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REPORT.

Office of the State Geologist, Room 32, State Hall,
Albany, N. Y., *April 24th, 1896.*

To His Excellency Levi P. Morton, *Governor of the State of New York:*

Sir:—I have the honor to submit the annual report of the State Geologist, embracing an account of the work done in the field and office.

The geologic map of the State, to which reference was made in my report of last year, has been completed so far as we had information in regard to the distribution of the several formations at the date of its submission. This map has been printed in colors under the direction of the United States Geological Survey in Washington, and 400 copies have been presented to the State of New York for distribution to educational institutions and departments, as well as to the members of the Legislature. The distribution of these copies has been essentially completed.

The field work of last season was carried on with special reference to completing the map in such portions of the State as were yet incompletely surveyed, and this work has contributed to our knowledge of the distribution and accurate limits of the geologic formations in the several counties under survey. The knowledge thus acquired will enable us to add much new matter to the map, and to reduce the uncolored areas in any future edition. At the same time attention has been given to the economic resources of such portions of country as have been examined, and the result will appear under the head of the counties described in the report.

The same method of work as heretofore mentioned has been continued, and the services of the professors in several of the colleges have been secured during their vacation time, the State incurring only their traveling and field expenses.

Professor Charles S. Prosser of Union College, has been engaged in the central portion of the State, and Professor Clarke, assistant State geologist, has been giving special attention to the relations of the Oneonta sandstones and shales to the Ithaca and Portage groups of central New York.

Mr. D. D. Luther, who has already contributed a valuable report upon the Livonia salt shaft and the products of the salt field generally, has reported upon the general and economic geology of Onondaga county, and has also been working upon the stratigraphic relations of the Portage sandstones in the Naples valley, and along the line of their outcrop from Seneca lake to Lake Erie.

Dr. Heinrich Ries of Columbia College, has made an elaborate investigation of the geology and economic resources of Orange county, N. Y., contributing much to our previous knowledge of the distribution of the rock formations in that part of the State. Professor I. P. Bishop, of the State Normal School at Buffalo, has investigated the structural and economic geology of Erie county, and has communicated a valuable map showing the distribution of the geologic formations, and the localities of oil and gas, with other economic resources of that county.

Professor C. H. Smyth, Jr., of Hamilton College, has been engaged in the study of the rock formations occupying parts of the counties of St. Lawrence, Lewis and Jefferson, and has communicated a report upon the same. Professor Smyth has also made a report on the talc industry of St. Lawrence county, which will form an important addition to our knowledge of the economic resources of the State. Professor H. P. Cushing, formerly of Columbia College, now of Adelbert College, Ohio, has made an examination of Clinton county, and the adjacent portions of Franklin, and will furnish a report upon the topography and structural geology of that region.

Professor J. F. Kemp, of Columbia College, has continued his investigations of the geology and economic resources of Essex county, and this report, accompanied by maps and diagrams, will form a part of the present report of the State Geologist.

The following synopses of these several reports and contributions will give an idea of the nature and results of the investigations carried on in this department.

SYNOPSES

OF THE RESULTS OF THE REPORTS

Communicated by the Several Assistants

IN THE FIELD AND OFFICE, RELATING TO THE GEOLOGIC MAP OF THE STATE.

The Stratigraphic and Faunal Relations of the Oneonta Sandstones and Shales, the Ithaca and the Portage Groups in Central New York.

By John M. Clarke.

This report presents a revision and summary of observations previously made by the same author with reference to the position of the Oneonta sandstones, and their extent westward from the Chenango river, and adds thereto more recent data bearing upon the passage of the Ithaca fauna, in the region of its highest development in Cortland and western Chenango counties, into the peculiar and typical fauna of the Portage group.

It is shown that the Oneonta group, characterized by its highly colored beds of shale and sandstone, and of prime economic importance on account of its high-grade sandstones and flags, lies above an eastern extension of sandy shales carrying the fauna of the Ithaca group. In the Chenango valley, at Greene, it is overlaid, at a height of 300 feet, by a fauna having many strong Chemung features, but in which certain of the Ithaca species are still present. In the sections along the Genegantslet creek westward of the Chenango valley, the barren red and green shales are found to alternate with gray sands carrying the fossils of the Ithaca group and, in a few instances, highly colored shales are observed, in which a few Ithaca species occur. Over the next divide to the west, and into the valley of the Otselic river, almost every trace of the red and green beds of the Oneonta group has disappeared. It is therefore concluded that the westward disappearance of the Oneonta group is due to recurrent thinning of the beds, the fossiliferous Ithaca beds coming in between and dovetailing with them. There is no satisfactory evidence that the Oneonta beds are followed by a normal Ithaca fauna, but rather by a fauna whose affinities are decidedly with that of the Chemung group. The fauna of the Ithaca group is most highly developed along the valley of the Otselic river and throughout Cortland county.

In making the detailed sections of this group, the base line taken is the Tully limestone, and the sections result in showing outcrops of this limestone at points considerably south of those previously reported. This is especially notable along the Tioughnioga valley and in the valley of the Cheningo. In the Otselic valley the sections of the rocks overlying both the Tully limestone and the very thin layer of Genesee slate show, first, a series of barren, sandy shales and flagstones, which are believed to correspond with certain barren sands lying at the base of the Portage section at Ithaca and some points further west in the more typical Portage region. The same beds are known to occur further east, and at Sherburne, in the Chenango valley, they were early termed by Vanuxem, the "Sherburne sandstones."

Above these lie beds of sandy shale, often with considerable quantities of argillaceous shale, bearing fossils which, for the most part, are Hamilton species, showing no variation. Gradually, however, forms appear which are not known to occur in the normal Hamilton fauna, among others *Spirifer mesastrialis*, which becomes abundant and large at about 300 feet above the base of the fossiliferous beds. In the upper portions of the group the fossils are distributed in thin beds, separated by wide, barren intervals; these barren sandstones and flags finally predominating to such an extent that fossils are seldom seen. In the Otselic river section, fossils which occur in the typical Portage section are very rarely seen; the fauna is a Hamilton fauna, modified by the presence of some non-Hamilton species, and by certain characteristic variations of the Hamilton species themselves.

In the Tioughnioga valley, the presence of some of the more abundant and widespread Portage species is noticeable. The commingling of the two faunas in the Cayuga lake section is well known. Through Schuyler county, in sections made at Havana and northward on the west side of Seneca lake, the predominating fossils are still the brachiopods of the Ithaca group, but with an increase in the representation of the Portage fauna, which manifests itself in places in Yates county by some of its indicial types. It is not until the western limit of Yates county is reached that the normal Portage fauna, with its peculiar types of life, so distinct from those of the Ithaca group, is fairly pronounced, and this expression of the fauna is intensified further westward in Ontario and Livingston counties, where evidences of the Ithaca fauna are met with only at rare intervals.

The Classification and Distribution of the Hamilton and Chemung Series of Central and Eastern New York.

By CHARLES S. PROSSER.

These investigations of the rock series from Chenango county eastward were undertaken principally for the purpose of tracing the boundaries of the Oneonta group of sandstones and shales, of ascertaining their stratigraphic and faunal relations to the deposits above and below, and, also, of elucidating so far as possible, the division line between the Hamilton group and the overlying strata and fauna. The latter is a peculiarly perplexing problem. East of the Chenango river the Tully limestone and Genesee slate are wanting, and the sandy shales of the Hamilton group pass upward into those of the Ithaca group with slight lithologic changes and with alterations of the fauna so gradual as to be perceptible only upon very careful observation. The Sherburne sandstones, of Vanuxem, are shown to be a mass of virtually barren deposits separating the faunas of the Hamilton and Ithaca groups, corresponding with the lower barren sandstones shown in some sections of the Portage of western New York, especially at Ithaca, where these beds have been designated as the "Lower Portage." There is good reason for recognizing this old and well-defined term in application to this mass of barren sands coming in between the Genesee slate and the overlying fossil-bearing beds. The term "Sherburne sandstones" would, then, designate an horizon pretty clearly defined from Cayuga lake eastward into Otsego county or beyond the disappearance of the Genesee and Tully formations. The rocks in the Chenango valley sections lying above this horizon, which have heretofore been referred to the Ithaca group, are shown to contain a fauna which bears a much greater resemblance to that of the Hamilton group beneath than to the fauna contained in the typical exposures of the Ithaca rocks at Ithaca. It is true that the section at Ithaca is through rocks whose organic content is a commingling of the species more fully and typically represented in Cortland and Chenango counties, with those which are properly members of the normal Portage fauna.

The Stratigraphic Position of the Portage Sandstones in the Naples Valley and the Adjoining Region.

By D. D. LUTHER.

The purpose of this work was to ascertain approximately the line of division between the Portage and the overlying Chemung group in western New York. The problem is a difficult one, so far as based upon lithologic grounds, for the rock series consists of sandstones, flags and sandy shales, varying among themselves. The original upper limitation of the Portage group, however, was fixed by a mass of heavy bedded sandstones, which were termed the "Portage sandstones."

The author introduces his work by giving a detailed account of a carefully studied section of the entire Portage formation in the Naples valley, in which the precise position of the Portage sandstones is shown and their exact relation to the faunas of the Portage and Chemung group determined. These sandstones lie at an elevation of 600 feet above the base of the Portage formation. A few feet below them is a bed of shales in which are found characteristic species of the peculiar and distinctive Portage fauna. Between this layer, however, and the sandstones themselves is a thin stratum bearing a small fauna unlike anything occurring in the normal Portage fauna. This stratum contains brachiopods (*Liorhynchus*, *Atrypa reticularis*, *Productella*, etc.), which indicate an encroaching fauna, not distinctively Chemung, but more closely allied to the Ithaca fauna of the regions east of Seneca lake.

It is further shown that the true Chemung fauna with *Hydnoceras tuberosum* and characteristic brachiopods, is well developed within 100 feet above these Portage sandstones, the intervening rocks not being clearly exposed in this section, but apparently consisting of barren sandy shales. The vertical distance from the base of the Portage group to the first pronounced development of a Chemung fauna, in this section, is less than 700 feet. This is a considerably less thickness than is commonly accredited to this formation, and much less than that which exists in the typical section on the Genesee river at, and below, Portageville, but the former has been measured with much care. With these data in hand the author has traced the heavy bedded Portage sandstones eastward to Seneca lake and westward to Lake Erie.

The Economic Geology of Onondaga County, N. Y.

By D. D. LUTHER.

In this paper the rock formations are discussed in their proper order of succession, and while attention is given to the geologic character and distribution of each, many facts of interest are brought out, and the especial value of the report consists in its exhaustive treatment of the most important economic products of this county, viz.: Salt, soda-ash, gypsum, hydraulic cement and quarry stone.

Following a brief description of the somewhat peculiar topography of the region, the shales of the Clinton group, the lowest formation represented, are described. These outcrops are in the low lands of the northern part of the county, and have shown no contact with the overlying Niagara limestone. The Niagara group is very obscurely developed through the same region eastward, and though quarried at several exposures for local use, it attains no great thickness and bears but few fossils. The rocks of the Salina group are shown to be of great importance. Their lower layers, the "red shales," are extensively excavated on their exposures, for the manufacture of brick and tile. This group is also the horizon of the salt brines of this region and of the rock-salt beds so extensively exploited by the Solvay Process Company in the vicinity of Tully. A recapitulation is here given of the history of the salt industry and the mode of production under the control of the State, followed by an account of the Solvay Company's soda-ash plant, and a statement of their process furnished by the company for this report. The facts brought forward show the enormous industrial importance of the enterprise. The well records of the nearly forty borings put down by this company in the vicinity of the Tully lakes are discussed and summarized. The importance of this industry is indicated by the statement that the Solvay Company consumes 800,000 gallons of brine, 1,000 tons of coal and 1,200 tons of limestone per day, and gives employment to 3,000 men.

The gypsiferous beds of the Salina group, overlying those containing the salt, vary somewhat in character, most of the output being from two shaly layers near the bottom. The history and development of this large industry is also concisely given, together with its mode of handling, list of producers, their output and market.

Under the Lower Helderberg group are considered the productive water-lime beds. The lower courses of this formation are blue, comparatively high-grade limestone, largely used for the production of quicklime. The productive hydraulic or cement rock lies in two beds, near the top of the group. The mode of quarrying and treating this rock in the manufacture of hydraulic cement is given at length; account being taken of all the principal producers and their output. Fossils of Lower Helderberg age are found both above and below these cement beds.

The Oriskany sandstone is shown to vary considerably in thickness, being actually thicker at the western than at the eastern limit of the county; in one section within the county totally disappearing, so that the limestones below come into actual contact with the Corniferous limestone above. It is fossiliferous, very interesting from a geologic standpoint, but is of little economic importance.

The grand exposures of the Onondaga and Corniferous limestones render them of great importance to the community. Following an historical account of the working, is given a description of the usual mode of exploiting and handling, a list of producers and product and of the notable buildings in Syracuse, affording illustrations of the usefulness and beauty of the rock.

The Marcellus formation is considered, with especial reference to the development of the Goniatite limestone.

The shales and sands of the Hamilton group, covering the high lands of the southern part of the district, are described, and notice taken of all their principal exposures.

The Tully limestone, a highly important base line among the formations in this region, is carefully traced throughout the county and its variations in thickness measured. It has some value as quarry stone, and its exploitation is described.

A bed of black shale, overlying the Tully limestone and having a thickness of 90 feet, is recognized as the continuation of the Genesee slate of western New York, together with the bituminous shale beds occurring in the lower part of the Portage formation in Ontario and Livingston counties. As these black bands within the Portage shales are but sparingly fossiliferous and their species are for the most part unlike those of the true Portage fauna, the assumption that the Onondaga county bituminous beds represent the completed tendency of the ancient seas to such sedimentation at this period may be probable, while its demonstration from sections would, in the paucity of fossil remains, be more difficult. The Portage shales and sandstones appear only in the tops of the high hills at the south, and bear a fauna characterizing the Ithaca group.

Under the caption, "Quaternary Era," the various surface modifications of the county in late geologic time are considered. In this connection notice is taken of clay, sand and marl deposits of economic importance, and of the actual product therefrom.

Following this is a discussion of the condition of the rock strata, with especial reference to dip, folding and faulting, with citation of illustrative phenomena; and much interest attaches to the author's account of the peridotite eruptive dikes in the city of Syracuse, first discovered by Vanuxem, and carefully studied in later years by G. H. Williams, and afterwards by Darton and Kemp.

The report closes with a statistical table of all economic products of the county, with names of producers and amount and value of output.

The report is accompanied by a geologic map of the county, various smaller maps, diagrams and sections, and numerous photographs.

The Structural and Economic Geology of Erie County.

By I. P. BISHOP.

After a brief introductory account of the topography of this region is a more detailed description of the stratigraphic succession of the rocks. The lowest rocks are the shales and marls of the Salina group, and the highest, according to this author's determination, the upper beds of the Portage group.

Each subdivision is described at considerable length, and features of special interest are the accounts given of the extensive water-lime beds, the limestones of the Upper Helderberg division, the Stafford limestone of the Marcellus shale, the Encrinal limestone of the Hamilton group, and the section of the Genesee slate. It is shown that the Tully limestone, which is absent in all the country west of Canandaigua lake, is here represented by a layer of pyrite at the top of the Hamilton shales, as shown by D. D. Luther to be the case in the counties eastward between Erie and Ontario. The section of the Genesee slate has a thickness of only seventeen feet, about two feet of this belonging to the Styliola band, which has thus been shown to extend from Yates county to Lake Erie. The lithologic characters of the Portage shales and sands are carefully given, but their fossils have received little attention in this connexion; the upper limit of this formation, in the region described, is not clearly determined.

Superficial deposits, sands, gravels and clays are treated under the head of "Quaternary geology," and in connexion therewith is an account of the soils, springs, pre-glacial rivers and erosion, and the ancient Lake Erie shore line in Buffalo. This part of the paper closes with a brief notice of modern geologic changes.

The second main heading is that of economic geology, under which are considered, first, the rock formations quarried for building stone, viz.; the hydraulic limestone, Onondaga limestone, Corniferous limestone, Stafford limestone, Encrinal limestone and Portage sandstones. The interests here represented are large, as shown by the statistics of producers, and the quality and amount of the products. Similar consideration is given to the product of road metal.

Following this is an extended description of the production and manufacture of hydraulic cement; the nature of the cement rock and a list of its fossil contents. The production of quicklime, brick, tile, sewer pipe and fire clays, sand and gravel, is also described at length.

A large part of this report is especially concerned with the product of natural gas and records of the wells which have been drilled in and about the city of Buffalo. This account has been prepared with elaborate care, giving a full list of the gas-producing companies or individuals, their well records and product. The tabulated list of wells, productive and non-productive, embraces sixty-seven. These statistics are supplemented by some discussion of the geology and supply of natural gas. Brief accounts of the rock salt and water power of the county are followed by the description of a general geologic section from Lake Ontario to Cattaraugus creek.

The paper is accompanied by a geologic map of Erie county, with several maps showing the location of the gas wells, and by numerous photographs.

Report on the Geology of Orange County.

By HEINRICH RIES.

The introductory parts of this report are devoted to a description of the physical geography and topography of the region, followed by a summary of geologic literature pertaining to the district.

The geologic formations present are then taken up in consecutive order for brief discussion.

The pre-Cambrian rocks are largely developed, consisting of gneisses, gneissoid rocks and limestones, all frequently traversed by dykes of igneous rock. The bodies of iron ore which are worked in this county lie in these crystalline rocks.

The Cambrian rocks are light colored, generally heavy bedded magnesian limestones, and though apparently without fossils, they seem to be a continuation of the limestones of northern New Jersey, in which fossils have been found. These limestones frequently become crystalline as a result of granite intrusions.

The Trenton group is represented only by a single exposure near Newburgh. The Hudson river shales and sandstones are very widely extended and cover nearly two-thirds of the area of the county. In a few localities they have furnished fossils. In the Shawangunk mountains, the Medina sandstone has a thickness of about fifty feet in the town of Deer Park, and also appears in the vicinity of Skunnemunk mountain. The Lower Helderberg series appears at several points, and at the best exposures its different members can be determined. The Oriskany sandstone and quartzite occurs in two belts, one passing through Port Jervis, and the other along the western side of Skunnemunk mountain. The Cauda-galli grit, "Esopus slate," as it has been termed by Darton, rests on the Oriskany in eastern Deer Park township. Outcrops of the Corniferous limestone are restricted to localities near Port Jervis and Port Orange, its thickness being estimated at 250 feet. The Hamilton group is well developed in the county. The Marcellus shales are seen along the Neversink valley, and are estimated to attain the enormous thickness of 800 feet. Overlying them in the same region are arenaceous shales of the Hamilton group with a thickness of 1,800 feet. A second area of Hamilton rocks in the Skunnemunk mountain region has been separated into local subdivisions, viz.: the Monroe shales, Bellvale flags, and Skunnemunk conglomerate. The Chemung formation caps the rock section, and is represented by non-fossiliferous beds in the western portion of Deer Park.

Following this summary statement of the distribution of the geologic formations, the author enters more explicitly into a discussion of the geologic relations of each, and more detailed accounts of their areal extent. The following captions show the general mode of treatment: Geology of the Warwick Cambrian limestones, and the granites; Relations of the limestones and Hudson river slates; Geology of the region along Bellvale mountain; Pre-Cambrian gneiss; Geologic relations of the area along Skunnemunk mountain; The relations along the northwest side of Skunnemunk mountain; Geology of the region east and southeast of Skunnemunk mountain; The area west of Cornwall; Geology of Deer Park township; Hudson river slates and sandstones; The Neelytown limestone; Geology of Newburgh and New Windsor townships; The Highland area of gneissic rocks; Tuxedo township, Monroe township, Woodbury township, Highland township, Cornwall township; Dike rocks; Quartz porphyry; Pleistocene geology.

These chapters, each of which is elaborated in detail and precision, precede a special consideration of the economic geology of the county.

The various materials available for road making are described; brick clays, their quality, workers and product; limestone, lead ore, building stone, flagstone, iron ores and their workings, handling and product, are fully considered· and, finally, the soils, mineral springs, water power and water supply.

Report on the Talc Industry of St. Lawrence County.

By C. H. SMYTH, JR.

In a previous report the author had given some consideration to a certain portion of the talc deposits in this region. A fuller account of the talc, its nature, occurrence and exploitation is here presented. The deposits of this mineral are largely in the towns of Edwards and Fowler. It may occur at several horizons in beds of considerable thickness, and it is evident that these beds are intimately related to the crystalline limestones with which they are associated. The walls of these talc beds consist of a tremolite rock passing gradually into the limestone, and one evidence that the talc is derived by gradual alteration from the tremolite is the fact that much of the mineral is distinctly fibrous, a condition of first importance to the economic applications of the talc The soft, scaly, non-fibrous talc is regarded as the ultimate condition of the mineral resulting from the continuation of the decomposition of the tremolite. Some account of the number of mines is given, followed by a description of the process of manufacture, and some discussion of the value of variations in physical character of the mineral, and finally a statement of its uses in manufactures.

Report on the Crystalline Rocks of St. Lawrence County.

By C. H. SMYTH, JR.

This is an account of work done in this county in continuation of observations already made in a previous report. The townships whose geology is especially considered are those not canvassed in the previous survey by the author. The principal purpose of the work has been to determine the distribution of the crystalline limestones, for which the writer had already introduced the term, "Oswegatchie series;" and, also, to collect data bearing upon the question of the origin of the gneisses and the relation existing between these rocks and the limestones. The limestones occur principally in belts, as well as in small scattered patches. The extent of these limestone areas is described, and in the same connection the areal distribution of the gneisses. Three or four distinct belts of limestone are defined, together with smaller accessory areas. The limestones are highly crystalline, with a considerable range of color, and carry masses of embedded silicates, among them tremolite in such abundance as sometimes to constitute a tremolite schist. Interbedded with the limestones are, sometimes, gneissic rocks. The author infers that the limestones, having their greatest development in the northwest part of the county, decrease rapidly in passing southeastward toward the heart of the Adirondacks.

Under the heading, "Origin of the Gneisses," the two important problems are discussed—the origin of the gneisses, and their relations to the limestones. In considering the first of these, three explanations are presented as possible, and worthy of consideration; the first, that the gneisses are metamorphosed sediments; the second, that they are of igneous origin; the third, that they are partly metamorphic and partly igneous. It is shown that the principal evidence in favor of the first hypothesis lies in the association of the limestones with the gneisses, but this is regarded as insufficient to prove that the gneisses belong to the limestone series. The second hypothesis is considered in much detail. Evidence in its favor is found in the general foliation of the gneisses, and in the microscopic structure of the rock affording various evidences of pressure, flow, and secondary changes. Facts are brought forward to show that the gneiss contains masses which are inclusions of some older formation, perhaps taken up by the gneiss when it was in a molten state.

As the author does not regard the gneisses and the limestones as parts of one series, the former must be older or younger than the latter, and he believes that the gneiss is, in part at least, the younger, and instances are cited where the gneiss appears to be intrusive into the limestones, and accompanied by local metamorphic contact effects. With regard to the general relations of the gneisses and limestone, it is concluded by the author that the gneisses constitute a complete series of rocks, differing somewhat in age, and largely, if not almost wholly, of igneous origin; that parts of this series are younger than the limestones; and while it is possible that other parts may be older than the latter, there is, however, no absolute proof of this assumption.

Report on the Geology of Clinton County.

By H. P. CUSHING.

After a general presentation of the topography of this region, the author takes up for especial consideration *seriatim* the geologic formations, as follows:

1. Gneissic series; 2. Limestone series; 3. Gabbro series; 4. Palaeozoic series: (*a*) Potsdam sandstone, (*b*) Calciferous sandrock, (*c*) Chazy limestone, (*d*) Black River limestone, (*e*) Trenton limestone, (*f*) Utica slate; 5. Dike series; 6. Pleistocene deposits.

Then follow important chapters on the metamorphism of the Pre-Cambrian Rocks and on Post-Champlain (Lower Silurian) Disturbances.

The latter half of the paper is devoted to the discussion of the areal geology by townships, in the following order:

Clinton, Mooers, Ellenburg, Dannemora, Saranac, Black Brook, Ausable, Peru, Schuyler Falls, Plattsburg, Beekmantown, Altona, Chazy, Champlain.

