capital district. In Albany the Rensselaer gravel pit in North Albany is known to everybody. The production of sand and gravel is by no means a small industry in the State. It had a value in 1924 of $13,397,540. Albany county produced in 1925, $146,953 worth; Rensselaer county $60,130; Saratoga county, $35,358; and Schenectady county, $151,453.

Water being a mineral, the sale of spring water, amounting to $36,855 in Rensselaer county, is also properly considered a mineral industry.

There is also a slight possibility that gas may be found in commercial quantities in the capital district, for two gas wells, of short production only, were drilled in the shales in the '80's at Altamont (then Knowersville); gas was struck in 1906 at the Hilton farm at Voorheesville and it ran for several years in sufficient quantity to light a street lamp. C. A. Hartnagel is of the opinion that the gas was derived from the underlying rocks (Schenectady beds) and accumulated in glacial sands below the Albany clay. Also at the site of Keeler's Hotel in Albany a few years ago, a small amount of gas was found in a well. If anywhere a proper trapping structure is present, gas may have accumulated in larger quantity.

In round figures the four counties of the capital district furnish $3,000,000 worth of clay products a year, not counting those of the General Electric Company; over three-quarters of a million dollars in molding sand; close to $400,000 in limestone and sandstone; and nearly $400,000 in sand and gravel. Counting all mineral products the industry amounts to over four and a half million dollars a year, certainly an astounding figure for a region lacking the major mineral resources.

POINTS OF GEOLOGIC INTEREST IN ALBANY, TROY, SCHENECTADY AND VICINITIES

There have come such frequent requests for information on the geology of the cities of the capital district that we consider it worth while to publish separate notes on the principal geologic features of the three cities of Albany, Troy and Schenectady, inclusive of their vicinities.

Albany is built on the clay deposited in Lake Albany at the end of the Glacial period. This clay, that can be seen in practically all building operations, and in the clay pits in north and south Albany, as well as in the street cuts in West Albany, rests on a very irregular rock surface which appears to have a deep depression directly under the city. The rock comes to the surface north of Albany along the New York Central Railroad tracks at "Black Rock cut" near Tivoli lake, and in South Albany in Lincoln Park, in the ravine, where formerly it formed "Buttermilk fall." The rock is mostly gray and black shale, all belonging to the Snake Hill formation. The same rock, with some sandstone and grit beds, is also exposed at Normansville below and above the bridge, and it is especially well seen in the cliff below the bridge.

The south end of Albany is, however, underlain by the Normanskill beds. The shales and grit beds of this formation are well shown at Kenwood in the cut of the Delaware and Hudson Railroad and in the stone quarry where the grit beds are worked. The fossils, graptolites, for which the formation is noted among geologists, were first collected and described (Hall, '47) from a temporary outcrop, produced in the mill race of and in excavations for a mill that was located just above the bridge. Remains of the mill and mill dam are still visible. Other fine collections were obtained in the West Shore Railroad cut at Glenmont. Graptolites can still be found at Kenwood about the old mill, in the railroad cut, and at Glenmont. At the latter place, along the road on both sides of the viaduct, the white-weathering chert of the Normanskill beds is well exposed.

Within easy reach of Albany, and visible from State street, is the interesting geologic locality of Rysedorph hill, one and one-half miles southeast of Rensselaer. There the Rysedorph Hill conglomerate, which has furnished large and interesting faunas, is exposed. The loose pebbles on the west side of the hill will always furnish fossils, especially Trenton brachiopods, as Plectambonites and Rafinesquina.

Albany is also the natural starting point of geologic parties studying the Helderbergs. Prosser, in the Guide to Excursions ('99) has already described the following excursions: (1) Albany-Clarksville-Reidsville-Albany; (2) Albany-New Salem-Countryman hill-Albany; (3) Albany-Indian Ladder-Thompson's lake-Altamont-Albany. Miss Goldring is engaged in a detailed description of the New Salem and Indian Ladder region. The state roads that have been constructed since Prosser's time have much improved the outcrops. Complete sections are now exposed along the New Salem-Indian Ladder road, New Salem-Wolf hill-Berne road, and the Albany-Clarksville road.