Preliminary Report on the Geology of Essex County.

By J. F. KEMP.

This report is a continuation of the author's geologic investigations, published in the report of the State Geologist for 1893. Townships not previously described are taken up for special consideration and description, and the areal geology of each is given, so far as determined. Special notice is taken of economic products, mainly of iron ores.

In the town of Chesterfield, so far as explored, the gneisses are extensively developed, but no new facts in regard to other series of rocks have been obtained since the last report.

In Jay, the gneisses constitute the northeastern corner; the crystalline limestones occur in upper Jay, and constitute the northerly continuation of the area of similar rocks occurring in Keene; rocks of the gabbro family cover the main portion of the town, while no palaeozoic sediments or dikes of irruptive rocks have been observed.

In Wilmington, the gneisses and gneissoid rocks with crystalline limestones are believed to be absent. The entire eastern portion of the town is covered with gabbros and anorthosites, while no sedimentary rocks are found in the town. A single trap dike is observed at the high falls of the West Branch of the Ausable.

St. Armand. The gneisses are well represented, but the crystalline limestones and their associated rocks are not met with in the town. The area of gabbros, represented on the map largely from inference, appears to be considerable. No palaeozoic or irruptive rocks have been noted.

In North Hudson, so far as explored, only the gabbros have been noted.

In Schroon, the gneisses and crystalline limestones cover almost the entire township except the northern portion where there are gabbros, and a small area at Schroon Lake post office, correctly regarded as Calciferous sandrock. The last is the remotest outlier yet observed of palaeozoic sediments in the mountains. Several dikes are noted; one at Pharaoh pond, others west of Schroon Lake post office. Iron ore occurs in the Schofield bed at the extreme east of the town.

Minerva is chiefly covered with gneisses and crystalline limestone; on the northeast, gabbros and related rocks occur, and the same are present along the eastern border. No palaeozoic rocks or dikes were met with. There is little iron ore in the town, and garnet is worked at one locality for an abrasive.

Newcomb has been but partially studied. The gneisses and crystalline limestones are widespread; the folding of the latter has been an important factor in producing the lake basins in the central part of the town and in determining the water courses. The anorthosites and gabbros make up the eastern third of the township. No palaeozoic rocks or irruptive dikes have been observed in the town. In the vicinity of lakes Sandford and Henderson are extensive iron mines. These mines were opened at the village of McIntyre and bloomeries established about 1835, by the late Hon. Archibald McIntyre. A very complete history of their workings, with a description of the ores, analyses, and a map of the mines, are given. The amount of ore in sight is enormous, and though highly titaniferous, it is thought that it may be profitably worked with the revival of the iron demand and an improvement in shipping facilities.

The geologic notes made upon the separate townships are often in considerable detail, involving careful analyses of rock structure and derivation.

Thickness of the Lower Silurian Formations along West Canada Creek and the Mohawk River.

By CHARLES S. PROSSER and EDGAR S. CUMINGS.

The writers here consider *in extenso* the rock sections exposed in the gorge of the West Canada creek at Trenton Falls, at Newport and at Little Falls.

These sections have all been previously studied by other observers, some of them frequently, and not always with concordant results. In this paper, both measurements of thickness, and identification of species of fossils have been made with care, and while the conclusions are not in complete harmony with already expressed opinions, they doubtless afford a more precise knowledge of the formations considered.

PALAEONTOLOGY.

Note on the Discovery of a Sessile Conularia.

BY R. RUEDEMANN.

This important paper by Dr. Ruedemann, who contributed to the report of last year an interesting memoir on the Graptolites, is based upon the study of some obscure organisms found in the Utica slate at Dolgeville, N. Y. Portions of this paper have already been published during the past year in the *American Geologist*, and they make so significant a contribution to our knowledge of the fossils of this State that, with the author's consent, these portions are here reproduced with their accompanying plates. To these are added further observations and illustrations. As a result of this study much light is thrown upon the nature and mode of development of this wide-spread but little understood organism, *Conularia*, in regard to whose taxonomic position there has been a widely diverse expression of opinion.

A Discussion of Streptelasma and Allied Genera of Rugose Corals.

BY JAMES HALL.

The genus *Streptelasma* has never yet been clearly defined, and thus the nomenclature assigned to it has been one of general and conventional use. The entire group of American species which have been referred to this genus are here brought together and their structural characteristics carefully analyzed. It has been found that the term *Streptelasma* must be carefully restricted to forms like the *S. corniculum*, Hall, of the Trenton fauna. Deviations from this type of generic structure are here recognized under distinct designations: Thus the *S. mammifer*, Hall, of the Upper Helderberg limestone, *S. caliculum*, Hall, of the Niagara group, and *S. rectum*, Hall, of the Hamilton shale, are each made the type of a distinct genus. A new form from the Trenton limestone is described as *Streptophyllum cystosum.* A new species from the Hamilton group is, as *Lopholasma carinatum*, made the type of a new genus. The *Petraia Fanningani*, of Safford, is likewise made the type of a new genus. The genus *Duncanella*, Nicholson, is also reviewed, additional structural features determined, and some new specific forms described. The paper is accompanied by a lithographic plate and numerous text illustrations

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The Palaeozoic Hexactinellid Sponges Constituting the Family Dictyospongidæ.

Part I.

This work was communicated with the annual report of last year, but on account of its necessarily extensive illustration, the State printer was deterred from producing it. The appreciative co-operation of the Wynkoop Hallenbeck Crawford Company, the present State printers, and the endorsement of the Hon. James A. Roberts, Comptroller of the State, have made its publication at this time possible. It is proposed to present with this report that portion of the work concerned with the general introductory discussion of the nature and structure of these interesting fossils, and the description of such species as are known to occur in the Silurian and Devonian formations. This will be followed, in the next annual report, by accounts of other representatives of this family occurring in the faunas of the lower Carboniferous formation. This arrangement will make possible the publication of the one thousand separate copies of this monograph which are called for by Chapter 932 of the Laws of 1895, without serious delay.

The *Dictyospongidæ* constitute a family of thin-walled, reticulate, siliceous sponges whose life, so far as known, was restricted to palaeozoic time. The first of these fossils to be described was regarded as a Cephalopod and termed *Hydnoceras* (*Hydnoceras tuberosum*, Conrad. Journal Philadelphia Academy Natural Science, vol. viii. 1842); subsequently this and other species were interpreted as remains of marine algæ and a few species from the later Devonian rocks became pretty well known to collectors of New York State fossils. Their real nature was recognized about fifteen years ago by Prof. R. P. Whitfield, from the study of specimens found in the soft calcareous shales of Crawfordsville, Indiana, which retained the spicular skeleton of the sponge in the condition of iron pyrites.

In this memoir an effort has been made to bring together all that is now known concerning this remarkable family. The work is based upon the result of more than fifty years of care and watchfulness in securing the material which is here illustrated, and more than once during this period it has seemed as if the end of these resources had been reached, but in every case new forms have come to light. Explorations carried on in late years, in the Chemung rocks of this State, especially by Mr. E. B. Hall, of Wellsville, Allegany county, have shown a most surprising development of these fossils and we have good reason to believe that, notwithstanding the frequent occurrence of living hexactinellid sponges in existing seas, the Chemung period was the time of culmination of the entire order *Hexactinellida*, to which this family belongs. At the present time more than seventy species of these Dictyosponges have been recognized in the Chemung fauna alone, and we have been able to locate areas where they grew in colonies or plantations on the sea bottom of that ancient period. In previous faunas they were much fewer, and in those succeeding the Chemung, they continued for only a brief period, though with most interesting manifestations of form and structure. This memoir will embrace descriptions and illustrations of over one hundred and twenty species, at present recognized under twenty-nine genera.

Very respectfully, your obedient servant,

JAMES HALL,

State Geologist and Palaeontologist.

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.
(GEOLOGIC MAP.)

THE STRATIGRAPHIC AND FAUNAL RELATIONS OF THE ONEONTA SANDSTONES AND SHALES, THE ITHACA AND THE PORTAGE GROUPS IN CENTRAL NEW YORK.

JAMES HALL,
State Geologist.

JOHN M. CLARKE,
Assistant State Geologist.

1895.

James Hall, *State Geologist.*

Sir:—The report herewith submitted is in continuation of that made by me in the Thirteenth Annual Report, and concerns the inter-relations of the various geologic deposits laid down during Portage time, especially as developed through the central region of the State. The stratigraphy and faunal succession in Chenango county, west of the Chenango river, have been previously discussed in some detail. Here I have endeavored to correlate those observations with such as have since been made further westward through the counties of Cortland, Schuyler and Yates.

Respectfully yours,

JOHN M. CLARKE.

Albany, *January 1st, 1896.*

PLATE I

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The Stratigraphic and Faunal Relations of the Oneonta Sandstones and Shales, the Ithaca and the Portage Groups in Central New York.

By John M. Clarke.

In the Thirteenth Annual Report of the State Geologist, dated 1894, the writer communicated the preliminary results of observations made in Chenango county, with especial reference to the westward extension through that region of the barren sandstones, red and green shales constituting the Oneonta beds, as defined by the late Lardner Vanuxem. Sufficient evidence was there brought forward to show that westward of the Chenango river this group of beds, so important economically for its high-grade sandstones and so strikingly characterized by the brilliant coloration of many of its softer beds, rapidly thins out. Even before reaching the western limit of Chenango county the last positive evidence of it has disappeared. The Genegantslet creek, a considerable water course rising in the high land of Pharsalia township and flowing almost due south into the Chenango river, gives a number of instructive sections which offer a clew to the mode of its disappearance. The entire mass of this distinctly eastern sediment does not thin to a single edge. Between it and the contemporaneous sediments of the fossil-bearing Ithaca group, which predominate in western Chenango county, there was a constant oscillation and a mutual encroachment; consequently the rock sections show recurrences of Oneonta conditions after the main body of such deposits had been left far below. Thus, in the village of Greene, on Birdsall's brook (Station M, Report of 1894), a section lying almost as low as the river level in the Chenango valley, the characteristic Oneonta shales and sands, with their reds and greens, are well shown. But northward along the Genegantslet, flowing through high lands well elevated above this spot are repeated evidences of such highly colored beds, separated from those beneath by intervals of fossiliferous rocks. At Station N, two miles north of Greene on the highway to Smithville Flats, are fossiliferous shales, 150 to 200 feet higher than the beds at Station M; at Station O, two and one-half miles north of Smithville Flats and considerably higher in the section, are again green shales and sands with fish remains, a repetition of the Oneonta sediments, together with shaly layers bearing fossils. Still further north, a short distance south of the village of McDonough, and still higher in the section, are fossil-bearing rocks, and in the town of Pharsalia (Stations T, T[1], T[2]), at about the same elevation in the section, there lies, above certain fossiliferous beds, a peculiar fawn-colored cavernous sandstone which reproduces an Oneonta character, inasmuch as a similar rock has been elsewhere observed, only with typical Oneonta sediments at Station E, near Norwich. Westward of the Genegantslet valley, evidences of these Oneonta beds may exist for a short distance into the divide between the Genegantslet and Otselic rivers, but they have not been observed in the valley of the latter stream. Traces of such red and green beds may naturally be expected westward in Cortland county, intercalated among the deposits properly belonging to the Ithaca group, but none have been seen by me. Such instances as those quoted serve to show that the Oneonta deposits disappear westward both by thinning and recurrence, not contracting to a single edge, but dovetailed by a number of edges or long planes into the sediments bearing the Ithaca fauna. No recurrence of these beds in the easterly region, where their development is pronounced and typical, has been recorded.

In the region along the Chenango valley, where the Oneonta beds have not been penetrated by the straggling representatives of the western fauna, opportunity is afforded of studying closely the important question as to the composition and nature of the fauna succeeding the body of the Oneonta deposits. This matter has already been referred to in my preliminary report, and since then additional evidence has come into my hands which I shall take the opportunity of presenting at this point.

In the report referred to, attention was called to the outcrops on Juliand hill (Station K) in the village of Greene. The first exposure here is about 150 feet above the Chenango river and not less than 100 feet above the top of the Oneonta beds as exposed on Birdsall's brook. Several species were recorded from the various exposures on the hill, which individually and collectively give a decided Chemung expression to the fauna. The principal of these were: *Schizophoria impressa; Atrypa reticularis,* very large form; *Liorhynchus globuliformis; Leptostrophia perplana,* var. *nervosa.* I take occasion to correct, with the help of added material, two identifications then made, namely: *Spirifer mesastrialis* and *Productella* cf. *lachrymosa.* The former of these proves to be a varicose, narrow-winged shell of the *S. mucronatus* type, strikingly near the normal form of the species as it occurs in the Hamilton group. Further notice will be taken of it presently. The other species is a rather large form of *Productella speciosa.*

The desirability of having this Juliand hill section more fully elaborated has led me to request Mr. F. H. Williams, of Greene, a very careful observer, to collect the desired data for me. Mr. Williams, at the expense of some time and no little labor, most cordially responded to my application, collecting with much care from all exposures, not only on Juliand hill, but also on the neighboring Cowles hill, and in a ravine known as Flag Gulf, about three miles south of Greene.

It will be observed that these sections serve to fortify the conclusion previously drawn in regard to the character of this higher fauna. Certain Chemung traits are evident therein, notwithstanding both the absence of some distinctive Chemung types and the presence of some continued Ithacan features The fauna is doubtless one of those passage groups which, in easy rock successions, cannot be referred with precision to either the preceding or the following fauna except upon a careful weighing of the predominant traits. Here the majority of organic characters points to a closer alliance with the later (Chemung) fauna than with that which has been left below.*

Juliand Hill. (Figure 1.)

The first outcrop (**A**) is at an old quarry 150 feet above the Chenango river, probably 75–100 feet above the Oneonta green sands and shales exposed on Birdsall's brook, Greene (Station M, Report 1894). The rock is a flaggy gray sandstone, with the following fossils:

Atrypa reticularis. This is the very large, expanded and gibbous form common at certain Chemung horizons in the western counties. It is here abundant and associated with smaller specimens of relatively coarser plication; undoubtedly young forms of the same variety.

Tentaculites spiculus.

Spirifer mucronatus var. A diminutive form, short winged, faintly varicose and with but a trace of the median plication at the bottom of the sinus. It is a distinct departure from any expression of this species occurring in the Hamilton group, and is probably identical with the variety *posterus.*

Actinopteria eta.

Goniophora sp.

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* Such introductory faunas, preceding the culmination of a given organic assemblage, though they may embarrass the subdivision of sedimentary formations and obscure lines of demarkation, especially where, as in this State, the succession is undisturbed, yet involve many importantt questions pertaining to the history of organic life and the bathymetry of ancient seas. In another place the writer has used the expression, *prenuncial* fauna, for one which appears abruptly and in partial development, and after a brief sojourn disappears, to reappear in the same vertical section after a considerable interval and in full form. Thus the fauna of the Genundewah or Styliola limestone of the Genesee beds in western New York is prenuncial of the Naples fauna, from which it is separated by a mass of bituminous shales, with but few fossils, and those of but little similarity to the members of adjoining faunas. For an introductory fauna which heralds the incoming of a new organic association and passes gradually, without interval or interruption, into that culminant assemblage, the term *proemial* fauna may appropriately be used.

Poteriocrinus sp.

B, a short distance above, exposes about fifteen feet of a sandy shale with

Schizophoria impressa, very large and highly convex: abundant.

Atrypa reticularis, as above; common.

Spirifer mucronatus, small variety, as above.

Leptostrophia perplana var. *nervosa*.

This shell is somewhat smaller and of less irregular form than in its occurrence in the Chemung of the southwesterly counties. This difference in the early and later forms of this variety has already been adverted to by

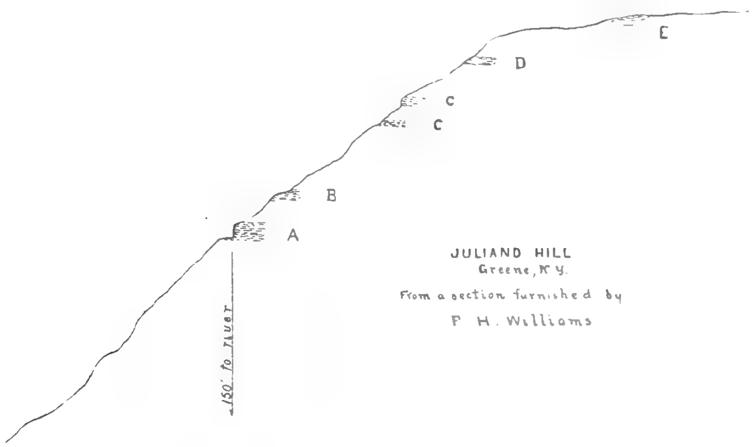


FIGURE 1.

Professor H. S. Williams, who speaks of the Chemung form as the "coarser and more irregular."

Tentaculites spiculus.

Actinopteria eta, common.

At **C** and **C**[1], fifty feet higher, are two exposures of sandy shale separated by about six feet.

Schizophoria impressa, as above; common.

Atrypa reticularis, as above; common.

Productella speciosa, common.

Actinopteria eta.

Microdon gregarius.

Spathella typica.

Grammysia elliptica.

Bellerophon Maera. This shell is somewhat smaller than the usual form of the Chemung fauna, and its surface pustules do not always extend to the aperture; in some specimens a considerable portion of the apertural part of the body whorl is smooth.

Cyclonema multilira (*obsoletum?*).

D, fifteen feet above, affords an exposure of two to three feet of flags with:

Stropheodonta demissa, large and fine examples of the characteristic Chemung form with finely divided plications, obliquely undulated cardinal slopes and extended cardinal extremities.

Atrypa reticularis, as above; common.

Schizophoria impressa, with ventral valve highly arcuate.

Productella speciosa.

Actinopteria eta.

Cryptonella.

E, at the summit of the hill, twenty feet above, contains:

Atrypa reticularis, as above.

Liorhynchus globularis. The original specimens of this species of Vanuxem's seem to have come from Otsego county. I am not aware that the species has been recorded in faunas of whose Chemung age there is no question.

Tentaculites spiculus.

This is a repetition, with some important additions, of the fauna previously made out by me in these rocks. The top of the hill lies about 300 feet above the Chenango river and the rock section here given is, thus, through 150 feet, approximately.

Cowles Hill. (Figure 2.) The section at the Cameron quarry, in this hill, has been referred to as Station L of my preliminary paper. Mr. F. H. Williams has examined the entire section from this old quarry, mentioned by Vanuxem in his report of the Third district (1842), and which lies near the base of the hill, upward to its summit, an interval of about 350 feet. Cowles hill lies in the southwest portion of the village of Greene and about one-half mile due south of Juliand hill.

1. The Cameron quarry, approximately 100 feet above the Chenango river. Here, at the base, are ten feet of compact sandstones, with a concretionary layer near the top, and above, in the same exposure, forty feet of arenaceous shales.

The fossils collected are:

Tentaculites spiculus. Vanuxem refers to the abundance of Tentaculites at this spot.

Microdon gregarius.

Grammysia elliptica.

Actinopteria eta.

Atrypa reticularis, large, as above.

Schizophoria impressa, large, as above.

Spirifer mucronatus. This is a form of the species which presents the characters normal to the typical form; delicately varicose surface, well defined median plication at the bottom of the sinus, and narrow, considerably extended wings.

Cyrtina recta.

Spirifer mucronatus. The small, short-winged variety mentioned above.

Productella speciosa.

Liorhynchus globuliformis.

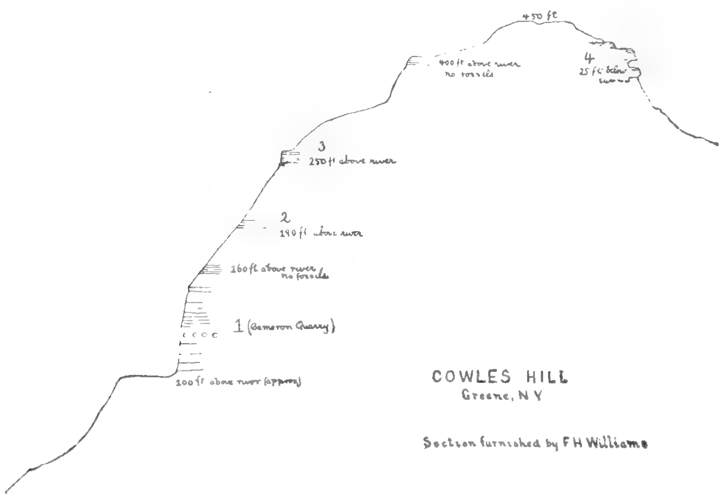


FIGURE 2.

2, Is ninety feet higher up; sandy shales, containing:

Atrypa reticularis, very abundant.

Schizophoria impressa.

Liorhynchus globuliformis.

Spirifer mucronatus, both the normal form and the variety above mentioned.

3. Calcareous and arenaceous shales, sixty feet above.

Spirifer mucronatus. The small variety above mentioned; abundant.

Schizophoria impressa, large.

Productella speciosa.

Atrypa reticularis, large.

Stropheodonta demissa, the Chemung variety.

Liorhynchus globuliformis.

Leptostrophia mucronata.

Spirifer lævis.

4, Is 175 feet higher and twenty-five feet below the summit of the hill. The rock exposed consists of sandy shales, with some soft olive shale intercalated. Fossils are apparently abundant, and the following have been identified:

Lyriopecten cf. *interradiatus.* This shell is usually of small size and, on the whole, is nearer to the form suggested than to *L. tricostatus.* It will be observed that the normal form of the latter species is present in the Flag Gulf section given below. The two species differ only in the number of finer intercalary ribs between the principal plications; these in *L. interradiatus* are few, sometimes no more than a single one, but in *L. tricostatus* they may number three to five. The former species has thus far been recorded only from the shales of the Hamilton group at Fultonham, Schoharie county, while *L. tricostatus*, though generally found in the normal Chemung fauna, occurs in undoubted Hamilton beds at Summit, Schoharie county, where it is associated with *Chonetes syrtalis.*

Schizodus Chemungensis.

Actinopteria of the type of *Boydi, eta*, etc.; much larger than the prevailing form of the latter, with very distinct surface characters; probably a distinct species.

Spathella typica.

Palæoneilo cf. *plana.*

Palæoneilo cf. *muta.*

Grammysia cf. *communis.*

Bellerophon Maera.

Pleurotomaria cf. *Itys;* a variety.

Schizophoria impressa, as above.

Atrypa reticularis, as above.

Productella speciosa.

Stropheodonta demissa, as above.

Spirifer mucronatus, both forms as above mentioned.

Spirifer lævis.

Species of especial interest in the last two localities are *Leptostrophia mucronata* and *Spirifer lævis.* The former is abundant in a thin calcareous layer, is uniformly of small size, and though without mucronate cardinal extremities, bears all the characters distinctive of the common expression of the species in its occurrence through the Ithaca fauna of Cortland, Tompkins and Schuyler counties. The mucronate extension of the hinge is by no means a persistent feature of typical forms; indeed, the name itself was based upon forms in which this extension is but slight, and it is not unusual to meet with individuals in which there is no evidence of any lateral prolongation of the hinge angle; the condition of the shells at the horizon under consideration. But this mucronation of the shell may be carried to a great extreme and afford unprecedented illustration of such configuration among the stropheodontoid brachiopoda. A specimen from Spafford, Onondaga county, 375 feet above the Tully limestone and associated with *Tornoceras uniangulare*, *Buchiola speciosa*, *Paracyclas lirata*, etc., bears at each angle a curving cardinal spine having fully as great length as the shell itself (Figure 3). Several specimens

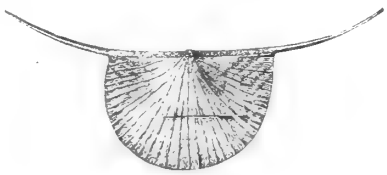


FIGURE 3. *Leptostrophia mucronata*, Conrad (sp.). Spafford, N. Y

from that locality all show the same character. Close analysis of this feature is needed to show whether its variations possess a definite local or time value. Suffice it to say that in all observed specimens from the Cowles hill section the shells are small and the angles not produced.

Of the specimens referred to *Spirifer lævis*, nine have been seen from the two stations **3** and **4**. These are, for the most part, internal casts, one a cast of the exterior affording the superficial characters of the shell, and one or two partially exfoliated shells. Upon careful comparison of these specimens with the species as it occurs at its typical locality, Ithaca, involving close analysis of all the structural characters that can be made out, there remains but a single palpable distinction; the Cowles hill specimens are uniformly smaller. This may be a difference of significance in consideration of the great time interval in their appearance, but with a reservation in favor of this point only, I unhesitatingly refer the forms under consideration to that specific type.

The reappearance of this species is the more interesting as in the Ithaca meridian it is best developed at a well-defined horizon near the base of the entire Portage sediment, where it is highly abundant, but strongly localized. Professor Williams has recorded its brief recurrence in this meridian after the withdrawal of the Ithaca fauna, about 500 feet higher in the strata.* Aside from the occurrence about Ithaca and that at Greene the species has been found, I believe, only at Hait's quarry near Homer, and (as recorded on a later page of this paper) near McGrawville, Cortland county; in both instances with but few specimens.

This reappearance of *Spirifer lævis* at an horizon which cannot be less than 1,200 feet above its first appearance and most profuse development in the rock series of the Ithaca section, and several hundred feet above its last appearance in that section, is remarkable and unexpected. Its association with *Leptostrophia mucronata* shows that, as we have already suggested, the Ithaca fauna is not yet wholly extinguished, though its relicts are here consorting with predominant and more and more emphatic Chemung types.

Their presence in this association can no more modify our conception of the post-Portage age of this fauna than if they were altogether absent, or, rather, the fact of their presence here, under certain structural modifications, is very evidence of such age.

Flag Gulf (Figure 4). This is a ravine lying three miles south of Greene on the east side of the Chenango river. The succession of rocks and fossils is as follows:

The lowest exposure (**1**) is about seventy-five feet above the river and consists of gray flags; no fossils observed.

Above this are three feet of soft shales (**2**), followed by four feet of sandstone (**3**); no fossils were found here.

At (**4**) are five feet of flags and shales containing:

Schizophoria impressa, large form.

Productella speciosa.

Spirifer mucronatus, small variety.

Above (**5**) are six feet of soft shales with *Spirifer mucronatus*, small variety.

Leptostrophia perplana, var. *nervosa*, typical Chemung form.

Actinopteria eta.

At (**6**) are twelve feet of sandy shales with but few fossils, namely:

Actinopteria eta.

Goniophora minor.

Spirifer mucronatus, small variety.

* Mr. E. M. Kindle, in a publication entitled "The Relation of the Fauna of the Ithaca group to the Faunas of the Portage and Chemung," (Bull. Amer. Palæontology, No. 6, dated December 25, 1896) mentions the occurrence of this species at an horizon 130 feet below this upper *S. lævis* zone (p. 36) and refers to the abundance of the fossil at its later appearance (p. 29). See further note on this paper on page 57.

Then follow five feet of shales (**7**) with

Schizophoria impressa, large and medium.

Spirifer mucronatus of typical form, long winged and with varicose surface.

Lyriopecten tricostatus, the typical Chemung form.

The rocks above this for one hundred feet (**8**) are covered with gravel; then follows an exposure of fifteen feet of soft shales (**9**) with

Productella speciosa.

Stropheodonta demissa, Chemung var., abundant.

Schizophoria impressa, large.

Liorhynchus globuliformis, common.

Atrypa reticularis, large form.

Actinopteria eta.

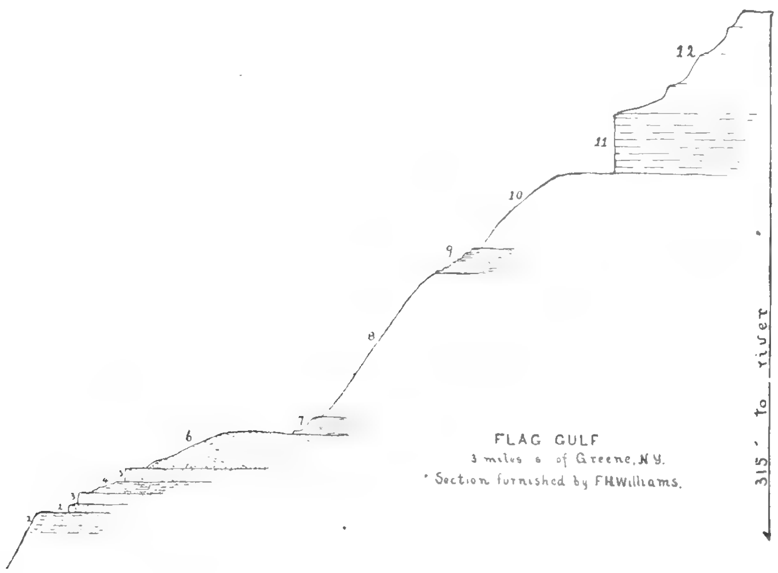


FIGURE 4.

The next sixty feet above (**10**) are covered, then follows (**11**) an exposure of about forty feet of flags, sands and shales in an old quarry which was worked about sixty years ago. These rocks have afforded

Productella speciosa, common

Schizophoria impressa, as above.

Spirifer mucronatus, normal.

Liorhynchus globuliformis.

Atrypa reticularis.

Lyriopecten tricostatus, as above.

Bellerophon Maera.

From this quarry it is about seventy-five feet to the top of the hill, and the exposures in this distance have not yet been examined by Mr. Williams. The total height of the hill proves from the measurements given in this section to be about 400 feet.

It is clear that the same fauna permeates all these sections. If we allow 150 feet for the southerly dip of the rocks in the interval of three miles between Juliand hill and Flag gulf, the lowest outcrop on the former will be, approximately, just below that first appearing in the Flag gulf, so that our former section is essentially reproduced in the latter, with an upward addition thereto of 250 feet. These consecutive sections give us evidence of a Chemung fauna antedating the *Spirifer disjunctus* fauna, and extending through at least 400 feet of strata.

It is necessary to observe that the lower horizons of this essentially homogeneous fauna lie no higher above the Oneonta beds than do some of the smaller, quite distinct faunules which manifest themselves at intervals in the hills bounding the Genegantslet creek, northward to the village of McDonough. But all of the latter are much less firmly characterized by such distinctive Chemung types. In these outcrops are observed such species as the following: *Spirifer mucronatus* var. *posterus*, *Grammysia elliptica*, *Sphenomya subcuneata*, *Leptodesma Rogersi*, *Leda diversa*, *Camarotœchia congregata*, *Goniophora subrecta*, etc., none actually suggesting a Chemung fauna. In this region, however, we are approaching the vanishing western edges of the Oneonta formation. At Greene the evidence is very clear that the Oneonta formation is directly followed by the introduction of a Chemung fauna, and hence occupies the position which I ascribed to it in my preliminary report, replacing the upper part of the Portage beds and representing, in this region, the closing stages of Portage time.

Explanation of Geologic Map 1.

Tully Limestone.

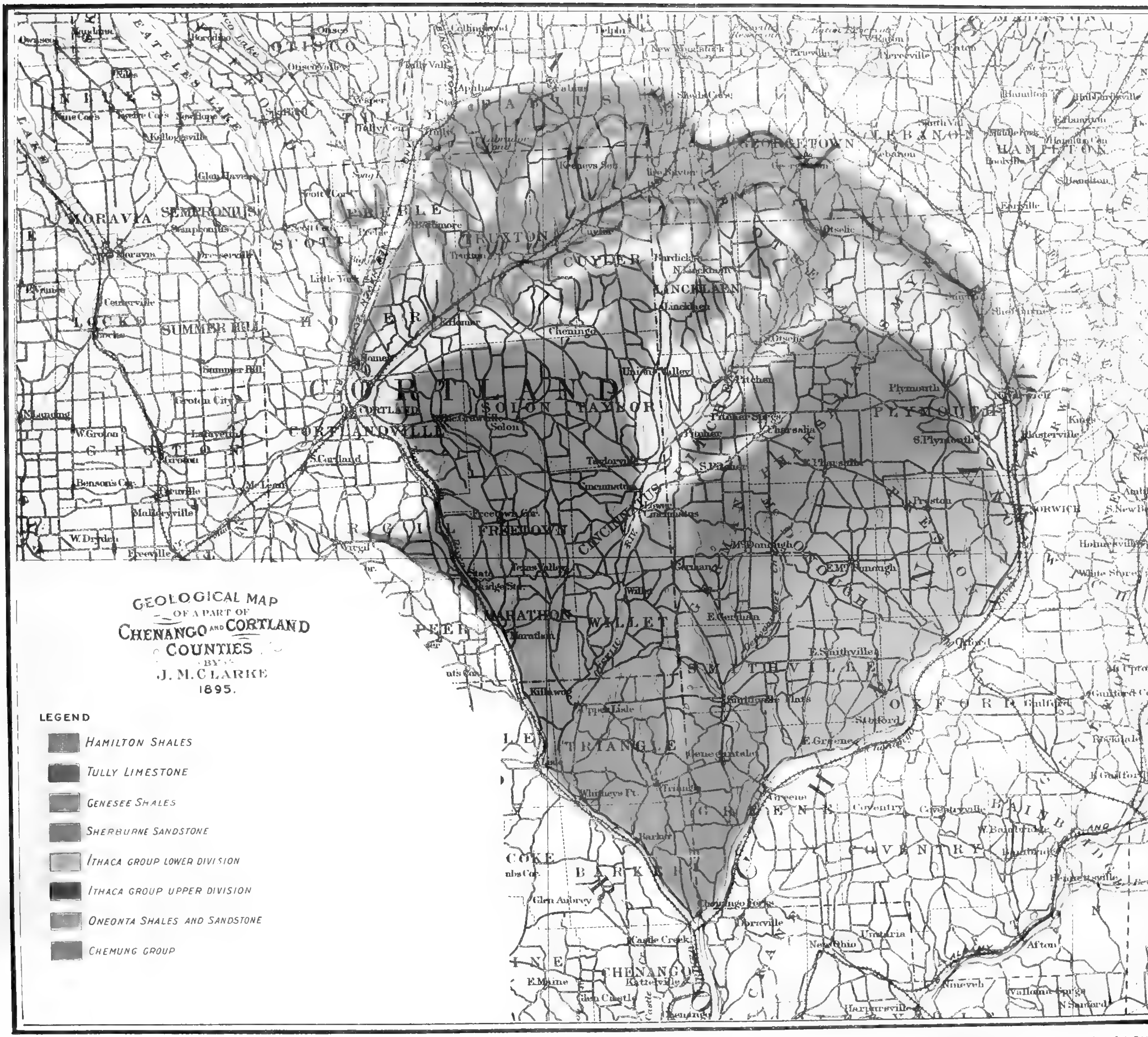
Previous maps representing the outcrop of this formation have given only the northern exposures through the central portion of this region. In the southern towns of Onondaga county, Tully and Fabius, the best known of these outcrops are in the vicinity of the Tully lakes, and at Tinkers Falls. The outcrop bends thence southward into the town of Cuyler, Cortland county, along the eastern branch of the Tioughnioga river, and may be traced on the west side of the Tioughnioga valley through the town of Truxton and almost to the township line of Homer. On the east side of this valley it extends nearly as far to the south-west, bending southeastward for a short distance up the valley of Cheningo creek, where it is exposed on the north side, but was not observed on the south side of this valley. An excellent exposure at Station VII², Tripoli brook, three-quarters of a mile northwest of Cuyler village, is described more fully in the following pages.

It is seen at several places in the town of DeRuyter, Madison county, along the south slope of the same valley, passes over the watershed between that and the Otselic valley, probably extending as far southward on the latter as the village of Otselic, Chenango county. It is thence continued in the direction of Smyrna and, as stated by Vanuxem, S. G. Williams and Prosser, disappears by thinning at about one and a half miles northwest of that village, in the Chenango valley. At only the station cited does the exposure give a clear section of the entire formation, measuring about eighteen feet. The exposures in the town of DeRuyter are of portions of the beds only.

East of Keeney Settlement, near the north line of Cortland county, the limestone bounds an outlier, extending north into Fabius, east to the Madison county line, and south to the Tioughnioga.

Genesee Slate.

This formation is exposed at but a few points. It was observed on Tripoli brook (Station VII²), where about ten feet are shown, and near DeRuyter (Station I) to a thickness of eight feet, the upper portion probably being covered. Toward the east it rapidly thins out, disappearing not far



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west of the village of Smyrna, though, as determined by Prosser, it can be traced somewhat eastward beyond the vanishing point of the Tully limestone.

Sherburne Sandstones.

In adopting this term of Vanuxem's, I follow the suggestion of Professor Prosser, who points out the fact that these beds of sandstones, flags and sandy shales are continuous from the Chenango river westward at least as far as the meridian of Cayuga lake. Their lithologic character together with their notable paucity of fossils permits the identification of them still farther westward. The heavier beds, lying at the base of the Portage series in Seneca and Yates counties, indicate an extension of this division into more westerly regions; but with the growing predominance of the typical Portage or Naples fauna over that of the Ithaca group, the individual character of the deposits here becomes gradually lost. In the region, however, between the Tioughnioga and Chenango rivers, it is a well-defined formation, standing in sharp contrast to the Tully and Genesee beds beneath and to the beds immediately overlying, which contain the reappearing and modified fauna of the Hamilton group.

Ithaca Group (lower division).

The rocks which are properly included within the Ithaca group of Vanuxem are here represented in two colors, as there is, for this region át least, a ready distinction in the faunas of the lower and upper beds. From the detailed description of the sections of these strata given in the following pages it is seen that the lower division, which is on the whole less arenaceous than the upper, contains strongly developed faunal characters of the Hamilton group, a fact clearly brought out by the observations of both Professor Prosser and the writer at North Norwich, Norwich, South Otselic and Pitcher Springs, in Chenango county.

Thus at Stations A and B, of my preliminary paper, in the east-west section from Norwich toward Preston, are such characterizing species as *Phacops rana*, *Homalonotus DeKayi*, *Bellerophon patulus*, *Athyris spiriferoides*, and *Spirifer audaculus*, in addition to which are many other species of the Hamilton fauna which extend into the higher beds of the Ithaca formation. At South Otselic (Station III), these beds are admirably exposed. Directly overlying the fucoidal layers of the Sherburne sandstones are compact dark shales with a small association of certain Hamilton species not abundantly represented in the Ithaca beds elsewhere: *Hyolithes aclis*, *Strophalosia truncata*, *Pholidops Hamiltoniæ*, *Lingula ligea*, var. (Hall), and some others. Above these beds comes in a more extensive and pronounced Hamilton fauna containing *Phacops rana*, *Spirifer mucronatus* (the Hamilton type of the species), *Spirifer asper*, *Atrypa reticularis* (large and finely plicated), *Rhipidomella Vanuxemi*, *Actinopteria Boydi* (strictly the Hamilton form), and some others of wider range into the higher beds of the group. While we may speak of these associations of fossils as recurrent appearances of the Hamilton fauna, this is not an accurate expression, for there appear associated with such species as the above, others which serve to demonstrate that this fauna lying above the lower Portage beds (Sherburne sandstones) is a Hamilton fauna modified by the introduction of certain species and variations foreign to the normal fauna of the Hamilton group. One of the most striking witnesses of this modification is the presence of *Leptaena rhomboidalis*, found at Station III; of a large and abundant new species of *Cyrtina*; of *Poteriocrinus gregarius*, *Actinopteria zeta* and *A. perstrialis*. The association of species is constantly varying through the different horizons of these rocks; some of them are restricted in their range, *e. g.* *Phacops rana*, *Homalonotus DeKayi*, *Spirifer asper*, and the fossiliferous horizons were generally widely separated by intervals of barren rocks. It is noteworthy that the species *Phacops rana* and its associates, which evidence strong Hamilton characters, are less abundant and much more sharply restricted in the Otselic valley sections where the whole series is separated from the true Hamilton beds below by the Genesee shale and Tully limestone, than in the Chenango valley, as at North Norwich and Norwich, where those beds have totally disappeared from the section.

Ithaca Group (upper division).

The distinctive difference in the lower and upper faunas of the Ithaca group is due to the introduction of *Spirifer mesastrialis*. So far as my own observations extend, and I believe they are confirmed by those of Professor Prosser, this species does not appear in the lower beds. Its first appearance at South Otselic was found by Prosser at 585 feet above the valley, which is essentially the same distance above the top of the Sherburne sandstones. Its associated fossils have more or less strongly developed Hamilton characters as shown by the species recorded from sections in the village of Cincinnatus, Cortland county (Station V, 1894); near Pitcher, Chenango county (Station T); at Solon, (Station VIII); in the vicinity of McGrawville (Station IX[1]);

north of Marathon (Station XI); and near Lisle, Broome county (Station XII).

In their upper portion these beds become distinctly more arenaceous, the fossiliferous horizons more widely separated. The difficulty of making a well-defined line of distinction between these upper beds and the formations of the Chemung group has already been mentioned. So far south as the formations have been traced by me in the Tioughnioga valley, no satisfactory evidence of a Chemung fauna has been observed. The fauna found at Lisle indicates the presence of the Ithaca fauna, and my observations have not extended south of this point. Professor Prosser reports *Dictyophyton* and other Chemung fossils at Whitney's Point, three miles below.

Oneonta Group.

The attempt has been made to represent upon the map the relation of this group to the Ithaca group as explained in the introductory pages of this paper. On the Chenango river the red and green shales and sands rest upon beds which rarely contain *Spirifer mesastrialis.* Westward these beds disappear by thinning, dovetailed into the edges of the upper Ithaca beds, and at Greene we doubtless have actual superposition of a Chemung fauna upon the Oneonta beds.

The Historical and Actual Significance of the Terms, "Ithaca Group" and "Ithaca Fauna."

It is quite essential to acquire a clear conception of the precise footing upon which the terms *Ithaca group* and *Ithaca fauna* now rest in the New York nomenclature, in order to fully apprehend the difficulties of applying either in the region eastward of the Ithaca meridian.

The name *Ithaca group* was first used by Professor James Hall (1839). In discussing the geologic formations of Tompkins and Chemung counties, in the Third Annual Report of the Fourth Geological District (pp. 318-322), the account given of this formation and its distribution is so full that I reproduce it here in its entirety.

"The *Ithaca group* follows the rocks last described [the shales and flags immediately overlying the Genesee slate]. Like the preceding, it consists of alternations of shale, both slaty and compact, and argillaceous sandstone, but differs from it in the contained fossils, and in some particulars of its lithological character. It sometimes contains thin layers of impure limestone, the calcareous matter arising principally from the contained shells. This group is well characterized in Ithaca at the inclined plane of the railroad; it extends also much above the rocks here visible, attaining a much greater thickness, as can be seen in the valley of the Chemung, south of Seneca lake. In the rocks of this series individuals of two species of ferns have been found, precursors of the great abundance of that tribe in the coal formation; and among the many testaceous fossils are *Producta*, *Leptæna*, *Orthis*, *Pterinea*, etc. These diminish farther west, a few only of the more characteristic occurring on Seneca lake.

"With the deposition of the Tully limestone the family of trilobites ceased to exist, yet we find with the characteristic fossils of this group the buckler of *Dipleura Dekayi* and *Calymene bufo*, with other fossils which lived at the period of the deposition of the Moscow and Ludlowville shales. These fragments, being the lighter part of the animal, were floated upwards with the detritus of the lower rocks and deposited at this era. Similar instances occur in some of the lower rocks, but the occurrence of such fossils is not to be considered as characteristic of a rock, or as evidence of their existence at the time of its deposition.

"At Hector Falls, and above, we find about four hundred feet of this group exposed; the lower part contains the ferns of Ithaca, and above some of the other fossils. At this place we find a few thick layers of sandstone, very compact and firm, which have been quarried by Mr. Lawrence. Few durable building stones are found in this county, if we except this sandstone, which, however, is little used. It furnishes the fine flagstones used in Ithaca and elsewhere. In general characters it differs but little from that of the group below, but Fucoides are found in greater quantities on the surface, many stems of which attain a diameter of two or three inches. One species, the most abundant, occurs on the under side of the layers, as if growing on the bottom of mud and clay, when overwhelmed with the inundation of sand. This species is always straight or anastomosing at various angles, sometimes presenting imperfect reticulations, and at other times a fancied resemblance to a bird's foot. It occurs on many layers through a considerable extent, though separated by thick masses of shale. The surface of most of the layers is smooth, or even glazed with a thin coating of shale, which appears to have flowed over it, leaving marks of unequal deposition and little ridges or prominences where the paste was less fluid. The deposition of these shales and sandstones progressed slowly, considerable time having elapsed between the deposition of the different layers, and in some instances a lower stratum became partially indurated before the succeeding deposit was made. There are numerous proofs of the general operation, and in particular of the latter, where we find, near Jefferson, the surface of a layer worn smooth and grooved, as if by a current, transporting some hard body over it. The scratches do not present the roughness of alluvial scratches, but appear to have been made before the rock was entirely indurated, or else they have been modified by the deposition of shale which succeeded. In this instance I have not been able to ascertain the direction of the current, though it was probably from the north, and like all other currents in the ancient seas, took the direction from the greatest elevation to the lowest point.

"In some localities the sandstone is replaced by a kind of sandy shale, being a mixture of sand and clay, and the whole is rippled, the markings affecting each thin layer, and showing that it was deposited from water in motion, which might transport from different directions the two materials of the rock. This group appears to have been deposited from an ocean alternately at rest and disturbed. Thick masses of sandy shale occur, bearing ripple marks through their whole depth; these are succeeded by others of variable thickness, without ripple marks, and having the faces smooth and plain. Numerous alternations of this kind have been noticed through many hundred feet. Fossils never accompany the rippled layers, but are invariably found with the smooth. The materials of the two differ very slightly in mineral composition, the rippled ones being more sandy. The absence of fossils in the latter may be explained by supposing the unquiet state of water during the deposition of the rippled shale to have been unfavorable to the development of organic life. So far as I have observed in this and other localities, the greater accumulation of fossils is always accompanied by fewer ripple marks.

"The changeful state of our planet at that period may have occasioned numerous risings and sinkings of the crust, some portions of which may have been disturbed oftener than others, one undergoing the oscillatory movement while another was at rest. This may be considered proved from the fact that undulations are exhibited in some localities, while a distance of a few miles shows a plane and undisturbed surface. Thus the undulations of the rocks on Seneca lake have not been communicated to those on the western shore of Crooked lake, although the latter are part of the same mass, separated only by a distance of ten or twelve miles. The valley of Crooked lake could have had no influence in interrupting the motive force, as probably at that time it was not excavated; and farther south we find other undulations of which the counterparts are exhibited on each side of the valley.

"These uplifting movements would form bays or protect some portions of the sea where animals might exist in great numbers, while every other part for miles in extent were too unquiet for the development or preservation of animal life.

"In numerous localities of these rocks the edges of strata, when exposed in ravines and other places, are found covered with crystals of sulphate of lime. This circumstance is by no means universal among the shales below, although observed in some localities, while in the present group there are few exceptions. Pyrites in minute particles are everywhere disseminated, decomposing on exposure and hastening the destruction of the rocks, while the sulphuric acid combines with the minute proportion of lime which they contain, exhibiting the crystals along the edges. Wherever larger masses of pyrites occur we find a proportionate increase in the quantity of sulphate of lime. Similar conditions in some of the limestones below have produced a mass of gypsum, filing the cavity previously occupied by the pyrites; and analogous circumstances, varying in extent and effect, may have formed the vast gypsum beds of the same series, extending throughout the whole of western New York. The latter, however, could only have occurred before the entire induration of the surrounding rocks.

"CHEMUNG COUNTY.

"In this county the group last described forms the surface rocks of the northern towns, and in the ravines and valleys extends south to the southern line of the towns of Veteran and Catlin. The rocks here retain most of their essential characteristics, but fossil shells are exceedingly rare, and in many localities entirely wanting. The peculiar fucoidal markings are everywhere preserved in the thin layers of sandstone. The rocks of this group are well developed in Gulf creek, near Jefferson, at the head of Seneca lake, and at many points south on the west branch of the valley and the ravines coming into it.