Schenectady is also built on the Albany clay. The rock foundation, although so deeply buried that it is nowhere seen in the city, consists of the Schenectady beds. The shales and sandstones of this formation are well seen on the hillside two and one-half miles west of Schenectady where the road, after crossing the tracks of the West Shore Railroad, leads up the hill. The best outcrops are now at Aqueduct and Rexford where formerly large quarries were worked, and the alternating shales and sandstones are still beautifully exposed, especially in the cliff below the Aqueduct-Rexford bridge. The shales in these localities have afforded numerous specimens of the remarkable seaweed *Sphenophycus latifolius,* at Aqueduct, with air sacs as floating apparatus. Excellent opportunity for collecting was formerly afforded in the Dettbarn quarries between Van Vrancken avenue and the river. The Schenectady eurypterids were discovered there. These shallow quarries have been filled in and built over.

The cliffs on both sides of the river below Aqueduct are in the Schenectady beds. They exhibit the small disturbances of the region, faults and low folds.

In the farther vicinity of Schenectady, the outcrops about Ballston lake are noteworthy, most of all, the fault line in Forest Park where the vertical Schenectady beds can be seen in the ridge on the west of the lake. On the other side of the lake, the undisturbed Schenectady beds with much sandstone are exposed along the shore of the southern part of the lake, and the Snake Hill shales to the best advantage in road cuts and road metal pits along the road paralleling the northern portion of the lake.

Troy. By far the most interesting city of the capital district geologically is Troy. There are numerous outcrops scattered about the city, revealing most remarkable geologic features.

Beginning with the campus of the Rensselaer Polytechnic Institute, the Lower Cambrian limestone, containing fossils, as *Obolella*

crassa, is exposed at the east end of the dining hall; close by the greenish gray Cambrian shales are shown. At the gate leading out to Sage avenue on the north side of the campus the Poestenkill fault breccia is well shown in a small cliff, and a little below, on the other side of the avenue, the Snake Hill shale has been quarried for road metal. It is thus apparent that the overthrust line separating the overlying Lower Cambrian rocks from the subjacent Snake Hill beds passes through the campus. This same Snake Hill shale can be traced along the Fitchburgh railroad to Lansingburg, where it is replaced by similar Normanskill shale.

The best exposure of the great overthrust line, the so-called Logan's line, is in the bed and banks of the Poestenkill below the falls. Coming up from Spring street, one finds first, close to the bridge, on the north side, Normanskill shale in which the writer once collected a fairly representative graptolite-fauna. Going up-stream, one passes over the heavy typical Normanskill grit beds, and then just above the dam and below the high falls comes upon the Poestenkill fault breccia, best shown at low water in the creek bed. The Ordovician-Cambrian contact is at the upper end of the pool below the falls, and the overthrust plane can be distinctly seen, from the edge of the water at the foot of the cliff, rising on the opposite (north) side toward the west. On the other (south) side of Spring street is the Brothers quarry, just north of the Seminary (popularly known as "Four Steeples"), where the Snake Hill shale and sandstone are well exposed in highly folded condition. Fossils were found here in the shale.

The Normanskill shale is well shown in several places in Troy, notably at the north end of Lansingburg, in the wooded hill north of the Lansingburg-Waterford bridge, where the white-weathering chert also is found. The ridges to the east of this locality also consist of Normanskill shale and chert. The isolated hill known as Mount Olympus, close to River street, north of the Green Island bridge, consists of Normanskill shale and has afforded good collections of graptolites. The Normanskill grits are well exposed along upper Congress street below Mount Ida Park. A cliff to the west of the street furnished Normanskill graptolites in the grit.

The Lower Cambrian rocks are well exposed at the Oakwood Cemetery, and especially at the locality known as Diamond Rock where the quartzite forms a ridge. The oldest and best known Cambrian locality in Troy is the old quarry back of Beman Park. It was here that W. S. Ford collected his brachiopods and trilobites that first established the Lower Cambrian age of these rocks. The

fossils occur there in the pebbles of what appears to be a conglomerate but is in reality an alternating limestone and shale in which the limestone bed has been torn apart into a crush breccia by the intense folding (see under Structural Geology). Here also the Lower Cambrian shale is seen in strong development. Along the Wynantskill below Albia may also be seen old road metal quarries with the Lower Cambrian olive grit in characteristic development. Going down the creek, one passes Normanskill grit and finally the dark gray Snake Hill shales.

Two miles east of Troy, in the gorge of the Poestenkill, the red Cambrian shale is found, which there has afforded the calcareous alga *Oldhamia occidens.*

Across the river from Troy numerous outcrops of the Snake Hill beds can be found along the shores of Green island, Van Schaick island and Peobles island. Some of these have afforded excellent opportunities for collecting (for these, see stars on the map).