"From Jefferson to Millport the rocks dip south, exhibiting throughout continued alternations of shale and sandstone, and towards the upper part the compact shale is covered with fragments of a Fucoid, different from those below, and appearing only in curved fragments.

"In the vicinity of Millport and farther south the sandstone layers attain a thickness of a foot or more, and are quarried for works on the canal and various other purposes, and at Pine valley the sandy layers of the rocks are quarried in two places. Mr. Sexton, the owner of the last, informs me that the firmest layers of sandstone often pass into shale so as to be unfit for any economical purpose. This appears to be unlike the thinning out of the layer, but the proportion of argillaceous matter becomes so great that the mass crumbles on exposure.

"At the last-named quarry I observed the singular fact of non-conformable strata, as yet the only instance noticed, and which various circumstances seem to render incredible. The strata are parts of the same mass, once continuous, the lower dipping south at an angle of four or five degrees, and the upper dipping north at about the same angle; and a short distance farther south the whole mass dips north. The only explanation that now offers is that at the time the rocks were subjected to the force which produced the undulations the upper part slipped over the lower, and at this point partook of the elevation south, while the lower was affected only by the uplifting to the north. The point of the greatest depression is a short distance south of this locality. In this quarry was found the only specimen yet seen of a fern of the genus *Sphenopteris*, and through the liberality of Mr. Sexton, to whom I am farther indebted, I am enabled to place this specimen in the collection of the State. With the exception of the curved fragments of *Fucoides*, the upper part of this group is nearly destitute of fossils."

This description of vertical extent of the *Ithaca group*, though not giving a definite conception of its lower limit, specifically carries its upper limit so far south as to include the heavier sandstone beds at Millport and further south. Our evidence now points to the fact that these sandstones are continuous with the typical Portage sandstones of the Genesee valley. The exposures near Millport are of these sandstones; Jefferson is the former name of the village of Watkins, and the rock section there is essentially reproduced in the Havana glen section given in detail in the following pages. All this region of country, then a part of Chemung county, now constitutes a part of the county of Schuyler.

The historical *Ithaca group* is thus the sedimental equal of the major part of the entire Portage formation. Professor Hall's description, while showing the lithologic similarity of the *Ithaca group* to those beds along the Genesee river to which he subsequently applied the names Cashaqua shales, Gardeau flags and Portage sandstones, also suggests a critical difference in fossil contents though without citing such data as can serve the requirements of the present day.

In subsequent reports of geologists Hall and Vanuxem, the *Ithaca group* was not similarly construed. Vanuxem, in his Fourth Annual Report (1840), p. 381, places the *Ithaca group* between the "Sherburne Flagstone" and the "Chemung group," saying: "Consisting of sandstone and shales, forming a thick mass, highly fossiliferous. Names not [yet] given to the fossils. The top part of this mass terminates in a series of these sandstone flags with fucoides resembling those below the group, and which separates the succeeding group from the Ithaca." This view accords with the original definition of the term.

In his report for the same year Professor Hall made no further reference to the *Ithaca group* except to include it in tabulations of the New York formations given on pp. 452, 453. On the former it is placed between the "Cashaqua shale" and the "Gardeau and Portage groups;" on the latter it is given the same stratigraphic position, between the "Cashaqua Shale and Sandstone" and the "Gardeau Flagstones."

In Vanuxem's final report on the Third District (1842), the *Ithaca group* is placed in the succession above the "Portage or Nunda group," (pp. 12, 13, 174). It is perfectly evident, however, from reading the accounts of both of these groups, that Vanuxem had no clear conception of the true relations of the formations and was accepting the last named division on the evidence derived from the Fourth District. His description of the *Ithaca group* is quite brief and, in the special discussions by counties, the Portage and Ithaca groups are generally mentioned together without further attempt at distinction, the former division being represented by the rocks which this author had originally termed the "Sherburne Flagstones." Then, as to-day, there were no difficulties in apprehending the value of this "Ithaca group," eastward of the Ithaca meridian.

The final report on the Fourth District (1843) places a new construction on the formation. On page 250, Professor Hall remarked:

"*Ithaca group.* In the annual reports this name was adopted for designating the highly fossiliferous shales and shaly sandstones, so well developed at the inclined plane of the railroad and on the Cascadilla and Fall creeks near Ithaca. Subsequently an examination of the highly fossiliferous strata along the Chemung river, and particularly in Chemung county, resulted in the adoption of that name as designating this portion of the system.

"Succeeding examinations satisfied me of the identity of the formations at Ithaca with those of Chemung, and this opinion was advanced in the annual report of 1841.

"The reasons for merging the two in one were stated to be the impossibility of identifying them as distinct by any characteristic fossils. The same opinion is still entertained after a full examination of the strata, and a comparison of the fossils collected here and elsewhere in well authenticated localities of the Chemung. There is scarcely a fossil known at Ithaca which is not found at numerous other localities; though it is true not only of Ithaca but of many other places that some of the fossils are confined to a single locality in which they occur."

Largely in consequence of this opinion, the term thereafter passed into desuetude.

In the subsequent New York reports the section at Ithaca has been generally referred to as lower Chemung, doubtless in the broader application of the name Chemung as a major term for all the upper Devonian sediments of this meridian. So completely was the name lost sight of, that in volumes of the Palaeontology of New York, many localities lying within the limits of the *Ithaca group*, especially as this term was employed by Vanuxem in the Third Geological District, were cited generally as of the age of the Hamilton shales, though sometimes referred to the Chemung; and in Dana's "Manual of Geology," 3d edition, 1880, the name *Ithaca group* does not appear.

Up to this date the fauna of this group had received no attention further than that indicated in the foregoing extracts from Professor Hall's reports, and the depiction by Vanuxem of two of its brachiopod species, only one of which is now recognized, *Leptostrophia mucronata*. In 1884, Prof. H. S. Williams published an account of the succession of the faunas in the typical section of the *Ithaca group* (Bull. No. 3, U. S. Geol. Surv.). This is an important document for the reason, among others, that it clearly shows the presence here in repeated manifestations of two distinct faunas, the one from the west, marked by the presence of goniatites and cardioconchs, and by the absence of brachiopods; the other from the east characterized especially by the prevalence of Hamilton types of brachiopods and lamellibranchs; the former is the fauna of the typical Portage series of the western sections, the latter is termed by Williams the *Ithaca fauna*. This is the first precise use of this expression, and it is at once clearly evident that this Ithaca fauna is not the fauna of the *Ithaca group*, as outlined by Hall, but of only a part of that group. The section studied by Williams shows that here the fundamentally distinct faunas of the east and west are interleaved and commingled, each encroaching upon the province of the other and, in turn, being invaded by that other, so that in a vertical section the succession presents the aspect of rapid alternations of these faunas. The data given by Williams permit the construction of the accompanying diagram (Figure 5) designed to express the interpenetration of the two faunas along this meridian, it being understood that the interlocking angles are highly exaggerated. The author has distinguished several subdivisions of the eastward fauna but restricts the term "Ithaca fauna" proper, to its uppermost or latest manifestation. The fundamental distinction in the eastern and western faunas is, however, sharply defined from bottom to top, and the eastern fauna, manifesting itself near the base of the series in the *Cladochonus fauna*, ends only with the disappearance of the "Ithaca fauna," 500 or 600 feet below the first appearance of well defined Chemung species. The "recurrent Hamilton fauna" lying not far below the "Ithaca fauna" (as restricted by Williams), is such a reappearance of strong Hamilton types as we have observed in even greater force at a lower horizon in the rocks both at South Otselic and at Norwich, and is not in any sense out of harmony with the rest of the fauna which is, in the main, a similar recurrence of Hamilton types. Williams's

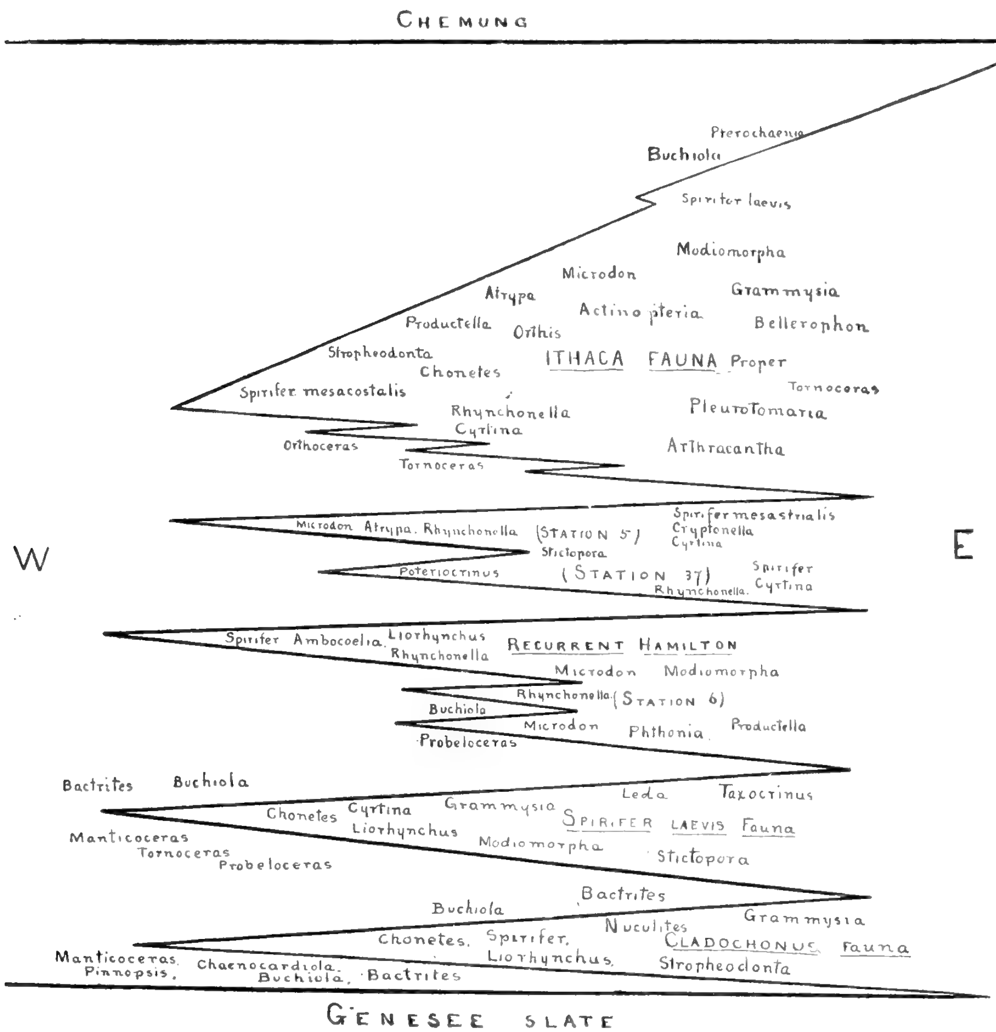


FIGURE 5.

"Ithaca fauna" is that part of the more easterly fauna which comes in above the horizon of *Spirifer mesastrialis*, a division which is of local significance as, in the counties to the east, Cortland and Chenango, *Spirifer mesastrialis* having once appeared, manifests itself throughout all higher beds of the formation. A comparison of the succession at Ithaca with the results we have obtained in Chenango and Cortland counties indicates a general equivalence exemplified, for example, in the presence of the Cladochonus fauna at various points, the appearance of *Spirifer lævis* at Station IX[1], and its second and final appearance at Cowles hill, Greene, strong reappearances of Hamilton types, as cited above, and the relative position of *Spirifer mesastrialis* in its first appearance.

While it is doubtless correct, to a certain degree, and in accordance with the views expressed by Professors Hall and Williams, to regard the entire fauna present in the strata lying between the Sherburne flags beneath and the well defined Chemung fauna above, as a transitional expression from the Hamilton to the Chemung fauna, it is evident that this fauna requires a single term, as the expression of its relation to the single geologic horizon to which it pertains. If, therefore, the term "Ithaca" is to be perpetuated in geologic nomenclature, it must be modified slightly as a geologic term, and expanded in its application to the fauna.

In view of the fact that the local name was unfortunately chosen and that the typical section is through interpenetrating faunas neither of which is at its normal, it would probably be advantageous to our nomenclature if we should follow the example of Professor Hall in abandoning the term in all its applications; such procedure would bring us at once to a ready solution of our difficulties, as excellent terms expressive of the formation and the faunas in their purity are at hand in the counties of Cortland and Chenango. The Otselic river, rising in Madison county and meeting the Tioughnioga at Whitney's Point, transects in an almost north and south line the entire formation in its best development, and affords numerous admirable exposures of both rocks and faunas. The term, *Otselic group*, for the geologic formation, and its equivalent, *Otselic fauna; lower Otselic fauna* for the earlier manifestations without *Spirifer mesastrialis* and with the Hamilton expression strongly emphasized; the *upper Otselic fauna* for the later expressions with *Spirifer mesastrialis*, would be precise and grateful terms. Eventually such terms will be required, but with proper respect to historic rights, we, for the present, continue to employ the old terms though with a modified meaning.

It is my desire to enforce, at this point, the far reaching contrast in the western, or Naples, and the central, or Ithaca fauna of the Portage epoch, but this is possible only under disadvantages. The Naples fauna is composed to a very considerable degree of unnamed species, many of which can be mentioned only in paraphrase, and no one has yet recorded in full the composition of the Ithaca fauna. The lists which are appended are compiled from my own records with the aid of those published by Professors Williams and Prosser.

This cautionary remark seems in point. The occasional occurrence of species of one fauna in association with those of the other and especially within the province of that other, is not to be construed as conclusive evidence that the species appertains to both faunas alike. Thus, *Manticoceras Patersoni* is one of the indicial fossils of the western or Naples fauna; it is occasionally found to have wandered eastward among the species of the adjoining Ithaca fauna; it is thus in the Ithaca fauna, but not of it. The same is true of several other species, and in separating the indicial features of these two faunas, such facts must be carefully considered.

In this list are included the species of the Styliola layer (Genundewah limestone) of the Genesee slate, which represent, as shown in other places, the earliest appearance of the Naples fauna.

Partial list of species constituting the PORTAGE (Ithaca) FAUNA in Chenango and Cortland counties:	Partial list of species of the normal PORTAGE (Naples) FAUNA in Ontario and Livingston counties:
	Dinichthys Newberryi, Clarke.
	Acanthodes priscus, Clarke.
	Palæoniscus devonicus, Clarke.
Rhinocaris (?) Cipennis, Clarke.	Conodonts.
Phacops rana, Green (sp.).	Echinocaris Whitfieldi, Clarke.
Homalonotus DeKayi, Green (sp.).	E (?) Beecheri, Clarke.
Manticoceras Patersoni, Hall (sp.).*	Manticoceras Patersoni Hall (sp.).
	" " var. styliophilum, nov.
	" " var. contractum, nov.
	M. simulator, Hall (sp.).
	M. nodifer, Clarke.
	M. tardum, nov.
	M. accelerans, nov.
	M. oxy, nov.
Gephyroceras perlatum, Hall (sp.).	Gephyroceras Genundewah, nov.
	G. eryceum, nov.
	Anabeloceras pseustes, nov.
	Beloceras iynx, nov.
	Probeloceras Lutheri, Clarke.
	Sandbergeroceras syngonum, nov.

* The names here applied to the cephalopoda are those employed by the writer in an account of this element of the Portage fauna, now ready for the press.

Tornoceras uniangulare, Hall (sp.).	Tornoceras uniangulare, Hall (sp.).
	" var. obesum, nov.
	" var. compressum, nov.
	T. peracutum, Hall (sp.).
	T. bicostatum, Hall (sp.).
	Cyrtoclymenia Neapolitana, Clarke.
	Bactrites cf. gracilis, Sandberger.
	B.
	Orthoceras pacator, Hall.
	O. Ontario, Clarke.
	O. filosum, Hall.
	Gomphoceras, sp.
Hyolithes aclis, Hall.	Hyolithes Neapolis, Clarke.
Tentaculites bellulus, Hall.	Tentaculites gracilistriatus, Hall.
T. spiculus, Hall.	
T. sp. nov.	
Styliolina fissurella, Hall (sp.).	Styliolina fissurella, Hall (sp.).
Conularia undulata, Hall.	[Clarke.
Bellerophon patulus, Hall.	Bellerophon striatus (Ferussac),
B. sp. nov.	B. natator, Hall.
Platyceras sp.	B. incisus, Clarke.
Murchisonia micula, Hall.	Loxonema Noe, Clarke.
	Palæotrochus præcursor, Clarke.
	Protocalyptræa Marshalli, Clarke.
Pleurotomaria sulcomarginata, Conrad	Pleurotomaria Itys, Hall.
P. cf. trilix, Hall. [(sp.).	
P. Itys, Hall.	P. Itys, var. tenuispira, Hall.
	Diaphorostoma minutissimum, Clarke.
	Diaphorostoma, sp. nov.
	Macrochilus, sp. nov.
Liopteria lævis, Hall.	Liopteria lævis, Hall.
L. Savi, Hall.	"Ungulina" suborbicularis, Hall.
L. Greeni, Hall.	Cardiola Wyomingensis, Williams.
	C. Varysburgia, Williams.
	C. Doris, Hall,
	Cardiola, several undescr. species.
	Buchiola speciosa, Hall (sp.).
	Buchiola, several undescr. species.

	Lunulicardium ornatum, Hall.
	L. fragile, Hall.
	L. læve, Williams.
	L. many undescr. species.
	Pholadella, sp. nov.
Palæoneilo emarginata, Hall.	Palæoneilo muta, Hall.
P. constricta, Conrad (sp.).	
P. brevis, Hall.	
P. fecunda, Hall.	
P. maxima, Conrad (sp.).	
Leda diversa, Hall.	
L. brevirostris, Hall.	
Paracyclas lirata, Conrad (sp.).	
Leptodesma Rogersi, Hall,	Leptodesma sp.
Microdon bellistriatus, Hall.	Ptychopteria mesastrialis, Williams.
M. gregarius, Hall.	
Nucula lirata, Conrad (sp.).	
N. corbuliformis, Hall.	
Modiomorpha subalata, Conrad (sp.).	
M. mytiloides, Conrad (sp.).	
M. concentrica, Hall.	
M. sp. nov.	
Modiella pygmæa, Hall.	
Goniophora rugosa, Conrad (sp.).	
G. subrecta, Hall.	
G. Hamiltonensis, Hall.	
Mytilarca sp.	
Grammysia constricta, Hall.	
G. magna, Hall.	
G. elliptica, Hall.	
G. bisulcata, Conrad (sp.).	
G. arcuata, Conrad (sp.).	
Sphenomya cuneata, Hall.	
Cimitaria elongata, Conrad (sp).	
Sphenotus contractus, Hall.	
Actinopteria Boydi, Conrad (sp.)	
A. perstrialis, Hall.	
A. zeta, Hall.	

A. eta, Hall.	
Schizodus appressus, Conrad (sp.).	
Spirifer mucronatus, Conrad (sp.).	
" " var. posterus.	
S. lævis, Hall.	
S. Tullius, Hall.	
S. sculptilis, Hall.	
S. mesastrialis, Hall.	
S. asper, Hall.	
S. audaculus, Conrad.	
Cyrtina Hamiltonensis, Hall.	
C. cf. curvilineata, Hall.	
C. sp. nov.	
Leptostrophia mucronata, Conrad (sp.)	
Strophonella perplana, Conrad (sp.).	
Leptæna rhomboidalis, Wilckens.	
Strophalosia truncata, Hall.	Strophalosia truncata, Hall.
Orthothetes arctostriata, Hall (sp.).	Orthothetes arctostriata, Hall (sp.).
Productella spinulicosta, Hall.	
Chonetes scitula, Hall.	Chonetes scitula, Hall.
C. lepida, Hall.	
C. deflecta, Conrad (sp.).	
Rhipidomella Vanuxemi, Hall (sp.).	
Schizophoria impressa, Hall (sp.).	
Tropidoleptus carinatus, Conrad (sp.).	
Atrypa reticularis, Linné.	
Liorhynchus mesacostalis, Hall.	
Ambocœlia umbonata, Conrad (sp.).	
Athyris spiriferoides, Eaton (sp.).	
Camarotœchia congregata, Hall (sp.).	
Pholidops Hamiltoniæ, Hall.	
Lingula ligea, var. Hall.	Lingula ligea, var. Hall.
	L. triquetra, Clarke.
	L. spatulata, Hall.
Stictopora Gilberti, Meek.	
Aulopora annectens, Clarke.	Aulopora annectens, Clarke.
Cladochonus.	Cladochonus.

Melocrinus tricyclus, Eaton (sp.).
Poteriocrinus gregarius, Williams.
Taxocrinus Ithacensis, Williams.

Melocrinus Clarkei, Williams

Without further comment, the fundamental difference in these two faunas is apparent, the one (Ithaca) indigenous, whose ancestral stock manifests itself in the immediately preceding faunas; the other exotic and introduced. The latter characterized by its high development of the Goniatitinæ, of Lunulicardium and the cardioconchs, the former by their absence. In fact, there is almost nothing common to the two faunas in their purity, and it is fair to infer that, as suggested above, the few Ithacan species present in the Naples beds, have strayed in from the east.*

The Seneca Lake Section.

The reader who cares to follow the detailed description of sections in Schuyler and Yates counties given in the following pages will see nothing more clearly than the westward disappearance of the Ithaca element in the composite fauna of these meridians.

This lessening of the eastern elements makes itself manifest in the long section made at Havana (Stations XIII and XIV). The rocks of this region are very sparsely fossiliferous and the various substations listed in Havana Glen indicate each a separate association where species of the two faunas are often present. In following the general trend of the formation to the northwest, into Yates county, a distinct increase in representatives of the Naples fauna is

* Since this report was written I have received, by the courtesy of Professor G. D. Harris, of Cornell University, a copy of No 6, of his "Bulletins of American Palaeontology," dated December 25th, 1896, and entitled: *The Relation of the Fauna of the Ithaca group to the Faunas of the Portage and Chemung* (pp. 1-56, plate 1), by E. M. Kindle.

This useful contribution gives a review of the succession of faunules in the Ithaca section and adds considerably to the known lists of species and local manifestations of the faunules.

These lists show that, with the alterations in appearance of the eastern and western faunas, there not unfrequently occurs an actual commingling of the species of the two at one plane. They serve also to enforce the importance of the cautionary remarks made above, that an elucidation of the true nature of the faunal constitution in this rock series is not possible without a clear comprehension of the two distinct faunal elements entering into its composition.

It seems necessary for me to advert here to a single point raised by Mr. Kindle as to the propriety of the term *Naples beds*, which I introduced in 1885 for the strata which bear the Intumescens fauna. It is observed that Professor H. S. Williams, in describing the lower Chemung fauna at High Point, in the town of Naples (*American Journal of Science*, vol. xxv, p. 97, 1883), a fauna which appears at several hundred feet above the first clear manifestation of the Chemung fauna in that meridian, applied to the containing strata the term *Naples beds*, and that, hence, this term being of totally different significance from my use of it, its earlier date entitles it to precedence. I have to confess that this is the first time my attention has been directed to the employment of this term by Professor Williams. Upon turning to his paper "On a remarkable Fauna at the base of the Chemung group in New York" (*loc. cit.*), I find this expression used but once and in the following language: "The author is indebted to the kindness of Professor J. M. Clarke, of Northampton, Mass., and Mr. D. D. Luther, of Naples, N. Y., for the discovery of these Naples beds" (p. 97). This is, as Professor Williams himself would doubtless admit, but a casual expression, one of several used in the same paper to express a similar meaning, thus: "The Naples rocks" (p. 97), "the High Point fauna" (p. 97), "the fauna at High Point" (p. 99), "High Point beds" (p. 99). These expressions are each used several times, while "Naples beds" occurs but once in the paper and has never been employed since by Professor Williams or any one else with reference to the now well-known *High Point fauna* of the *High Point beds*, which are, with these terms, quite sufficiently denominated. The term "Naples beds" has come into use, with well defined meaning, as a local name for the strata which carry the fauna of the Intumescens-zone, and the term has been neither conceived nor employed as a geologic designation in any other sense.

evident. This is seen in lists from stations along the west shore of Seneca lake (XV, XV[1], XV[2], XVI, XVII). At Belknap's Gully, two miles north of Branchport, Yates county, the fauna has, so far as observed, virtually lost its Ithacan component and presents only species abounding in the Naples section.

Now and then among the fossils in the Ontario and Livingston county sections will be found a straggler from the east; *Orthothetes arctostriata*, *Liopteria laevis* and *Strophalosia truncata* are among the less frequent forms. The pelagic *Styliolina fissurella* has been swept in in enormous quantities. *Chonetes scitula* and *Ambocœlia umbonata* are occasionally seen. With the exception of *Styliolina*, these are all of unusual occurrence, and we have evidence that such isolated representatives of the Ithaca fauna are to be found in the Naples fauna as far westward as Erie county.

The boundary lines of the Portage series of rocks have been, by the labors of Mr. D. D. Luther and the writer, made out with precision in Ontario and the adjoining counties. In the Naples section the vertical thickness of these rocks from the Genesee shales to top of the Portage sandstones is 600 feet. These heavy-bedded Portage sandstones were regarded as the upper boundary of the Portage series in the original delimitation of the group, and they form a well defined bench mark throughout western New York, but in more westerly sections they are overlaid by a considerable mass of flags and sands which continue to carry a Naples fauna with some modifications, but embracing no typical Chemung species.

The faunules of the beds lying immediately below the heavy sandstones are, in interesting respects, unlike those of the more prolific beds below. Thus in Naples village, at a distance of twenty feet below these beds, are shales with a Naples faunule, viz.: *Buchiola speciosa*, *Bactrites*, *Palæoneilo muta*, *Cardiola* sp. *Pleurotomaria capillaria*, *Manticoceras Patersoni*. Just below the heavy-bedded sandstones comes in a faunule unlike anything observed beneath, in this section; abundant in individuals though not in species, viz.: *Liorhynchus*, which at maturity is of large size and has the aspect of *L. quadricostatus*, while younger shells resemble *L. limitaris* of the Marcellus shales; *Atrypa reticularis* of small size with coarse plications, and three or four strong concentric varices, free at their edges; *Productella speciosa*, *Leptostrophia mucronata* and an *Orbiculoidea*, probably undescribed. Evidently this faunule has entered from the east, and it heralds the dispossession of the Naples fauna and the occupancy of the region by wholly distinct types of life.

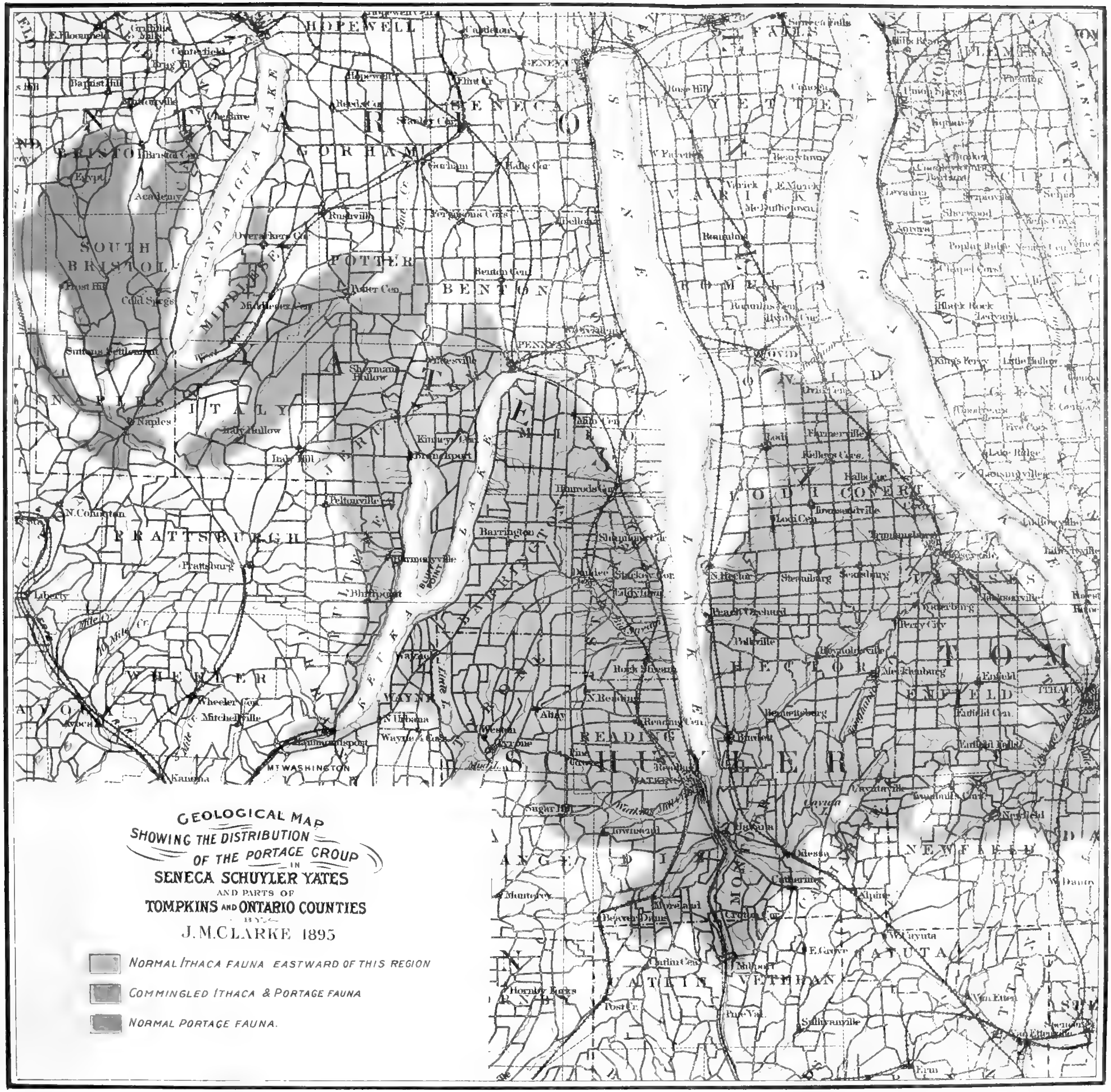
Recent observations, on this meridian, have shown, and undoubtedly future investigations will give us much more detailed evidence of the fact that about these Portage sandstones, for a few feet above and below them, are repeated oscillations of faunules, some of them with Naples species, others with forms of later date.

At the village reservoir, Naples, just beneath the sandstones and hence at the horizon of the faunule above mentioned, occurs a species of *Leptodesma* of distinctly Chemung aspect, though undescribed. Again, Mr. Luther has recently found at the base of these sandstones in the Tannery gully several interesting species of Dictyosponges. In the same section at about 100 feet above the top of the Portage sandstones comes in a well defined Chemung fauna, shown at Deyo basin with *Hydnoceras tuberosum*, *Ceratodictya annulata*, *Hydriodictya*, *Ambocœlia umbonata* var. *gregaria*, *Spirifer mesacostalis*, *Atrypa hystrix*, *Productella speciosa*, *Arthracantha*; on the West Hollow road, near Charles Sutton's, with *Orthis Tioga*, *Liorhynchus mesacostalis*, *Productella spinulicosta*, *Ambocœlia umbonata*; and at the Hamlin farm, with *Hydnoceras tuberosum*, *Aviculopecten cancellatus*, *Sphenotus* sp., *Ambocœlia umbonata*, var. *gregaria*, *Stropheodonta Cayuta*, *S. variabilis*, *S. arcuata*, *Leptostrophia perplana* var. *nervosa*, *Arthracantha*.

Explanation of Geologic Map 2.

The purpose of this map is to express graphically the gradual change westward of the fauna of the Portage rocks.

At the eastern limit of the region the fauna is the commingled Ithaca and Naples faunas; westward the former element is lost and the typical Naples species gradually attain predominance.



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Summary.

(1) The fauna of the Ithaca group is a modified Hamilton fauna; it contains a more abundant representation of unmodified Hamilton species in the meridional section along the Chenango river where the Tully limestone and Genesee slate are absent. The Hamilton features of the fauna are most strongly expressed in the lower part of the group, before the appearance of *Spirifer mesastrialis*. The fauna of the rock section at Ithaca is not normal and typical but contains an intermingling of Ithaca and typical Portage (Naples) species. The terms *Ithaca group* and *Ithaca fauna* are inexact, and their continued employment is at the cost of precision and lucidity.

(2) The Oneonta group, comprising sandstones and shales often highly colored with red and green, occupies the upper part of the Portage series as developed along the Chenango valley and eastward. West of this valley these beds rapidly disappear, thinning out and penetrating the upper beds of the Ithaca group and being penetrated by them. Above them lie proemial Chemung faunules.

(3) Westward of Cortland county the Ithaca fauna gradually becomes almost totally extinct and is as gradually replaced by the fauna of the typical Portage series (Naples fauna).

(4) Above the Portage sandstones which cap the typical Portage sections west of the Naples meridian, are indications of the final appearance of the Naples fauna through a considerable thickness of strata.

(5) In the Canandaigua lake section the Portage rocks have, probably, not more than one-half the thickness exhibited in the sections through Cortland and Chenango counties.

(6) The *Portage group* is a series of arenaceous deposits representing the geological time which elapsed from the close of the Hamilton period (including the Tully limestone and a portion of the Genesee slate, where present) to the opening of the Chemung period. The typical and unmixed fauna of its westerly sections has little organic relation to the proper fauna of the Hamilton shales, the Chemung fauna succeeding, or the Ithaca faunas adjoining on the east. It is an exotic fauna, evidently derived from the west, and making its first appearance in the Genundewah limestone of the Genesee slates. It is the *Naples fauna*.

The fauna of the central and east-central sections is an indigenous fauna, and its organic composition stands in the closest relation to the fauna of the

Hamilton group, but in its later manifestations assumes many characters of the Chemung fauna. In the Chenango valley and eastward the upper portion

FIGURE 6. East and west section from the Chenango to the Genesee valley, showing the stratigraphic relations of the sediments deposited during Portage time.

FIGURE 7. Similar section showing the faunal provinces of Portage time.

of the deposits of this age is represented by the Oneonta group with a very sparse fauna and well characterized strata. In Chenango county they replace the higher beds bearing the Ithaca fauna.

Description of Sections in Chenango, Cortland, Schuyler and Yates Counties.*

Station I.† De Ruyter, Madison county. A small ravine on the farm of Mrs. Pamela Burdick, one mile south-east of the village and just east of the road leading due south to Burdick settlement, shows an exposure of Tully limestone, eighty-six feet above the creek level at the bridge (DeRuyter). The exposure of this rock is seven feet and the outcrop is compact and thick-bedded, the thin beds which in this vicinity usually compose the lower portion of the formation not being shown.

Overlying, with exposed contact, are the black Genesee slates, eight feet thick, possibly covered for a few feet at the top. These shales are arenaceous, scarcely bituminous, non-fossiliferous, without concretions or evidence of the Styliola limestone.

Above are characteristic Portage sandy shales and sands in thin layers, with "Fucoides graphica" and other inorganic markings, especially a crustacean trail which characterizes the horizon through all the more westerly sections. *Aulopora annectens*, Clarke, is the only fossil observed.

Among these sands are intercalated thin layers of olive green, homogeneous, smooth sandy shales, without fossils. These rocks continue to the top of the ravine, which opens on a cross-road. Thickness from base of Tully limestone, as exposed, to road, 180 feet.

On the upper (south) side of this cross-road is an old quarry (the Burdick quarry of Vanuxem's final report) from which stone was taken for the old DeRuyter Academy. Near the lower part of this exposure the elevation is forty-five feet above the road. The rock here exposed is much softer and more argillaceous than that below, less arenaceous and more slabby.

This hill-side also bears a smaller, slightly worked exposure a few rods due south. In the main quarry were found *Spirifer mucronatus*, var. *posterus*, otherwise no fossils but *Spirophyton*.

In the south exposure more fossils were found and these about fifteen feet below the horizon of the main quarry; as follows:

Pleurotomaria, probably an undescribed species, which may be compared in general aspect to *Pl. trilix* of the Hamilton shales, but is of much larger

* These sections, made in 1895, pertain essentially to the relations of the Ithaca to the Portage fauna. The rocks of the Oneonta group have not been observed in this region.

† In making the observations recorded upon Stations I.-IV., I was accompanied and aided by Professor C. S. Prosser, of Union College. The elevations given for these Stations are barometer measurements by Professor Prosser.

size. It bears two strong concentric ridges on the upper surface of the whorl, and four or five such ridges on the lower surface. Concentric lines fine and closely crowded. Abundant in a single thin layer.

Pleurotomaria Itys, (rare).

Nucula corbuliformis.

Spirifer mucronatus var. *posterus*.

Liorhynchus mesacostalis.

On the hill next eastward of this quarry and at an elevation of 100 feet above it, fossiliferous beds appear sparingly to the top. The rocks carry *Atrypa reticularis* abundantly, one loose block from the vicinity containing *Leptaena rhomboidalis*.

Station II. On the road from Burdick settlement to South Otselic, Chenango county, one-half mile south-east of the former village, is a long exposure along the highway and in the banks of a creek which the road follows.

The lowest outcrop is of Portage (Sherburne) fucoidal slabs with intervening shale beds, often two or three feet in thickness, but without fossils.

At 207 feet above the creek at DeRuyter, the following fossils were found :

Spirifer mucronatus, var. *posterus* (c).

Liorhynchus mesacostalis (c).

Chonetes scitula (c).

Tentaculites cf. *spiculus*.

Palæoneilo constricta.

Paracyclas lirata.

Liopteria lævis.

Leptodesma Rogersi.

Nucula corbuliformis.

Station III. South Otselic, Chenango county. A road entering the village from the east runs for a mile or more through a deep gorge which affords a fine natural exposure, supplemented by several quarries. The elevation of the South Otselic hotel is eighty-eight feet below the creek at DeRuyter, and the village is eight miles due south of the latitude of that place.

At the opening of the gorge on the west, the elevation is forty-five feet above the hotel. Here the Portage fucoidal layers and sandy slabs (Sherburne sandstone) are absent. The first twenty feet are of sandy compact shales, from which the following fossils were taken :

PLATE II

EAGLE CLIFF FALL, HAVANA GLEN

Hyolithes aclis (cc).

Chonetes lepida (c).

Strophalosia truncata.

Liorhynchus mesacostalis.

Chonetes scitula.

Productella spinulicosta.

Pholidops Hamiltoniæ.

Lingula ligea, var. (Hall).

Lunulicardium or *Panenka*, fragment of a large species.

Abdominal segment of *Echinocaris.*

Orthoceras sp.

At the top of these beds *Hyolithes* again appears in considerable abundance, associated with numerous specimens of *Lingula ligea*, var. (Hall) and

Spirifer mucronatus var. *posterus.*

Liorhynchus mesacostalis.

Chonetes scitula.

Ch. deflecta.

Nuculites, very short form, cf. *Nyssa.*

Twenty-five feet above are ten feet of darkish shales, with

Productella spinulicosta.

Strophalosia truncata.

Liopteria lævis.

Nuculites cf. *Nyssa.*

III[1]. This substation is ten feet above the last horizon, the rocks heavy bedded argillaceous sandstones which have been quarried for the purpose of building a catch-basin on the creek near by.

The fauna is highly characteristic and is almost wholly constituted of typical species of the Hamilton group with the remarkable addition of *Leptæna rhomboidalis*, a species which has not been known to occur in New York above the Corniferous limestone, though it reappears after the close of the Devonian in the Waverly sandstones of Ohio.

The species obtained are the following:

Leptæna rhomboidalis.

Phacops rana (c).

Spirifer mucronatus, indistinguishable from the short-winged Hamilton species (c).

Chonetes scitula, large form approaching *Ch. deflecta* (cc).

Cyrtina sp. nov., large, with smooth exterior and great median septum (c).

Rhipidomella Vanuxemi.

Atrypa reticularis, large and finely plicated.

Spirifer asper, widely extended form, much more alate than that of the Hamilton group (cc).

Actinopteria Boydi, the typical form of the Hamilton group with fasciculate radii and spinose concentric striæ (c).

Mytilarca with attached *Crania.*

Grammysia constricta.

Palæoneilo emarginata.

Conularia undulata.

Tentaculites spiculus, small form.

Murchisonia micula.

Poteriocrinus gregarius.

In the hundred feet immediately overlying this fauna the association of species is not maintained but only the forms more generally distributed in the rocks beneath were found, viz.:

Spirifer mucronatus, var. *posterus.*

Chonetes scitula, Liorhynchus mesacostalis, Nuculites cf. *Nyssa* and *Palæoneilo fecunda. Phacops rana* also occurs in the lower part of this section, but sparingly, and at the top *Paracyclas lirata.*

A short distance higher *Paracyclas* occurs abundantly in soft sandy shales, the following species being taken at the horizon:

Paracyclas lirata (cc).

Leptodesma Rogersi (cc).

Palæoneilo fecunda.

Modiomorpha subalata.

Tropidoleptus carinatus (c).

Chonetes scitula, large form (c).

Ch. lepida.

Productella spinulicosta.

Tornoceras uniangulare.

In the immediately overlying seventy feet, fossils occur in thin layers at considerable intervals. Various of these layers were examined, but the associations of species were found not to present great variations.

The rocks contain:

Spirifer mucronatus, the normal short-winged form (cc).

Spirifer; the most abundant species of this genus is a small shell with a sharp median septum, but with the external aspect of *S. mucronatus*, var. *posterus.* It is probably a variety of *S. mesacostalis.*

PLATE III

CENTRAL CASCADE, HAVANA GLEN.

Chonetes scitula (c).

Atrypa reticularis, both large and small forms (cc).

Liorhynchus mesacostalis (c).

Cyrtina Hamiltonensis.

Tropidoleptus carinatus.

Actinopteria perstrialis (cc).

A. Boydi.

Liopteria Sayi.

Palæoneilo fecunda.

P. emarginata.

Autodetus.

Diaphorostoma sp.

Carapace of *Tropidocaris?*

III^2. The first appearance of *Spirifer mesastrialis;* elevation 585 feet above the South Otselic hotel; near the top of the hill, on a tributary to the main creek.*

Spirifer mesastrialis, large and typical (cc).

" " small variety resembling *S. Tullius*.

Rhynchonella? eximia?

Liopteria Greeni.

Tentaculites sp. nov.; a long, slender species, very finely marked with delicate, subequal rings; not observed elsewhere (cc).

Station IV. Mineral Spring creek, in the town of Pitcher, Chenango county, running from Pitcher Springs westward and emptying into the Otselic valley. The opening of this ravine on the Pitcher highway is about forty feet below the hotel at South Otselic and four miles south of that place. The section here, from the mouth of the ravine to its commencement, is 140 feet in height, the rocks, thin sandstones with interbedded sandy shales. The lower ten feet is a Spirophyton sandstone without other fossils. The beds above contain associations of fossils at intervals, not varying greatly in their composition. The fauna as collected from the entire series of the fossiliferous bands is as follows:

Tropidoleptus carinatus, common in the lower layers.

Productella spinulicosta (c).

Cyrtina Hamiltonensis (c).

Chonetes lepida (c).

Ch. scitula, very large variety (cc).

* This locality was not seen by myself and the list of fossils is drawn from specimens collected by Professor Prosser.

Spirifer, small species with sharp median septum, cf. *mesacostalis*, var. (cc).

Atrypa reticularis (c).

Leptostrophia mucronata, the small variety occurring in Cortland county, more abundantly at Ithaca and in the Seneca lake section.

Paracyclas lirata, common in the lower layers.

Grammysia arcuata.

Palæoneilo emarginata.

P. fecunda (c).

Goniophora Hamiltonensis.

Modiomorpha concentrica (c).

Actinopteria perstrialis (c).

Pleurotomaria Itys.

Platyceras, small sp. resembling *P. symmetricum.*

Cladochonus.

Poteriocrinus gregarius (c).

Stictopora Gilberti (cc).

Station V. One-half mile northwest of South Otselic, a ravine known as Madison's gulf, on the west side of the Otselic river. Elevation of the lowest exposure, thirty feet above the hotel. Dip section showing a high angle, estimated at seventy-five feet per mile. Probable difference in elevation, fifty or sixty feet below lowest strata at Station III.

The exposure here which was followed for a thickness of forty feet, consists of unfossiliferous flags and sandy slabs, characterized by ripple marks, worm and crustacean tracks, fucoidal casts, etc., distinguishing the lower Portage (Sherburne) beds.

Station VI. DeRuyter; on the south road entering the west end of the village from the town of Lincklaen, and one-quarter of a mile south of the cemetery, in a creek running along the road-side, the Tully limestone is exposed.* Below it the Hamilton shales are shown at the cemetery and in a fifteen foot bluff a little further south. The Tully limestone is very impure and schistose below for a thickness of three feet, becoming more compact above. Top not clear and the Genesee shales not exposed. Directly up the hill from the Tully exposure, at an elevation of 225 feet, a quarry has been opened on the land of David Wilcox. This section is in the upper part of the lower and barren Sherburne sands, and the rocks bear the characteristic fucoidal and wave marks. A thin, yellowish, compact quartz sandstone bears *Paracyclas lirata* sparingly. The immediately overlying layers are softer

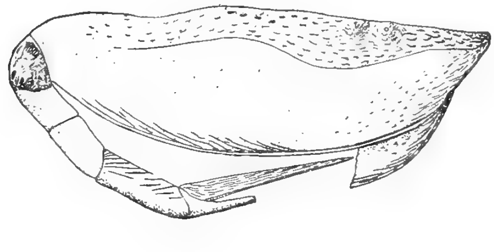
* It is also seen two miles east of DeRuyter on the Georgetown road, and one-half mile south of the Otselic stage road.

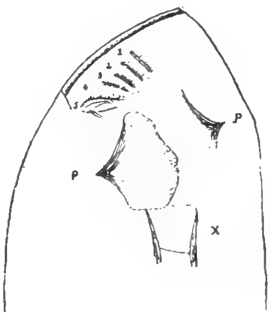
and more shaly, and contain *Spirifer mucronatus* var. *posterus* and *Orthoceras* sp. Here also were found three specimens of an interesting species of *Rhinocaris*.*

Station VII. Buel's creek, one and one-quarter miles east of Truxton, Cortland county. The exposure here consists at the base, of black, alternating

* *Rhinocaris* (?) *bipennis*, sp. nov. This interesting species has a long and comparatively narrow carapace; in the best preserved specimen the two valves appearing to be folded not exactly in the median line. The character of the hinge is obscured by the manner of folding and it is not possible to determine whether the species possessed a median plate with a hinge on either side as in true *Rhinocaris*, or whether the hinge line was actually median as in *Elymocaris*, *Emmelezoe* and *Ceratiocaris*, but the presumption from the general aspect of the carapace and from several other structural features, is that the fossil is a *Rhinocaris*. The anterior outline presents a somewhat truncate extremity which may have been prolonged into an acute termination as in many such carapaces, but as the specimen is somewhat broken at this point, its character can not be made out. There is no evidence of a movable rostrum. The lateral margins make a broad and low curve of about equal degree before and behind, and posteriorly the margin seems to have been somewhat truncated or slightly incurved, the specimen being somewhat imperfect here. The lateral surface of each valve bears a single fine sharp ridge, scarcely developed into such a carina as characterizes the single keeled genera *Echinocaris* and *Ptychocaris*. This ridge makes an ogee curve, bending downward in front and upward behind, becoming obsolete on the posterior region of the carapace. A very distinct ocular node lies at about one-third of the length of the carapace from the anterior extremity; at its summit the surface is smooth and bears a well-defined circular optic pit, as in *Rhinocaris* and *Mesothyra*. The ornamentation of the carapace is quite peculiar; the region above the ogee ridge is marked by elevated, chevron-shaped or squamose lines which are sharpest at the anterior extremity, becoming more diffuse and less obscure posteriorly. Their general direction is parallel to the hinge, though they curve around the optic and mandibular nodes. Below this curved ridge the surface is quite smooth except near the margins where there are a few faint anastomosing lines such as most of the Phyllocarida possess. The outer margins of the valves are thickened and the surface slightly grooved within them. Besides the optic node there is a well-defined node just behind it, probably of muscular or mandibular origin and some other ill-defined node-like irregularities on the surface which are probably due largely to compression. The abdomen is partially obscured at its proximal end, but shows three segments, the first two comparatively short, the third long, cylindrical and marked with oblique lines. These segments are similar in relative size and aspect to those of the Hamilton species, *R. columbina*, and are a further reason for assigning this species to the same genus with that. The telson is produced into a spine which appears to have been somewhat shorter than the cercopods, though it is not complete. One of the cercopods is preserved, a long slender spine, striated as in *Mesothyra* and bearing a crenulated inner margin which was the base of insertion of a setal fimbriæ. This is also a feature well defined in the specimens of the great *Mesothyra Oceani*, from the Ithaca fauna at Ithaca.