Finally, the Cohoes gorge is also worth visiting in this neighborhood. The Snake Hill shale, much contorted and affected by cleavage, is here well exposed in the cliffs.

Series of limestone concretions are seen in the bottom of the gorge, intercalated in the shale. The gorge also shows in the deep central channel the formation of such channels by a series of potholes which finally become united. The bank of the channel has also become scalloped by this confluence of successive potholes. It was also, over 60 years ago, in this gorge that James Hall, by counting the growth rings of a cedar tree whose roots had been exposed by erosion at the edge of the cliff, got estimates of the age of the gorge and incidentally the first figures on the length of postglacial time.

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Supplementary Note

The exchange of the base map of 1929 for that of 1902 on which the geologic map had been drawn, without knowledge of the author, until the proofs were received, has made so many small errors, that it was impossible to make all the changes. Minor discrepancies between the geology and topography, particularly in the Helderberg cliff region, could not be avoided.

A serious error is the omission of the overprint for pleistocene deposits in the city of Albany (see p. 204).

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Figure 41 Panorama looking east and northeast from Education Building. Shows Albany plain extending across the Hudson River valley to the Rensselaer grit plateau, a peneplane, in the background. In left background is Mount Rafinesque (Bald mountain), a monadnock, resulting from a cross-fold and harder rock. (E. Stein, photo.)

Figure 42 Panorama looking north from Education Building. Shows Albany plain at left, with Rensselaer gravel pit. In central distance Mount Willard, Louise and Bald Mountains near Schuylerville and Mount Rafinesque on right, all erosion remnants composed of harder rock. (E. Stein, photo.)

Figure 43 Nearer view of Rensselaer grit plateau from Troy-Poestenkill road, looking across Albany plain. Old lake bed and alluvial plain at bottom of hill at right in front of Poestenkill village.

Figure 44 View of level top of Helderberg plateau ("Helderberg mountain" on ridge on right) from the top of Copeland hill. The even crestline of the Helderberg plateau (peneplane) forms the horizon. In far distance Catskill mountains, their tops also showing an even sky line. (E. Stein, photo.)

Figure 45 View from Cass hill looking north. On left back slope of Helderberg cliff, dropping to Oniskethau valley with Clarksville on left. Copeland, Blodgett and Bennett hills, composed of Marcellus and Hamilton rocks, in central background. The hills show the back slopes of the surface, due to the southeasterly dip of the rocks. Note the shoulder on Copeland (first) hill, where the Hamilton rests on the Marcellus. (E. Stein, photo.)

Figure 46 Panorama looking northwest from Copeland hill, showing the even skyline (peneplane) of the Helderberg ridge at the left. Bennett, Wolf and Countrymen hills in central background. In near center Oniskethau valley and in right distance the back slope of the Helderberg cliff, a dip slope on Coeymans limestone. (E. Stein, photo.)

Figure 47 Traveling sanddunes, one mile east of Reynolds. (H. P. Whitlock, photo.)

Figure 48 Normanskill valley at Kenwood. Shows the folded Normanskill shale and grit in railroad cut and rapids of creek. Type locality of Normanskill shale. (J. N. Nevius, photo.)

Figure 49 View looking south two miles west of Nassau, showing the restless character of the surface in the background, where the rocks (Cambrian shale and quartzite) outcrop. (E. Stein, photo.)

Figure 50 A nearer view of typical Cambrian slate topography, where the rock is at the surface. North of Nassau road; opposite view in figure 49. (E. Stein, photo.)

Figure 51 View north of figure 50, showing typical glacial hills of the region, as contrasted with those of figures 50 and 51. (E. Stein, photo.)

Figure 52 Helderberg escarpment near Voorheesville. In front Albany plain; in middle of escarpment the Manlius-Coeymans cliff; above first terrace with farms; then Onondaga cliff below second level. Farmed hills on top of the Marcellus-Hamilton slope. (J. N. Nevius, photo.)

Figure 53 Nearer view of lower Helderberg cliff, showing massive Manlius limestone below and Coeymans limestone above, also jointing of rock and talus slope. A fault is near the pillar in center. (E. Stein, photo.)

Figure 54 Road-metal pit in Esopus shale on south side of New Indian Ladder road. The shale is much weathered. (E. Stein, photo.)

Figure 55 Boulder composed of alternating layers of Schoharie grit and Onondaga limestone, on road, 1¼ miles south of Keefer Corners. (E. Stein, photo.)