The accompanying sketch shows the described specimen in its natural proportions.





Traces of appendages. One of the specimens has lost the carapace by exposure to weather and shows traces of certain structures of the inferior surface. Exceedingly little is known of such structures in the fossil Phyllocarida. In an obscure species from the Carboniferous concretions of Mazon creek, Illinois, termed by Packard *Cryptozoæ*, Beecher made out traces of two or three cephalic appendages, which have been described and illustrated by the former writer; and Whitfield has figured examples of *Entomocaris* and *Ceratiocaris*, showing evidence of thoracic legs. What is here visible in *Rhinocaris* is not readily resolvable into agreement with the structure of the living *Nebalia*, but is described simply as it appears without any attempt to homologize the parts.

In this specimen the removal of the carapace has left exposed a portion of the under side covering rather more than the area of one valve. The most prominent features of the exposed surface are two angular hemi-lozenge-shaped plates, whose edge is sharply lined like marginal portions of the carapace (marked P in the figure) These lie in a somewhat symmetrical position with reference to each other, but that at the left is more fully retained than the other. The striated, sharply angled margin appears at first glance to be a lamellate body by itself, but closer inspection shows it to be continuous with a smooth area or plate whose outline is not very distinctly retained. Behind these lies another smooth somewhat quadrangular area, the margins of which are thickened, striated and continued backward. The bodies P P may possibly have been united into one trapezoidal plate, although the inner margin of P seems to be partially entire. In front of these plates are five flat and narrow impressions separated by their ridges. All are so directed as to converge to the same area. The fifth or last of these impressions seems to have a somewhat definite outline and to be faintly striated. The general aspect of these markings and their position suggests that they are remnants of cephalic appendages, the narrow ridges being the filling of the spaces between them.

with greenish, sandy shales which, with occasional flags, continue to a height of fifty-five feet. The black shales are so dark that they resemble in many places the more bituminous beds of the Genesee, though the rock is more arenaceous than is usual in that formation. The whole series is almost devoid of fossils, only a single species of *Lingula*, sp. indet., one of a small *Ambocœlia* and an occasional *Rhodea* having been seen. These are undoubtedly a part of the lower Portage beds.

VII[1]. Truxton; hill at the west end of the village. For a distance of 100 feet above the base the shaly beds of Station VII are exposed; at 300 feet above this is a slightly worked exposure of ten feet of thin sandstones with softish interbedded shales. No fossils. Loose blocks on the hill sides indicate the presence, in the section, of *Liorhynchus mesacostalis*.

VII[2]. Tripoli brook, three-fourths of a mile northwest of the village of Cuyler, Cortland county, affords an exposure of upper Hamilton shales, ending abruptly in the Tully limestones, producing falls forty feet in height. The limestone begins at the bottom with a thin six-inch band, followed by interbedded shales and thin limestones. The lower portion from the first limestone layer to the beginning of the compact limestone bed is eleven feet, the upper and more solid bed measuring six feet. It is interesting to observe that at the base of the falls, twenty feet below the impure beds, is a limestone layer, of the same lithological character as that at the top of the falls. This is highly fossiliferous as are also the upper and six-foot layer, and both appear to embrace the same fauna. The shale beds separating the lower limestone stratum from those above contain species of the Hamilton fauna.

Above the Tully limestone are Genesee black shales without fossils. The exposure is largely covered, but does not exceed, in total, ten feet. Over them lie dark olive sandy shales and fucoidal flags of the lower Portage group.

On the east of Cuyler village, is a brook along the highway entering from the east, where Hamilton shales are exposed at the foot of the south hill, the Tully and Portage terraces being well defined on the hill side, though no exposures are seen. From the brook level to the Tully terrace is about seventy-five feet.

At Müller's brook, two and one-half miles east of Truxton, the Tully limestone outcrops not far from the Cuyler road. The same rock appears one and one-half miles south of Truxton on the Goddard farm, west side of the Tioughnioga river; and also at the opening of the Cheningo creek into the latter valley, it is seen on the north side of the Cheningo valley in a small run on the farm of Otis Wicks, the exposure not exceeding one foot six inches.

PLATE IV

JACOB'S LADDER, HAVANA GLEN.

The high hill on the south side of the Cheningo valley and which is crossed in going to Solon, has an elevation of not less than 600 feet above the valley, and the exposures near the top afford *Spirifer mesastrialis*.

Station VIII. Solon, Cortland county. This village lies near the head of a stream known as Trout brook which empties into the Tioughnioga eight miles away. The only exposure found in the region is along this brook. The rock section is about forty feet in thickness and consists at the base of compact, soft sandy shales with abundant fossils, overlaid by more sandy beds and flags, also fossiliferous. The uppermost layers are made up of heavy sandstones containing concretionary masses of immense size, such as I recorded in a previous report as occurring at Greene, above the green and red Oneonta beds, and have noted elsewhere at Marathon and near Lisle in the Tioughnioga valley.

These upper beds are not fossiliferous, but the lower strata furnished the following species:

Cladochonus (cc).
Spirifer mesastrialis, large and normal (cc).
Chonetes scitula, large form (c).
Orthis impressa, large and normal (c).
Microdon bellistriatus, small variety (cc).
Liopteria Greenii (c).
Atrypa reticularis.
Leptostrophia mucronata.
Tropidoleptus carinatus.
Paracyclas lirata (c).
Modiomorpha subalata.
Nucula corbuliformis.
Actinopteria perstrialis.

A loose block in this stream furnished *Leptæna rhomboidalis*, *Spirifer mesastrialis* and *Actinopteria perstrialis*.

Station IX. McGrawville. This village lies in the Trout brook valley, four miles east of Cortland. The valley here is broad and though there are streams entering it abundantly from the north, there is but one from the south. Rock exposures are few on account of the overwhelming amount of alluvial deposits. The lowest outcrop observed is in the village and along its southeastern edge on a creek entering the valley from the town of Freetown, where there is an exposure of thirty feet of compact sandy shale with

Spirifer mesastrialis and *Spirifer mucronatus* var. *posterus*. No other outcrop occurs on this creek in this township.

IX[1]. Brook one mile east of McGrawville on the farm of Joel Pritchard, crossing the Solon road. Elevation, seventy-five feet above Station IX. The section here covers a thickness of about 100 feet, the rocks at the base being softish, compact, arenaceous shales, with the following species of fossils:

Spirifer mesastrialis (cc).
Ambocœlia umbonata.
Liorhynchus mesacostalis.
Spirifer mucronatus var. *posterus.*
Cyrtina Hamiltonensis.
Cyrtina, large form with plicated sinus; cf. *curvilineata.*
Atrypa reticularis (c).
Leptostrophia mucronata.
Productella spinulicosta.
Rhynchonella cf. *eximia.*
Manticoceras Patersoni.
Paracyclas lirata.
Bellerophon sp. nov. with large aperture, narrow whorls and fine concentric surface ornament.
Cladochonus (c).
Melocrinus tricyclus, Eaton (sp.); "tricircled encrinite," of Vanuxem (cc).

Immediately overlying are compact sandstones with

Spirifer lævis.
Melocrinus tricyclus.

With the exception of the occurrence on Cowles hill, Greene (see page 37), this is the easternmost appearance of the species, *Spirifer lævis.* It has, however, been recorded from Hait's quarry, near East Homer, which is almost on the same meridian and about five miles to the north.

From this point upward the rocks are much less fossiliferous, evidences of the "tricircled encrinite" occurring frequently, and the section is terminated by a thin sandstone bearing masses of *Stictopora Gilberti.* Loose blocks in the stream indicate the not remote presence of *Tropidoleptus carinatus* associated with *Spirifer mesastrialis.*

Station X. Preble, Cortland county. This village lies in the valley plain, just north of the junction of the west branch of the Tioughnioga river with a stream coming in from the west through the town of Scott. An exposure was observed along a creek just off the first road running northwest beyond

PLATE V

THE BRIDAL VEIL, HAVANA GLEN.

Preble village, on the west side of the valley. These beds lie about fifty feet above the valley road.

At the base are greenish gray compact shales, somewhat arenaceous, containing *Buchiola speciosa*, *Tornoceras uniangulare*, *Chonetes scitula*, *Ch. lepida*, and *Cladochonus*. Overlying are barren greenish sands. Seventy-five feet above, on the roadside, are greenish shales without fossils, fifteen feet. On the east side of this valley, at the hamlet called Baltimore, is an exposure along the road to Truxton. This is thirty feet high and consists of fissile black and greenish shales devoid of fossils. Above these, at an interval of forty feet, are greenish shaly sandstones, also without fossils. This outcrop lies below that first described, and at about the same level as the upper beds mentioned.

Three-quarters of a mile due north of the village, at an elevation of 200 feet on a hill at the west of this road, is a quarry from which the flagstones on the village sidewalks were taken. Many of these stones are covered with fucoidal markings and others are completely filled with *Cladochonus*.

Station XI. Marathon, Cortland county. A rock exposure begins two miles north of Marathon station on the D., L. and W. railroad, or one-fifth mile north of the mile-post marked "Owego 83 m." This section is continued almost to Messengerville, where it is completed in the Virgil creek at that place.

The base of the outcrop is of soft, compact shales, very sparsely fossiliferous, overlaid by schistose green sandstone with abundant fossils in thin layers. Above these layers are heavy bedded sandstones of highly concretionary structure, like those observed at Solon. These weather out by exfoliation into striking shapes and in their lower portion contain countless numbers of *Spirifer mesastrialis*. At about the same horizon this fossil again occurs in a thick calcareous sandstone which it fills to exclusion, and the association is repeated on a lesser scale in the rocks above. These *mesastrialis* layers are excellently shown along the Virgil creek. The fossils collected in these layers are:

Spirifer mesastrialis, large and typical (cc).
Leptostrophia mucronata.
Actinopteria Boydi (c).
Microdon gregarius (c).
Liopteria Greeni (c).
Palæoneilo fecunda.
P. maxima (c).

Nucula, with the form of *N. lirata*, but with a finely lineate surface; much more oblique than *N. corbuliformis* (cc).

Modiomorpha concentrica, normal form.

M. concentrica var. nov., an extremely oblique shell, distinct and new.

M. concentrica, a form intermediate in outline between the two foregoing.

Leda brevirostris.

Grammysia magna.

Tentaculites cf. *spiculus* (c).

T. sp. long, slender and sharply annulated; undescribed (c).

Above these heavy-bedded *mesastrialis*-layers are sandy shales and slabs from which the following species were collected:

Actinopteria perstrialis (c).

A. Boydi, very small form (c).

Palæoneilo constricta (c).

Microdon gregarius (c).

Spirifer mucronatus var. *posterus.*

Leptostrophia perplana (cc).

Schizophoria impressa (c).

Station XII. One mile north of Lisle, Broome county, at the narrows of the Tioughnioga river, seven miles due south of Marathon. Rocks are here exposed in high bluffs on both sides of the river, but are more accessible on the east side along the highway than on the west along the D., L. & W. railroad. On the east an escarpment of 100 to 125 feet has soft, compact, greenish argillaceous sandstones at the base. Overlying is a bank of heavy concretionary sandstones, similar to those observed at Station XI, but not less than 300 feet higher, showing the repetition of such formations in these upper beds. Fossils are very scarce in these beds, in contrast to their abundance at Station XI. The "tricircled encrinite" (*Melocrinus tricyclus*), is found throughout in thin layers, and the following additional species were collected:

Leptostrophia mucronata.

Spirifer mucronatus, var. *posterus.*

Sp. mesastrialis, small form only.

Atrypa reticularis.

Cyrtina Hamiltonensis.

Schizodus appressus.

Cladochonus

Seneca Lake Section.

Station XIII. The village of Havana (now called Montour Falls), Schuyler county. Montour creek enters the village from the west with a vertical fall of 165 feet (Montour Falls, Plate I); above this are a series of smaller cascades which together make the total fall of the creek from above the bridge on the west hill to the village street, 195 feet. The falls proper, or the lower escarpment, are shown in plate I. The steepness of the rock wall here renders a close analysis of its composition difficult, but a great part of the series is exposed in a more accessible condition along the road, which winds up the hill and crosses the stream above the falls As a whole the rocks are greenish, sandy shales with thin, sandy flags, abundantly marked with crustacean tracks.

The first fossiliferous horizon was found at an elevation of 110 feet above the main street, and the fossils here occurring re-appear at an horizon just above the top of the falls (165 feet), in both instances in a soft, argillaceous shale. The species obtained were:

Ambocœlia umbonata (cc).
Spirifer mucronatus, small varicose variety (cc).
Strophalosia truncata.
Productella spinulicosta (cc).
Leptostrophia mucronata (cc).
Manticoceras Patersoni (c).
Loxonema cf. *Noe.*
Cladochonus.
Arthracantha.
Cyclopteris.

Seventy-five feet higher the rocks become much more sandy, heavy layers of sandstone being frequent, and in two places these have been worked for flag and foundation stone of an inferior quality. Here *Lunulicardium fragile* occurs in great abundance.

Station XIV. Havana Glen. This well-known and beautiful ravine is situated one and one-half miles south of the village of Havana, and about three miles south of the celebrated Watkins Glen, at Watkins, which it equals in natural beauty. Although the public are admitted to its attractions only upon the payment of a fee, I was indebted to the proprietors for liberty to come and go at will, and to make as much debris as was necessary for the examination I had in hand.

The frequent abrupt cliffs and high falls throughout the gorge do not facilitate the careful examination of the strata, but the artificial means of scaling these have often brought otherwise inaccessible points within reach. The length of the exposure, cutting completely through from near the base of the Havana valley to the top of the eastern hill makes the detailed section an important one. As a whole the rocks are highly unfossiliferous. Fossils are found only at wide intervals in thin layers and in small numbers. This feature, however, is a characteristic of the strata in this meridian, where the fauna is distinctly less prolific than in the Cortland and Chenango county sections of the Ithaca beds and in the typical Portage beds of the western sections (meridians of Canandaigua lake and the Genesee valley).

The commencement of the rock exposure in the Havana glen lies at the summit of the delta plain of the stream which rises to no great elevation above the road.

XIV[1]. The beginning of the rock section affords soft, sandy shales, containing *Buchiola speciosa*, shown in the exposure below the entrance house and in the first falls, known as the "Portal Cascade" (Plate VI, 1).

Thirty-three feet above the entrance is a band of black, fissile, pyritous shale, seen on the approach to the first foot bridge, and not far above, in the escarpment of "Eagle Cliff" (Plate II), are thin sandy layers with beautiful specimens of *Plumalina plumularia*.

XIV[2]. At the top of the "Council Chamber" (Plate VI, 2, 3) and near the foot of the "Curtain Cascade" (elevation ninety-five feet above entrance) [Plate III] are some compact soft shales in which the following species are found:

Cladochonus (cc).

Ambocœlia umbonata.

Cyrtina Hamiltonensis.

Atrypa reticularis.

Leptostrophia mucronata.

Palæoneilo constricta.

P. cf. *lamellata.*

Loxonema Noe.

Diaphorostoma, a small, ventricose, undescribed species occurring in the Portage fauna of the Naples section.

Manticoceras Patersoni.

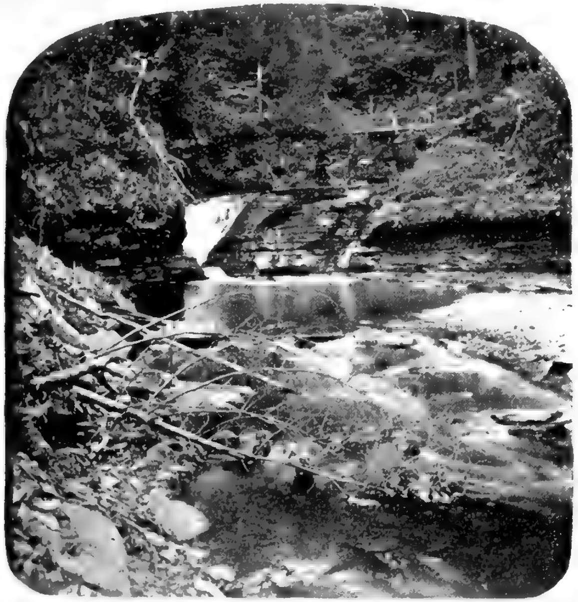
XIV[3]. Along the bridge approaching the "Curtain Cascade" and at a slightly greater elevation than the last, occur

Schizophoria impressa.

Centronella Julia. (?)

Atrypa reticularis, small and coarse-ribbed, and large, elongate forms.

PLATE VI



1. PORTAL CASCADE (STATION XIV₁), HAVANA GLEN.

2. COUNCIL CHAMBER (STATION XIV_2), HAVANA GLEN.

3. COUNCIL CHAMBER (STATION XIV_2), HAVANA GLEN.

4. WHISPERING FALLS (STATION XIV_6), HAVANA GLEN.

5. THE TUNNEL (STATION XIV_8), HAVANA GLEN.

Productella speciosa.

XIV[4]. Soft shales at the base of the last stairs but one leading to the "Bridal Veil" falls (see Plate V):

Manticoceras Patersoni.

Loxonema Noe (cc).

Lunulicardium (?), a peculiar undescribed species of a new generic form, with sharp fasciculate plications and a series of irregular spinous processes on the anterior margin. This form is not of infrequent occurrence in the Naples section, both in the Styliola limestone and in the Portage shales. Elevation, 200 feet above entrance.

XIV[5]. Soft shales at the base of "Whispering Falls," elevation 242 feet (Plate VI, 4), contain:

Manticoceras Patersoni.

Orthoceras.

Atrypa reticularis.

Cyrtina Hamiltonensis.

Cladochonus.

XIV[6]. At an elevation of 264 feet above the entrance, is the "Tunnel," an opening and passageway along a joint in a projecting cliff (Plate VI, 5). Here occurs a sandy layer with small calcareous concretionary masses, containing

Styliolina fissurella (cc).

Strophalosia truncata.

Chonetes lepida.

Ambocœlia umbonata.

Cladochonus.

Twelve feet below this horizon, at the foot of the stairs leading from the "Tunnel," occur:

Manticoceras Patersoni.

Chonetes scitula.

Productella spinulicosta (cc).

Cladochonus.

XIV[7]. "Glen Chaos;" elevation 253 feet. Here has been an interesting displacement of the rocks, a great mass having fallen along a joint plane for fully seventy-five feet, filling the gorge with upturned strata. These displaced rocks are, in part, soft, compact shales with fossils, and others are sandy layers with calcareous concretions containing essentially the same species. The fossils obtained are

Strophalosia truncata (cc).

Productella spinulicosta (cc).
Leptostrophia mucronata (c).
Spirifer subumbona.
Chonetes lepida.
Cladochonus.

XIV[8]. In the bed of the stream, at an elevation of 273 feet, are sandy layers with some calcareous matter in which *Cladochonus* is abundant, together with the following species:

Leptostrophia mucronata.
Chonetes lepida.
Schizophoria impressa, small form.
Buchiola speciosa.
Lunulicardium? sp. indes., with spines (see XIV[4]).
L. ornatum.

Above this horizon few traces of fossils were found. At the top of the "Summit Cascade," elevation 319 feet (Plate VII), *Manticoceras Patersoni* appeared, but no other species were observed. This is the top of the gorge, the rise beyond this point being very gradual and without striking features or rock exposures. The top of the hill on the north bank of the stream has an elevation of 425 feet above the entrance to the ravine.

On the highway going north from Havana to Watkins exposures of the lower beds shown in the Montour falls escarpment are seen for a mile and a half. The actual elevation of Havana is about 467 feet A. T.; that is not more than twenty feet above Seneca lake, from which the water sets back into the now abandoned Chemung canal as far as the first lock just north of Havana.

At the salt works on the lake (Salt Point), one and a half miles north of Watkins, and twenty feet above the lake, where an excavation has been made for the erection of water tanks, there is an outcrop of sandstone bearing *Cladochonus* abundantly. With an allowance for dip of twenty feet per mile, which is sufficiently large in this section, this outcrop corresponds in elevation to the stations at XIII and XIV[3].

Station XV. At Glenora, on the west shore of Seneca lake, ten miles due north of Havana, is the mouth of Big Stream, which has cut a deep and rather difficultly accessible gorge for upwards of two miles. The opening of this ravine at Glenora is bordered by a high escarpment (125 feet), making a large and beautiful amphitheatre. The beds are quite regularly alternating sands and shales, and contain, sparingly, the following fossils:

PLATE VII

SUMMIT CASCADE HAVANA GLEN.

Manticoceras Patersoni.
Tornoceras uniangulare.
Bactrites.
Spirifer mucronatus, small, varicose form of var. *posterus.*
Leptostrophia mucronata.
Ambocœlia umbonata.
Chonetes lepida.
Palæoneilo muta.
P. cf. *constricta.*
Cladochonus.

XV[1]. Another exposure favorable for examination lies on the same stream, where it is crossed by the highway at an elevation of about 425 feet above the lake, that is, not less than 300 feet above the outcrop last mentioned. The rocks are soft and in part sandy shales, with a characteristically Portage fauna throughout, viz.:

Buchiola speciosa.
Cardiola Doris (cc).
Lunulicardium fragile (c).
Chonetes scitula.
Lingula cf. *spatulata.*
Bellerophon, resembling an undescribed species from the Styliola limestone.
Probeloceras Lutheri, small variety.
Manticoceras Patersoni.
Tornoceras uniangulare.
Styliolina fissurella.

With proper allowance for dip the horizon of this fauna cannot be far from that of Station XIV[4] and the higher Lunulicardium beds of XIII.

XV[2]. At the village of Dundee, Yates county, on the same stream and at an elevation of 600 feet above the lake, are sandy, unfossiliferous shales abounding in large, flat clay-iron-stone concretions, having cone-in-cone fully developed.

Station XVI. The village of Starkey is about two and a half miles east of Dundee and the same distance north of Station XV. At the elevation of the Northern Central railroad station occurs a sandstone with *Cladochonus.* In similar layers above, the fauna is repeated. It consists of

Cladochonus (cc).
Spirifer mucronatus, small varicose variety.

Cyrtina Hamiltonensis.

Ambocœlia umbonata.

Orthis, sp.? a moderately large form of *Dalmanella.*

Lunulicardium cf. *ornatum.*

Manticoceras Patersoni.

Station XVII. Plum creek, running east and west through the village of Himrods, Yates county, and entering Seneca lake, makes a ravine through the lower Portage and upper Genesee beds. At the lake (elevation 447 feet A. T.) are the bituminous beds of the Genesee above the Styliola layer, whose position in this formation is just about at the lake level. The height of the Genesee slate in the sides of the ravine is 150 feet, and the beds near the top bear its characteristic fossils, *e. g.*,

Schizobolus truncatus.

Orbiculoidea Lodensis.

Chonetes scitula.

Liorhynchus quadricostatus.

Nucula corbuliformis.

Phthonia lirata.

Pleurotomaria rugulata.

Styliolina fissurella.

The Portage beds come in with a gradual change from black to greenish shales, followed by flags and thick sandstones. At 170 feet occur

Lunulicardium fragile.

Buchiola speciosa.

Cardiola Doris.

Bactrites cf. *gracilis.*

Probeloceras Lutheri.

Tornoceras uniangulare.

Beneath sandy layers similar to those described at Station XVI occur shales with *Buchiola speciosa* at the Northern Central railroad cut, two miles southeast of Penn Yan; and again, in close connexion with such beds, one and a half miles south of Penn Yan, on the road to Branchport, are sandy shales bearing *Lunulicardium fragile*, sixty feet above Keuka lake (elevation 718 feet A. T.).

Station XVIII. Belknap's gully, two miles north of Branchport, Yates county. Elevation of mouth of ravine not more than fifty feet above Keuka lake. A carefully measured section of the exposures here has been given by Mr. D. D. Luther in the Thirteenth Annual Report of the State Geologist

(1895), pp. 123–125. The lowest shale beds lie near the base of the Portage group, and are followed by a band of black shale ("Lower Black band"), forty feet in thickness, above them lying bluish sandy shales with thin flags (95 feet). The latter shales bear fossils at intervals:

"*Ungulina*" *suborbicularis.*

Buchiola speciosa.

Productella spinulicosta.

Above these are 125 feet of sandy shales and thin sandstones, which are capped by a western continuation of the red and green nodular limestone or "Goniatite concretionary layer," which is better developed in the Naples valley, and has been frequently described by the writer.

Thirty-five feet below this concretionary layer the following fossils were found:

Manticoceras Patersoni.

Bactrites cf. *gracilis.*

Bellerophon natator.

Buchiola speciosa.

Lunulicardium ornatum.

L. sp. nov., with extremely fine radial striae, frequent in the Naples section.

Lucina? ? sp. nov.; fine lined species representing an undescribed generic form; abundant in the Naples section.

At this point, lying just about half-way (twelve miles) between the Seneca lake section on the east and the Naples section on the west, the true Portage or Naples fauna prevails largely to the exclusion of representatives of the Ithaca fauna. The sections described have clearly shown the gradual appearance of certain of the more generally diffused species of the Portage fauna (*e. g., Manticoceras Patersoni, Buchiola speciosa*) as far to the eastward as the Tioughnioga valley, in the midst of a highly developed Ithaca fauna; the diminution of the latter with a notable increase of the former in all Seneca lake stations, and finally a virtual exclusion of the latter, at Branchport, though we do not find here the more prolific development of the former attained in the Naples valley and westward.

NOTE.—The diagrams given upon page 62 require a word of explanation. The upper curve in each is not a topographic line, but is employed to facilitate the expression of the varying thickness in the deposits of the Portage epoch. The differential crust movements, which are the important factors in this difference in sedimentation, might also have been suggested by a curvature of the strata underlying the Portage sediments. There is not sufficient difference in the lithologic character of the deposits throughout their extent to justify an assumption of material diversity in bathymetric conditions. Therefore we regard the Naples region, one of much less rapid crustal depression than the regions east and west. By introducing the upper curve of these diagrams, at the base of the Portage sediments, we might have indicated with approximate accuracy such differential depression of the crust during this later epoch of the Devonian. Such curvatures of the underlying rocks are, however, not yet deducible from recorded facts.

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

(GEOLOGICAL MAP.)

THE CLASSIFICATION AND DISTRIBUTION OF THE HAMILTON AND CHEMUNG SERIES OF CENTRAL AND EASTERN NEW YORK.

PART I.

JAMES HALL, *State Geologist.*

CHARLES S. PROSSER, *Assistant.*

1895.

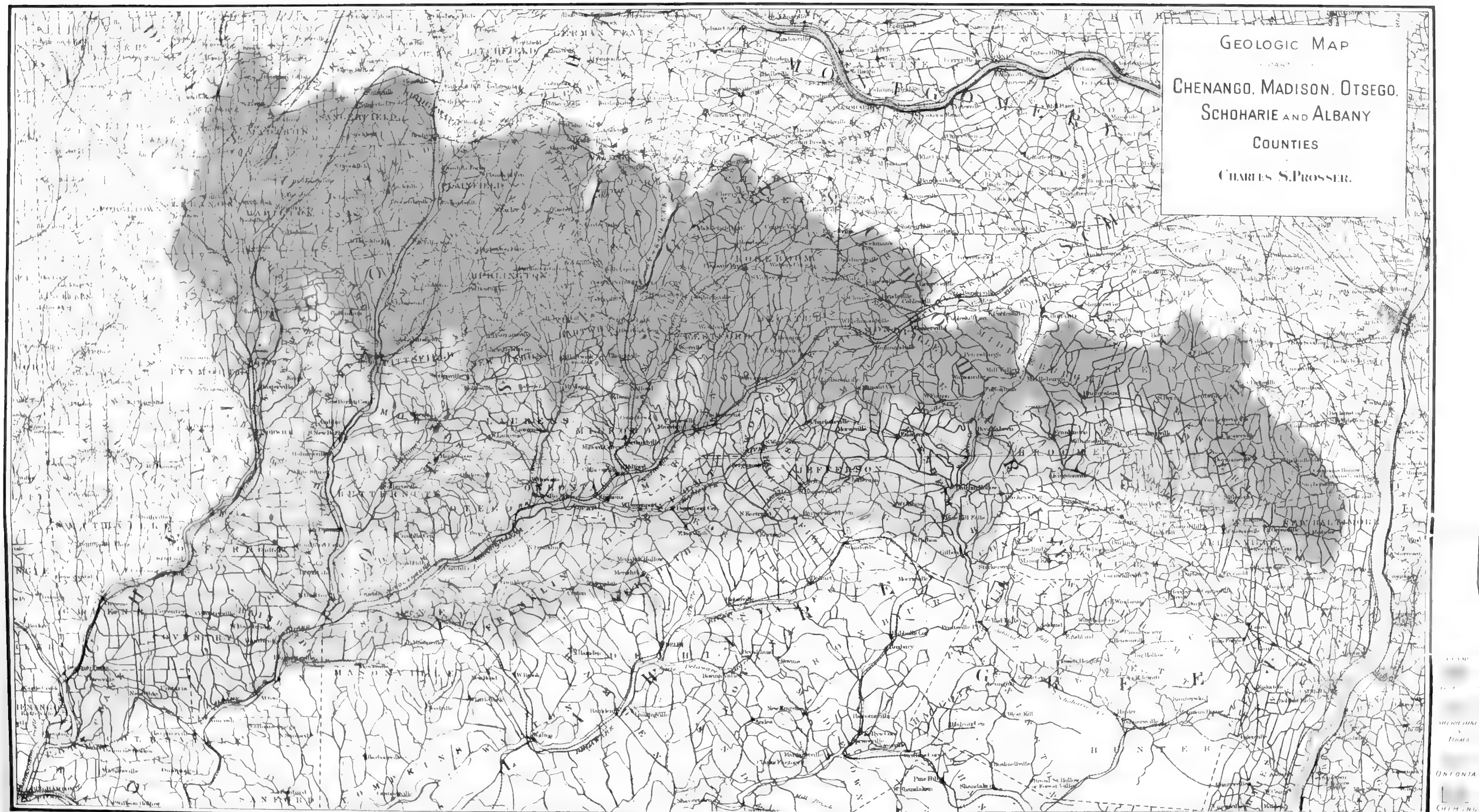
Dr. James Hall, State Geologist.

SIR:—I herewith present my report on the classification and distribution of the Hamilton and Chemung series of central and eastern New York. This report is based largely on field work conducted during the summer of 1895.

Respectfully yours,

CHARLES S. PROSSER.

UNION COLLEGE, SCHENECTADY, *Jan. 1, 1896.*


GEOLOGIC MAP
CHENANGO, MADISON, OTSEGO, SCHOHARIE AND ALBANY COUNTIES
CHARLES S. PROSSER.
ONEONTA

The Classification and Distribution of the Hamilton and Chemung Series of Central and Eastern New York.

PART I.

By Charles S. Prosser.

INTRODUCTION.

Ithaca formation.—During the summer of 1895 the Ithaca formation, with those immediately below and above, was carefully studied, proceeding eastward from the meridian of the Chenango river valley until its fauna disappears in Schoharie and Albany counties. A residence of nine years in Ithaca made the writer well acquainted with the typical exposures and fauna of this stage, while other investigations familiarized him with the same series of deposits in southeastern New York and eastern Pennsylvania. The region examined in 1895 had not been systematically studied in recent years, and it proves to be one of the most interesting of the New York Upper Devonian. However, before entering upon a systematic description of the characters and distribution of the Ithaca stage, it will be well to review briefly the former papers describing this formation.

Annual New York Reports.—The name *Ithaca group*[1] was proposed by Professor James Hall, in 1839, for a mass of rocks which consists of "alternations of shale, both slaty and compact, and argillaceous sandstone," typically exposed at Ithaca.[2] At this time the underlying shales and argillaceous sandstones, which were later called the Portage group, had not received a name, although they were recognized as constituting a group, and their stratigraphic position was correctly indicated.[3] Professor Hall separated the Ithaca group

[1] In this review the nomenclature of the New York reports is followed.
[2] Third Annual Report, Fourth Geological District, New York (Assembly Doc. No. 275, 1839), page 318.
[3] *Ibid.*, pp. 302-4, 314.

from the lower one because it differed "in the contained fossils, and in some particulars of its lithologic character."[1] The succeeding formation—the Chemung—was also named and briefly described in this report,[2] mention being made of "a great variety of beautiful and characteristic fossils," several of which were generically identified.[3]

Vanuxem, in 1840, reported flags of excellent quality near Sherburne, Chenango county, and proposed the name *Sherburne flagstones* for the group underlying the Ithaca, stating that, "the stones are of various grades of thickness, alternating with greenish or olive colored shale,"[4] and further that "the flagstone mass" extended from Cayuga lake through the Third Geological District.[5]

Immediately following the Sherburne flagstones is the Ithaca group, which Vanuxem described as "consisting of sandstone and shales, forming a thick mass, highly fossiliferous."[6] Next came the Chemung group, which 'forms the narrows of the Chemung river, whence its name," and finally the Montrose sandstone, or sandstone of Oneonta, which, according to Vanuxem, 'is the last or upper rock of the Third District * * * [and] is found in Otsego, Chenango and Broome counties."[7] Vanuxem also stated that the Montrose sandstone covered the whole of the upper part of Susquehanna county, Pennsylvania, its name being selected because it surrounds the town of Montrose, in that county. Although not explained in the report of 1840, the final report by Vanuxem shows that the other term, "sandstone of Oneonta," referred to the ledges of greenish grey sandstone on the hills near Oneonta, in the southern part of Otsego county, New York.

Professor Hall spent the field season of 1839 in western New York, studying the formations of Steuben, Allegany, Cattaraugus, Livingston and Genesee counties, and in his report we find a classification of the rocks of the Fourth District, "giving their order of succession, together with the names of a few of the most common and characteristic fossils;" the classification for that part of the series which is now under consideration being as follows:

"Old Red Sandstone.

"Chemung Group.

"Portage Group.

[1] Third Annual Report, Fourth Geological District, New York (Assembly Doc No. 275, 1839), p. 318.

[2] *Ibid.*, pp. 322–324.

[3] *Ibid.*, p. 322.

[4] Fourth Annual Report, Third Geological District, New York (Assembly Doc. No. 50, 1840), p. 381.

[5] The counties forming the eastern part of the Third Geological District were Fulton, Montgomery, Otsego, Chenango and Broome, which would imply that the group was regarded as reaching the eastern part of Otsego county.

[6] Fourth Annual Report, p. 381.

[7] *Ibid.*, p. 381.

"Gardeau Flagstones.

"Ithaca Group.

"Cashaqua Shale and Sandstone.

"Upper Black Shale [Genesee of the later reports].

"Tully Limestone.

"Moscow Shale;"[1] the upper division of the Hamilton group of the later reports.

That which especially claims our attention in the above classification is the position of this group. Professor Hall clearly indicated the relative position of the Ithaca group and its extension westward, stating that "in the order of succession the Ithaca group follows the Cashaqua shale; but in the Genesee valley, and the counties examined this season, that group [Ithaca] is entirely wanting, and will probably not be identified farther west than Seneca lake."[2] In the final report the Cashaqua shales, Gardeau sandstones and Portage group of this report were classed together as forming the Portage group,[3] while the Ithaca group was regarded as forming the lower division of the Chemung group.[4] Subsequent studies have shown the earlier to be the more accurate of the two correlations.

In the annual report of 1841, which is the last one of the series, Professor Hall said that "the tabular arrangement of strata given at the conclusion of last year's report, is fully borne out by the examinations of the past season, with the exception of the Ithaca group, which cannot in most parts of the district [Fourth] be identified as distinct from the Chemung."[5]

Conrad's report of 1841 contains a table of the New York formations which he referred to the Silurian system, dividing the system into a lower, middle and upper series, of which the following formations composed the upper series:

"26. Oneonta Group.

"25. Cazenovia Group.

"24. Tully Limestone.

"23. Sherburne Group.

"22. Shales near Apulia.

"21. Black Slate."[6]

Several of the formations were evidently named by Conrad, and the relative succession was not correct in all cases, as for example, with the

[1] Fourth Annual Report, Fourth Geological District (Assembly Doc. No. 50, 1840), p. 453.
[2] *Ibid.*, p. 390.
[3] Geology of New York, Part IV, 1843, p. 224.
[4] *Ibid.*, pp. 251, 259.
[5] Fifth Annual Report, Fourth Geological District (Assembly Doc. No. 150, 1841), p. 179.
[6] Fifth Annual Report on the Palaeontology of New York, 1841, *ibid.*, p. 31.

Cazenovia group, which is a part of the Hamilton formation of the final classification, and is below the Tully limestone.[1] No. 21, the "Black slate" of Conrad, is the Marcellus shale; the "shales near Apulia," "Sherburne group" and "Cazenovia group" belong to the Hamilton formation, while the "Oneonta group" belongs to the Ithaca group. The names Sherburne, Cazenovia and Oneonta groups were apparently proposed by Conrad, and it is important to observe that Vanuxem, in 1840, used two of these names for formations in a different sense from that in which Conrad applied them. The "Sherburne flagstones," of Vanuxem, being *above* the Tully limestone, and in the Portage group of the final reports; the "Sherburne group" of Conrad, *below* the Tully limestone and in the Hamilton group. The "Oneonta sandstone" of Vanuxem referred to the heavy greenish-grey and red sandstones in the *upper* part of the hills, near Oneonta, while the "Oneonta group" of Conrad, as shown by the fossils which he described therefrom, was composed of the bluish shales and sandstones in the *lower* part of the hills and along the Susquehanna river valley, in the vicinity of Oneonta.[2] The Chemung and Catskill groups, Conrad regarded as belonging to the "Old Red Sandstone" or the Devonian system.[3]

In 1842, Conrad published a paper entitled "Observations on the Silurian and Devonian Systems of the United States, with Descriptions of New Organic Remains," in which he drew the dividing line between the Devonian and Silurian at the base of the Ithaca group. Conrad stated that "the rocks of the Ithaca group, Chemung group and the Old Red Sandstone, near Blossburg, in Pennsylvania, constitute the Devonian system as developed in Europe, and contain a number of the organic remains which characterize the Devonian. * * * The lower or Ithaca rocks, many hundred feet thick, contain quite a distinct class of fossils, either from the Silurian below or from the Chemung strata above. The Chemung rocks, I have ascertained, hold many forms analogous to the rocks of Devon, which constitute the Devonian system, and some identical species."[4]

Final New York Reports.—The reports of 1841 closed the series of the annual reports of the New York geologists. Their final reports were the next publications, those of Emmons and Vanuxem appearing in 1842, and, in the following year, those of Mather and Hall. The Ithaca group, together with the formations immediately underlying and overlying it, does not occur in the

[1] In reference to the stratigraphic position of the Cazenovia group, see Prosser in American Journal of Science, third series, Vol XLVI, 1893, p. 214.

[2] See Prosser in Proceedings American Association Advancement of Science, Vol. XXXVI, 1887, p. 210; and American Journal of Science, third series, Vol. XLVI, 1893, pp. 214, 215.

[3] Fifth Annual Report, Palaeontology New York (Assembly Doc. No. 150, 1841), p 41.

[4] Journal Academy Natural Sciences, Philadelphia, Vol VIII, p. 232.

Second District, consequently Emmons in his final report does not discuss their relations.

Vanuxem in his final report referred to the Portage or Nunda group, the Cashaqua shale, Gardeau and Portage groups and Sherburne flagstone of the annual reports.[1]

The Ithaca group remained as a distinct formation between the Portage and Chemung groups. Vanuxem claimed that "the rocks at Ithaca presented a different mineral appearance from those below, and from those above them; being darker colored, and the shaly part coarse, harsh, dull, and less disposed to be in layers than either of them, containing numerous fossils, which were wanting in the flags, etc., below; while those of the lower part of the mass at Ithaca appeared to be different from those of the Chemung group."[2] And he further said that it was his intention at first "to unite the Sherburne and the Ithaca masses, not having discovered in the district those leading characters by which they could be readily distinguished * * * but finding, on the contrary, that Mr. Hall was desirous to unite the Ithaca and the Chemung groups, from the little or no difference which he could perceive between them in his district, and that the lower masses merited a distinct name, the original arrangement was retained, and the name of Sherburne changed to Portage or Nunda group."[3]

In describing the Chemung group, Vanuxem stated that "between the Ithaca and Chemung group no precise line of division was observed. A high ridge was seen rising above the inclined plane at Ithaca; the rocks to the south contained none of the brownish sandstone of the Ithaca, and there were different fossils noticed in the two; upon these differences the Chemung group was founded."[4]

Mather's final report, describing the First Geological District or southeastern New York, appeared in 1843. Mather states that the Ithaca and Chemung groups occur in the First Geological District,[5] and mentions their occurrence in the southwestern townships of Albany county,[6] but does not give any detailed account of the characters or distribution of these formations.

Hall's final report was also published in 1843, in which the geology of western New York is exhaustively described. In this report Professor Hall followed the opinion announced in his annual report of 1841, and referred the

[1] Geology of New York, Part III., 1842, p. 172.
[2] *Ibid.*, p. 171.
[3] *Ibid.*, p. 171.
[4] *Ibid.*, p. 179.
[5] Geology of New York, Part I., p. 317.
[6] *Ibid.*, p. 321, townships of "Rensselaerville and Westerlo, and a part of Bern."

Ithaca group to the Chemung, stating that the reason for uniting the two groups is "the impossibility of identifying them as distinct by any characteristic fossils."[1] To the Portage or Nunda group Professor Hall referred the Cashaqua shale, Gardeau and Portage groups, and the Sherburne flagstones of the annual reports.[2]

On the geologic map of New York, published in 1842, and the agricultural and geologic map, published in 1844, the Portage and Chemung groups were colored together, the Ithaca group not being mentioned.

Emmons prepared a report on the "Agriculture of New York," and Chapter VI. of Vol. I. is devoted to a classification and description of the rocks of the State.[3] In describing those formations which are under special consideration at present, Emmons used the heading, "Portage, Ithaca and Chemung groups of the central counties of New York."[4]

It seems that Emmons recognized a considerable difference between the Ithaca and typical Chemung, as shown by the fossils collected at several places, but that he was not prepared to actually separate the Ithaca from the Chemung group. In respect to this classification Emmons said: "It would seem, from a comparison of facts developed by a careful examination, that the Ithaca group is not equivalent to the Chemung as it is developed at the Chemung narrows, but rather that it is beneath, and situated between the Portage and Chemung groups. There is, however, no necessity for separating the Ithaca from the Chemung group; it is more simple to regard the masses as parts of one series, in which the inferior and superior may differ in many points."[5]

Professor Hall, in the descriptions of the fossils from the Ithaca group at Ithaca and other localities, has adhered to the classification in his final report, and referred them to the Chemung group.[6]

Views of More Recent Contributors.—The next important contribution to the literature of the Ithaca group was the bulletin of Prof. Henry S. Williams, on "The Fossil Faunas of the Upper Devonian," which bears the date of 1884. In this paper the characteristics of the rocks near Ithaca and southward into the typical Chemung of southern New York and northern Pennsylvania are described, accompanied by lists of fossils from numerous exposures. As a

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1 Geology of New York, Part IV., p. 250.

2 *Ibid.*, p. 224.

3 This volume was published in 1846, and Chapter VI., which is called the "New York System," comprises 95 of the 371 pages of the volume

4 Agriculture of New York, Vol. I., p. 190.

5 *Ibid.*, p. 191.

6 Geological Survey, New York, Palaeontology, Vol. IV., Part I., 1867, Brachiopoda; *ibid.*, Vol. V., Part I., Lamellibranchiata I., 1884; *ibid.*, II., 1885.

result of the studies explained in this bulletin and later papers, Professor Williams regarded the Ithaca group fauna as coming from the eastward and occurring in the midst of rocks which in western New York are called the Portage group, these being succeeded by the Chemung group. Professor Williams summarized the section as follows, beginning with the Genesee slate at the base of the section on Cayuga lake:

"1st. Genesee slate fauna.

"2d. Portage group fauna, distributed through approximately 1,300 feet of strata, but interrupted by the intrusion of the Ithaca fauna and several subfaunas.[1]

"3d. Chemung fauna, occupying at least 1,200 feet of strata."[2]

The distribution of the Ithaca fauna is indicated to some extent on a chart of "Meridional Sections of the Upper Devonian Deposits of New York, Pennsylvania and Ohio," by Prof. H. S. Williams, published in 1886. This paper considers the composition of the Ithaca fauna and its relation to other faunas, and the author says: "The Ithaca group of the State reports, contains faunas which I have defined as stages in the successive modifications of the Hamilton fauna. This set of faunas differs from the Chemung fauna in the absence of several of its common and abundant species, and by presenting unmistakable evidences of earlier stages in modification of species which are near enough alike to be classified under the same specific name."[3]

In 1886, Professor Williams repeated his statement that the Ithaca zone is separated from the lowest beds containing characteristic Chemung fossils by about 600 feet of flaggy and shaly deposits which contain a few Portage species. The author's opinion in reference to the relationship of the Ithaca fauna being expressed as follows: "The Ithaca fauna and its equivalents are

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[1] This mass of rocks is subdivided as follows by Professor Williams:

Upper Portage sandstones and shales			600′
Middle Portage	Upper Ithaca	200′	450′
	Typical Ithaca	100′	
	Lower Ithaca	150′	
Lower Portage sandstones and shales			250′
			1,300′

See Prosser, in Transactions American Institute Mining Engineers, Vol. XVI, 1888, p. 945.

[2] Bulletin United States Geological Survey, No. 3, on the "Fossil Faunas of the Upper Devonian along the meridian of 76° 30′ from Tompkins county, N. Y., to Bradford county, Pa.," p. 29. See also statement on p. 20 that "the study of the order of the faunas alone in this meridian furnishes strong evidence for the opinion that what I have called the Ithaca fauna, which was characteristic of the 'Ithaca group' of the early State geologists, is geographically a temporary fauna, preceded and followed by the conditions and fauna generally regarded as belonging to the Portage group." The following year Professor Williams said: "In the Portage group at Ithaca, as I have already shown, is a rich fauna, not equivalent to the Chemung, but intermediate between it and the Hamilton." (Proceedings American Association Advancement of Science, Vol. XXXIII, Pt. II, 1885, p. 423.)

[3] Proceedings American Association Advancement of Science, Vol. XXXIV, p. 233. This paragraph was condensed and quoted as follows by Professor Williams in 1891: "The 'Ithaca group' contains a *modified* Hamilton fauna, which differs from the Chemung fauna in the absence of some of its most characteristic species." (Bulletin United States Geological Survey, No. 80, Correlation Papers, Devonian and Carboniferous, p. 134.)

wanting in the more characteristic of the Chemung species, and its whole facies links it as intimately with the Hamilton as with the typical Chemung fauna."[1]

Finally, Williams, in describing the Genesee section of western New York, says that not a trace of the Ithaca fauna is seen in Wyoming and Allegany counties. The Cayuga lake section was briefly described in this bulletin, the author characterizing the Ithaca group as follows: "A rich fauna, the Ithaca fauna, is found in that section [Cayuga lake] before the termination of the Portage fauna, but in its species it resembles both the eastern Hamilton fauna and the true Chemung fauna. The studies of its species, and of those occurring above, proves that it represents an earlier stage than that of the Chemung fauna, and that it lies *below* as well as above deposits containing the genuine Portage fauna."[2]

In 1893, Prosser reviewed the section of the Ithaca group and limiting formations as exposed near Ithaca, and discussed the correlation of beds of similar age farther east.[3] Professor J. M. Clarke, in 1895, reporting on field work in Chenango county, discussed in a philosophical way the relation of the Ithaca and Portage groups. The presence of a slightly modified Hamilton fauna above the horizon of the Tully limestone and Genesee shales in the Chenango valley region, as noted by Clarke, makes this paper, which later we will consider more carefully when describing the geology of that valley, especially important.[4]

THE CHENANGO VALLEY SECTION.