Figure 56 Cliff of Lower Cambrian brecciated limestone on road to Snyder's lake. Bedding plane seen. (E. Stein, photo.)

Figure 57 Enlargement of portion of top of the cliff seen in figure 56 to show thin broken limestone bands (Edgewise conglomerate) in section of beds. (E. Stein, photo.)

Figure 58 Diamond Rock in Lansingburg. Lower Cambrian quartzite (Diamond Rock quartzite), projecting vertically in ledge from Cambrian shale. Albany plain in background across the Hudson River valley and Tertiary peneplane in far distance. (E. Stein, photo.)

Figure 59 Lower Cambrian (Nassau beds); red shale with interbedded thin greenish quartzite bands below and massive quartzite above. Along Albany-Pittsfield state road, one mile west of Brainard. (E. Stein, photo.)

Figure 60 Schaghticoke shale at Schaghticoke, showing alternating bands of white limestone and dark green shale. South bank of Hoosick river below Schaghticoke fall. (G. Van Ingen, photo.)

Figure 61 Rysedorph hill. The cliff of Rysedorph hill conglomerate is seen on the left of the tree on the hill. Normanskill shale on left slope of hill (Stoss-side) and in hill on right. (G. Van Ingen, photo.)

Figure 62 Poestenkill fault breccia (mylonite) in bottom of Poestenkill in Troy, below the fall. General view showing the enormous size of the blocks, as the one on the right, incorporated in the breccia. (E. Stein, photo.)

Figure 63 Nearer view of the mylonite, showing its shaly matrix and variety of boulders. (E. Stein, photo.)

Figure 64 Cliff of mylonite on campus of Rensselaer Polytechnic Institute, showing variety of material incorporated, especially Bald Mountain limestone (white) and Normanskill chert (black) and grit. (E. Stein, photo.)

Figure 65 Fault line ("Logan's line") of Cambrian-Ordovician overthrust in south wall of Poestenkill gorge below fall in Troy. Cambrian shale on left of fault line, mylonite and Normanskill grit on right. (E. Stein, photo.)

Figure 66 Intensely folded (crumpled) Schaghticoke shale in north bank of Hoosic river at Schaghticoke below fall. (G. Van Ingen, photo.)

Figure 67 Cohoes Falls, showing the "hanging valley" of the Mohawk river and the Snake Hill shale, forming the fall. In background intense folding is seen in the cliff. (Museum photo.)

Figure 68 Top of anticline in Rensselaer grit at Barberville. Red shale, overlying the grit, is seen on the left. (E. Stein, photo.)

Figure 69 Large recumbent fold in Rensselaer grit in East Nassau quarry. (E. Stein, photo.)

Figure 70 Closer view of left end of fold with small intersecting thrust fault. Picture also shows jointed character of grit beds and intercalation of thin shale seams. (E. Stein, photo.)

Figure 71 Small folds and overthrust (on left) in Manlius limestone in Sprayt Kill near South Bethlehem. (E. Stein, photo.)

Figure 72 Unconformable contact of Normanskill shale (left) and Manlius limestone (right). View taken opposite figure 71. (E. Stein, photo.)

Figure 73 Syncline on Sprayt Kill near South Bethlehem. The rock is Coeymans limestone. (E. Stein, photo.)

Figure 74 Syncline in Callanan's quarry. Manlius limestone below and Coeymans limestone on top. (H. Ries, photo.)

Figure 75 Small overturned fold and overthrust in bed of Oniskethau creek at Clarksville. (E. Stein, photo.)

Figure 76 Overthrust fault in western leg of syncline in Callanan's quarry in Manlius limestone. (E. Stein, photo.)

Figure 77 Small overthrust exposed along state road, half a mile east of Clarksville. Esopus shale on right, Onondaga limestone on left. (E. Stein, photo.)

Figure 78 Rensselaer gravel pit at North Albany. Shows stratification and structure of an esker. (J. N. Nevius, photo.)

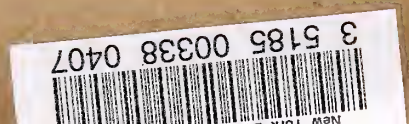
Figure 79 Stone crushing plant at Callanan's quarry at South Bethlehem. (E. Stein, photo.)

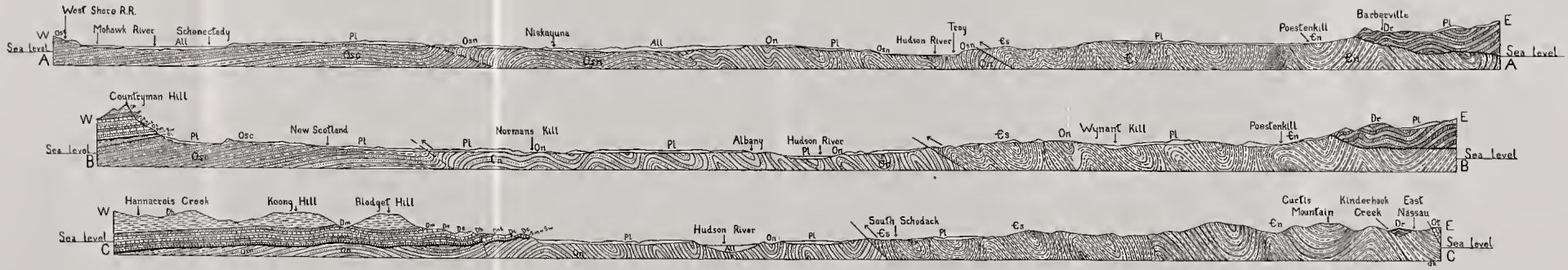
1 Geologic Map of Capital District (Albany, Cohoes, Troy and Schenectady Quadrangles)

2 Idealized Geologic Sections through the Capital District

XB
U812
no. 285
Dec. 1930

2 INSERTS

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South Schodack
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En
Cuelis Mountain
Kinderhook Creek
East Nassau
Dr
E
Sea level
C

CHARLTON
BALLSTON
STILLWATER
EASTON
CAMBRIDGE
GLENVILLE
CLIFTON PARK
SCHAGHTICOKE
SCHENECTADY
NISKAYUNA
ROTTERDAM
WATERFORD
PITTSTOWN
HALFMOON
MECHANICVILLE
SARATOGA LAKE
Round Lake
Ballston Lake
Stillwater
Mechanicville
Schaghticoke
Waterford
Troy
Rice Mtn
Mt Rafinesque
Peer Mtn
Bald Mtn
Beadles Mtn
Tomhannock Reservoir
Hudson River
Mohawk River
Erie Canal
Champlain Canal
Western Boundary of Distinct Taconic Folding
Boundary of Intense Taconic Folding
Washington Co
Rensselaer Co
Saratoga Co
Albany Co
Schenectady Co

LEGEND

DEVONIAN
- Rensselaer grit — Dark-green metamorphic grit with interbedded sedrigh and greenish shale and conglomerate.
- Dh — Hamilton beds — Thin-bedded sandstone and dark shale.
- Mar — Marcellus shale — Black argillaceous shale.
- Ond — Onondaga limestone (including Schoharie grit.)
- Ou — Esopus shale — Blackish, gritty or sandy shale.
- Orl — Oriskany sandstone — Dark thick-bedding quartzitic sandstone.
- Bec — Becraft limestone — Heavy bedded, light-gray crystalline limestone.

SILURIAN
- Dns — New Scotland beds — Thin-bedded, impure shaly limestone.
- Oc — Coeymans limestone — Bluish-gray thick bedded limestone.
- Mal — Manlius limestone and Rondout waterlime.
- Ind — Indian Ladder beds — Dark shale and sandstone.
- Sar — Schenectady beds — Alternating shale and sandstone.

ORDOVICIAN
- Utn — Utica shale — Black shale.
- Snake hill shale — Dark shale, some grit and conglomerate.
- Tk — Taconic calciferous shale.
- On — Normans Kill shale — Dark shale alternating with many grit and chert beds, including Pigeonhill Mill conglomerate on top.
- Deep Kill shale — Green and black shale with considerable thin limestone beds.
- Schaghticoke shale — Dark shale with sandstone and thin limestone beds.

CAMBRIAN
- Schodack shale and limestone; Troy shale; Diamond rock quartzite; Bennington grit.
- Nassau beds — Green and red shale and greenish quartzite.

- Pleistocene deposits — Where filling old valleys, or so widespread and thick as to prevent accurate mapping of the older rocks.
- Mostly modern alluvium and river deposits.
- Faults.
- Quarries.

Topography by U. S. Geological Survey
and the State of New York

GEOLOGY OF THE CAPITAL DISTRICT
(ALBANY AND VICINITY)

Geology by
Rudolf Ruedemann
1920-28.

Scale 4 miles

1 0 1 2 3 4 Miles

5000 0 5000 10000 15000 20000 Feet

1 0 1 2 3 4 5 Kilometers