For several reasons it is thought best to first describe the Chenango valley region before attempting to trace a dividing line between the Middle and Upper Devonian of central and eastern New York.

The Formations of Central New York.—In central New York, in recent years, the geologic formations and series composing the Middle and Upper Devonian have generally been given as follows, the base of the list being the oldest:

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[1] American Journal of Science, third series, Vol. XXXII., p. 198.

[2] Bulletin United States Geological Survey, No. 41, on the "Fossil Faunas of the Upper Devonian, the Genesee Section, New York," p. 23. The date of the publication of this bulletin is given as 1887, but owing to the delay in the Government Printing Office it was not published until near the close of 1888.

[3] American Journal Science, third series, Vol. XLVI., p. 217.

[4] Thirteenth Annual Report State Geologist [New York] for the year 1893 (1895), pp. 552–557.

NOTE.—Since this paper was written Mr. Edward M. Kindle has published a bulletin on "The relation of the fauna of the Ithaca group to the faunas of the Portage and Chemung" (Bulletins American Palaeontology, Vol. II., December 25, 1896, 56 pp., 3 pls.) In this bulletin Mr. Kindle gives a review of the Upper Devonian in New York, which is followed by a description of ten sections in the vicinity of Ithaca, together with lists of species occurring in the Portage and Ithaca groups. He concludes that the fauna of the Ithaca group shows "a closer relationship to the Portage [than to the Chemung], and should be classed in the Portage epoch." (p. 49.)

Chemung series	Catskill formation. Chemung formation. Oneonta sandstone. Portage formation.
Hamilton series	Genesee slate. Tully limestone. Hamilton formation. Marcellus shale.

The base of the Hamilton series throughout Pennsylvania and New York is usually sharply defined by the base of the black Marcellus shale which rests on a massive light grey limestone known as the Corniferous or Onondaga formation. In western New York, and as far east as the Chenango valley, the top of the Hamilton series is also clearly marked by another black shale—the Genesee. Some geologists have considered the Genesee shale or slate a part of the Hamilton series, and so the top of the Genesee has marked the line of separation between the Hamilton and Chemung series. Other geologists have considered the Genesee as the base of the Chemung series,[1] in which case the *base* of the Genesee slate became the line of separation between the Chemung and Hamilton series.

From the Chenango valley west into Ontario county[2] the Hamilton formation is terminated by the Tully limestone, a somewhat argillaceous limestone ranging from a few feet to thirty-five or more feet in thickness.[3] The Genesee slate accompanies the Tully limestone as far eastward as the Chenango valley, but apparently the limestone and shale do not extend to the east of

[1] See Dana's Manual of Geology, 4th ed., 1895, p. 602. Prof. H. S. Williams, as reporter of the American sub-committee on the Upper Palaeozoic (Devonic) for the International Congress of Geologists, said: "There can be no reason whatever for dividing the Genesee from the Portage, for in the typical section recurrences of the Genesee lithological conditions occur up to the very base of the Portage sandstones, which terminate the Portage group of the New York system." (*Congrès Géologique Internationale. Compte Rendu*, 4[me] Sess., 1891, Appendix A, p. 143 [p. C 23 of the copies printed in 1888 by the American committee]. Also see p. A 145.) Professor Williams was also inclined to refer the Tully limestone to the Portage, for he said: "In order to adapt our usage to the accepted usage of European standards, when speaking of Upper and Middle Devonian, we should include in the Upper Devonian the Genesee shale and so much of the Tully as contains the *Rhynchonella venustula* fauna." (*Ibid.*, and see p. A 145.) This opinion was also advanced by Professor Williams in his paper on "The Cuboides Zone and Its Fauna; a Discussion of Methods of Correlation," where he concludes with the following statement: "Therefore, if we wish to express precise correlation in our classification of American rocks, the line between Middle and Upper [Hamilton and Chemung] Devonian formations should be drawn at the base of the Tully limestone, to correspond with the usage of French, Belgian, German and Russian geologists." (Bulletin Geological Society America, Vol. I, May, 1890, p. 499.)

[2] For the western limit of the Tully limestone see Professor Hall's statement: "This rock is virtually absent at all places west of Canandaigua lake" (Geology of New York, Part IV., 1843, p. 213). Also the Geological Map of Ontario county, New York, by J. M. Clarke, on which it is represented as not reaching Canandaigua lake. The author says "the rock disappears entirely in Gorham some miles before reaching the east shore of Canandaigua lake" (Report State Geologist [New York] for 1884, 1885, p. 17). It has more recently been shown by D. D. Luther, that the westernmost outcrop of this limestone is about one mile from Gage's Landing, on the east shore of the lake mentioned, and that its place in the rock series from this point westward to Erie county is taken by a thin stratum of iron pyrites (Thirteenth Report State Geologist [New York] for the year 1893, Vol I., pp. 38-42, 1894).

[3] Professor H. S. Williams says: "From a few feet to over fifty feet" (Bulletin Geological Society of America, Vol. I., p 487). Professor S. G. Williams gave the greatest thickness as on Skaneateles lake, where he measured two sections, one twenty-five feet four inches, the other twenty-eight feet two inches, and at Tinker's Falls, "twenty-six or thirty-seven and one-half feet, according as one includes or excludes the impure mixed top and bottom portions" (Sixth Annual Report State Geologist [New York] for 1886, 1887, p. 20).

that valley.[1] From the above statements it may readily be seen that the section of the Chenango valley is a very important one as regards the classification of the Middle and Upper Devonian, especially as to where the line separating the two series is to be drawn. On this account it is considered advisable to describe somewhat fully all the formations exposed along the river valley, beginning with the base of the Middle Devonian, the Marcellus shale, and closing with the Chemung group near Binghamton.

Sangerfield and Madison.

Onondaga Limestone and Marcellus Shale.—The eastern branch of the Chenango river rises in the eastern central part of Sangerfield township, Oneida county. The greater part of the township is covered by rocks belonging to the Marcellus and Hamilton formations. The Onondaga limestone crosses the northern line of Sangerfield township near its central part, but soon returns into Marshall township for a short distance, and then cuts across the northwestern corner of Sangerfield, and extends halfway across the northern part of Madison township before it again turns northerly. In the northern part of Madison township the Marcellus is mostly covered, and there are but few exposures.

Hamilton Formation.—The lower part of the Hamilton formation, which consists of thin sandstones alternating with arenaceous and argillaceous shales, is better exposed than the Marcellus. The hill north of Solsville shows coarse, arenaceous shales containing large fossils, and also a sandstone stratum, two feet in thickness, which was quarried and used in the construction of the Chenango canal. Above the sandstone and arenaceous shales are blocky argillaceous shales, in which *Liorhynchus* is quite common, but other fossils are rare. The shales contain many small concretions which, on weathering, become considerably iron stained. Near the base of the hill, one-half mile southwest of Madison village, are ledges of coarse, arenaceous shales, in which *Spirifer granulosus* (Con.) Hall, *Stropheodonta*, *Chonetes* and large Lamellibranchs occur.

Hamilton and Brookfield.

Six miles south of Madison is Hamilton, a classic town to the geologist, since Vanuxem first applied the name *Hamilton group* to the exposures of rock in the vicinity of this village, stating that "West Hamilton [now Ham-

[1] It is true that Vanuxem reported the Genesee slate at North New Berlin (correctly New Berlin) (Geology New York, Part III., 1842, p. 292), which is in the Unadilla valley, some thirteen miles southeast of the last place noted in the Chenango valley, but careful search in the vicinity of New Berlin failed to reveal the Genesee slate, although there is an excellent exposure showing the contact of the Hamilton and Portage.

ilton] is the locality where it is well characterized."[1] On University Hill are several exposures of arenaceous shales and thin sandstones. About eighty feet above the main buildings of Colgate University is a small excavation in fairly coarse, arenaceous shales, in which Rhynchonellas are common. Near the summit of the hill is the large university quarry, with an exposure of twenty feet of shales and sandstones. Coarse, arenaceous shales predominate in the upper part of the quarry with thin sandstone strata, which were used for the older university buildings. In the middle and lower part of the quarry the sandstones are thicker and of better quality. The stone in the laboratory building came from the middle part of this quarry, and that in the theological hall from the bottom of the quarry, which furnishes a blue sandstone, eight inches or more in thickness. Fossils are common, particularly in certain layers, the most abundant being *Spirifer mucronatus* (Con.), Bill., some of the specimens of which are very much extended along the hinge line, representing the extremely mucronate form of the species; *Ambocœlia umbonata* (Con.), Hall, and *Tropidoleptus carinatus* (Con.), Hall. This quarry is supposed to be the one described by Vanuxem when he said: "At the top of the hill, about twenty feet of sandstone and shale are exposed. * * * Fossils are numerous at the quarry, among which are the mucronated delthyris [*Spirifer mucronatus* (Con.), Bill.], the one figured in the wood-cut being from this locality."[2] The figure of the *Spirifer* just mentioned[3] indicates that it is one of the strongly mucronate forms similar to those which I have mentioned as occurring in this quarry.

To the east of Hamilton township is Brookfield township, the geology of which has been carefully studied by the writer. Near the village of North Brookfield, in the valley of the East Branch of the Chenango river, and eight miles north of east of Hamilton village are excellent exposures of the rocks in the lower and middle part of the formation. Somewhat arenaceous shales in the bed of a small brook just north of the village contain numerous specimens of *Ambocœlia umbonata* (Con.), Hall, but other fossils are not abundant. The species noted from this brook are as follows:

1. *Ambocœlia umbonata* (Con.), Hall.
2. *Productella Shumardiana*, Hall.
3. *Strophalosia truncata*, Hall.

[1] Fourth Annual Report, (Assembly Doc. No. 50,) 1840, p. 890. Also see the description of the Hamilton group in Vanuxem's Final Report, 1842 (Geology New York, Part III., p 157). Again, under the description of the formations of Madison county, Vanuxem wrote: "The hill at the seminary [now Colgate University] is the most favorable point for the examination of the group [Hamilton] as it appears in the county." (*Ibid.*, p. 276.)

[2] Geology of New York, Part III., 1842, pp. 157, 158.

[3] *Ibid.*, Fig. 3, p. 150.

4. *Rhynchonella (Camarotœchia) prolifica*, Hall.
5. *Tropidoleptus carinatus* (Con.), Hall.
6. *Spirifer mucronatus* (Con.), Bill.
7. *Paracyclas lirata* (Con.), Hall.
8. *Nucula Randalli*, Hall.
9. *Homalonotus De Kayi* (Green), Emmons.
10. *Grammysia*, sp.

Near the highway from North Brookfield to Brookfield, about one and one-half miles east of North Brookfield, is a small quarry with five feet of massive bluish-grey sandstone at the base, capped by coarse arenaceous shales. The shales are fossiliferous, the fauna being as follows:

1. *Rhynchonella (Camarotœchia) sappho*, Hall.
2. *Rhynchonella (Camarotœchia) congregata* (Con.), Hall (?).
3. *Chonetes coronata* (Con.), Hall.
4. *Lingula ligea*, Hall (?).
5. *Orbiculoidea (Roemerella) grandis* (Van.), Hall and Clarke (?).
6. *Spirifer audaculus* (Con.), Hall.
7. *Spirifer mucronatus* (Con.), Bill.
8. *Modiomorpha complanata*, Hall.
9. *Grammysia bisulcata* (Con.), Hall (?).
10. *Goniophora Hamiltonensis*, Hall.
11. *Cimitaria recurva* (Con.), Hall.
12. *Tentaculites attenuatus*, Hall.
13. *Orthoceras constrictum*, Van. (?).
14. *Crinoid* stems.

In the upper part of the high hills near North Brookfield are dark argillaceous shales in which fossils are abundant. The outlet of Gorton lake, east of the village, exposes eighty feet of these soft shales, which have furnished the following species:

1. *Stropheodonta perplana* (Con.), Hall.
2. *Athyris spiriferoides* (Eaton), Hall.
3. *Spirifer audaculus* (Con.), Hall.
4. *Spirifer mucronatus* (Con.), Bill.
5. *Spirifer granulosus* (Con.), Hall.
6. *Rhynchonella (Camarotœchia) prolifica*, Hall.
7. *Orbiculoidea Doria*, Hall.
8. *Ambocœlia umbonata* (Con.), Hall.
9. *Nucleospira concinna*, Hall.

10. *Vitulina pustulosa*, Hall.
11. *Chonetes coronata* (Con.), Hall (?).
12. *Orthoceras constrictum*, Van.
13. *Orthoceras subulatum*, Hall.
14. *Orthoceras nuntium*, Hall.
15. *Paracyclas lirata* (Con.), Hall.
16. *Grammysia bisulcata* (Con.), Hall (?).
17. *Actinopteria decussata*, Hall.
18. *Pterinea flabellum* (Con.), Hall.
19. *Phacops rana* (Green), Hall.
20. *Homalonotus DeKayi* (Green), Emm.
21. *Favosites Hamiltoniæ*, Hall.
22. *Palæoneilo constricta* (Con.), Hall.
23. *Nuculites oblongatus*, Con.
24. *Tellinopsis subemarginata* (Con.), Hall.
25. *Nucula Randalli*, Hall.
26. *Nyassa arguta*, Hall (?).
27. *Nuculites triqueter*, Con.
28. *Nucula bellistriata* (Con.), Hall.

Eleven miles southwest of North Brookfield, and six miles south of Hamilton, is Earlville, situated between the East and West Branches of the Chenango river, and on the Madison-Chenango county line. The two branches of the river are a mile apart, forming a broad valley with but few exposures of bed rock in the vicinity of the village. About one-half mile northeast of the village near the top of the low hill, is the White quarry, in which about twenty feet of sandstones and arenaceous shales are exposed. The best building stone, a bluish sandstone, is near the bottom of the quarry, and about five feet above the bottom is a stratum composed almost entirely of shells, largely *Rhynchonellas*, which is called a "fire stone," and higher is another similar stratum. *Spirifer granulosus* (Con.), Hall, *Tropidoleptus carinatus* (Con.), Hall, and *Rhynchonella* are common in the quarry.

The best exposures near Earlville are to be found, however, in the cut on the old Syracuse and Chenango Valley railroad (now called the Chenango Branch of the West Shore railroad), a little over a mile above the Ontario and Western railroad station at Earlville. The cut is twenty-five feet deep in places, through dark blue, blocky shales which, on weathering, crumble to small pieces. The shales are also well exposed in the gorge of the brook at the same place. These shales underlie the coarse shales and sandstones of the White quarry, northeast of Earlville. Fossils are abundant, mainly small forms, although *Spirifer granulosus* (Con.), Hall, is common. The small Lamellibranchs are the abundant and characteristic fossils of this zone, especially the *Nuculidæ* and species of similar habitat, and the locality is well known to some collectors of Hamilton fossils.

The gorge in Kingsley's brook at Randallsville, four miles above Earlville, is another excellent locality for collecting. The rocks are blocky, moderately coarse arenaceous shales, which form cliffs twenty-five to thirty feet high along the brook. Fossils are common, especially *Ambocœlia umbonata* (Con.), Hall, and *Liorhynchus multicosta*, Hall, while in the finer shales *Spirifer mucronatus* (Con.), Bill., is abundant.

Smyrna.

Three and one-half miles southwest of Earlville is the village of Smyrna, in Smyrna township, which is in the northern tier of townships of Chenango county. The upper part of the Hamilton formation is well exposed in the brooks near Smyrna, especially along Pleasant brook from the village northwesterly.

In drawing the line of separation between the Hamilton and Portage formations in central New York, Smyrna township is an important region since it embraces the easternmost extension of the Tully limestone. To the east of this township and the Chenango valley, the calcareous conditions of deposition disappeared and the horizon of the Tully limestone is represented by shales or argillaceous sandstones. Vanuxem, in 1842, mentioned the occurrence of the Tully limestone in "the northwestern part of Smyrna,"[1] and stated that it had "not been seen beyond the town of Smyrna in an east direction."[2] Prosser, in 1887, recorded its presence and thickness near Upperville, on the south side of Pleasant brook, about two miles northwest of Smyrna village.[3] At this locality the limestone is capped by twenty feet of black, argillaceous shales of the Genesee. In the same year, Professor S. G. Williams published a paper on the "Tully limestone, its distribution and its known fossils," in which this locality is described,[4] and the map accompanying the report showing "The geographical distribution of the Tully limestone in central New York," indicates the eastern end of the Tully limestone at this locality.[5]

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[1] Geology of New York, Part III, p. 292.
[2] *Ibid.*, p. 164
[3] Proceedings American Association Advancement of Science, Vol. XXXVI, p. 210.
[4] Sixth Annual Report State Geologist [New York] for the year 1886, p. 18.
[5] *Ibid.*, map facing p. 28.

Prosser, in 1893, reviewed the evidence in relation to the presence of the Tully limestone near Smyrna, and showed that the higher fossiliferous zones at Norwich and Oxford, twelve and nineteen miles farther south must occur *above* the top of the Hamilton, instead of forming the upper part of the Hamilton formation.[1] Finally, J. M. Clarke, in 1894, has shown the same stratigraphic relations for the rocks somewhat farther west in the northwestern part of Chenango county.[2]

The various streams and steep hills of Smyrna township afford good exposures of the rocks, and on account of the importance of this locality in determining the line of separation between the Hamilton and Chemung series, the sections along Pleasant brook and other streams were carefully examined.

XVIII D¹.[3] East of Smyrna village are exposures along the small brook which enters Pleasant brook from the north, below the railroad station, about two miles west of the Chenango river. The lowest exposures on the brook, D¹, are only a few feet above the level of the railroad. They are generally somewhat coarse, arenaceous, blue shales, certain layers of which contain abundant fossils. There are, also, occasionally, thin and irregular strata which are quite calcareous, but not very fossiliferous. The fauna is as follows:

1. *Tropidoleptus carinatus* (Con.), Hall.	(c)[4]
2. *Spirifer mucronatus* (Con.), Bill.	(c)
3. *Spirifer audaculus* (Con.), Hall and Clarke = (*Spirifer medialis*, Hall).	(r)
4. *Nucleospira concinna*, Hall.	(rr)
5. *Spirifer granulosus* (Con.), Hall and Clarke.	(rr)
6. *Athyris spiriferoides* (Eaton), Hall.	(r)
7. *Stropheodonta perplana* (Con.), Hall.	(rr)
8. *Stropheodonta demissa* (Con.), Hall.	(rr)
9. *Stropheodonta concava*, Hall.	(rr)
10. *Strophalosia truncata* Hall (?).	(r)
11. *Chonetes setigera*, Hall (?).	(rr)
12. *Modiomorpha concentrica* (Con.), Hall.	(rr)
13. *Modiomorpha mytiloides* (Con.), Hall.	(rr)
14. *Modiomorpha subalata* (Con.), Hall.	(r)

[1] American Journal of Science, Third Series, Vol. XLVI, pp. 218-222.

[2] Thirteenth Annual Report State Geologist [New York] for the year 1893, p. 553.

[3] The system of numbering used in this paper is as follows: To the general region about some village, which may be used as a center of operations, is assigned a number which is called the station number, as XVIII is the station number for Smyrna. Then the various sections receive a letter, different strata or zones of which are indicated by primes

[4] The relative abundance of the species is indicated as follows: aa = very abundant; a = abundant; cc = very common; c = common; rr = very rare; r = rare.

15. *Microdon* (*Cypricardella*) *bellistriatus* (Con.), Hall. (r)
16. *Paracyclas tenuis*, Hall. (r)
17. *Palæoneilo constricta* (Con.), Hall. (rr)
18. *Nuculites oblongatus*, Con. (rr)
19. *Schizodus*, sp. (rr)
20. *Macrodon Hamiltoniæ*, Hall. (rr)
21. *Pholadella radiata* (Con.), Hall. (rr)
22. *Orthonota carinata*, Con. (rr)
23. *Pterinea flabella* (Con.), Hall. (rr)
24. *Cimitaria elongata* (Con.), Hall. (rr)
25. *Bellerophon*, sp. (rr)
26. *Platyceras* (?), sp. (rr)
27. *Trilobite*, sp. (fragments). (rr)
28. *Orthoceras* sp. (fragments). (rr)
29. *Plant* stems.

XVIII D^2. A little farther up the creek are falls, some twenty feet high, and a gorge, the sides of which are thirty feet or more in height. These shales are much coarser than those of D^1, and contain fossils of large size, as *Spirifer granulosus* (Con.), Hall, and large Lamellibranchs are common. Alternating with the coarse arenaceous shales are somewhat calcareous layers and these thick strata form the falls. The following species were collected:

1. *Chonetes scitula*, Hall. (a)
2. *Chonetes coronata* (Con.), Hall. (rr)
3. *Tropidoleptus carinatus* (Con.), Hall. (c)
4. *Spirifer mucronatus* (Con.), Bill. (c)
5. *Spirifer granulosus* (Con.), Hall and Clarke. (c)
6. *Stropheodonta perplana* (Con.), Hall. (rr)
7. *Orthis Vanuxemi*, Hall (?). (rr)
8. *Productella*, sp. (fragments). (rr)
9. *Pholadella radiata* (Con.), Hall. (rr)
10. *Pterinea flabella* (Con.), Hall. (r)
11. *Modiomorpha concentrica* (Con.), Hall. (rr)
12. *Pectenidæ* (a large specimen). (rr)
13. *Bellerophon*, sp. (rr)
14. *Bryozoa*. (r)

The lithologic appearance of these shales agrees with that of the upper Hamilton formation while the fauna is distinctively Hamilton, so that these shales unquestionably belong to the Hamilton formation.

XVIII F. By the highway at the eastern end of Smyrna village are exposures of somewhat coarse arenaceous shales which contain many fossils. The most abundant species are *Spirifer granulosus* (Con.), Hall and Clarke, and *Tropidoleptus carinatus* (Con.), Hall, of the Brachiopods; *Nuculites triqueter*, Con., of the Lamellibranchs, and associated with these are numerous species of Fucoids—the *Spirophyton*. The complete fauna observed is as follows:

1. *Spirifer granulosus* (Con.), Hall and Clarke. (c)
2. *Spirifer mucronatus* (Con.), Bill. (rr)
3. *Spirifer audaculus* (Con.), Hall and Clarke. (rr)
4. *Tropidoleptus carinatus* (Con.), Hall. (c)
5. *Cyrtina Hamiltonensis*, Hall. (r)
6. *Chonetes coronata* (Con.), Hall. (r)
7. *Chonetes deflecta*, Hall. (r)
8. *Chonetes setigera*, Hall (?). (rr)
9. *Chonetes scitula*, Hall (?). (rr)
10. *Atrypa reticularis* (Linné), Dal. (rr)
11. *Orbiculoidea*, sp. (rr)
12. *Stropheodonta perplana* (Con.), Hall. (r)
13. *Orthis Vanuxemi*, Hall. (rr)
14. *Nuculites triqueter*, Con. (c)
15. *Nuculites oblongatus*, Con. (r)
16. *Palæoneilo constricta* (Con.), Hall. (rr)
17. *Schizodus appressus* (Con.), Hall. (rr)
18. *Paracyclas tenuis*, Hall. (rr)
19. *Phthonia sectifrons* (Con.), Hall. (rr)
20. *Nucula bellistriata* (Con.), Hall. (rr)
21. *Modiomorpha mytiloides* (Con.), Hall. (r)
22. *Orthonota carinata*, Con. (rr)
23. *Microdon (Cypricardella) tenuistriatus*, Hall. (rr)
24. *Macrodon Hamiltoniæ*, Hall. (rr)
25. *Tellinopsis subemarginata* (Con.), Hall. (rr)
26. *Orthonota* (?) *parvula*, Hall. (rr)
27. *Sphenotus truncatus* (Con.), Hall (?). (rr)
   Too imperfectly preserved to admit of positive identification. It might be *S. arcæformis*.
28. *Grammysia arcuata* (Con.), Hall. (r)
29. *Glyptodesma erectum* (Con.), Hall. (rr)

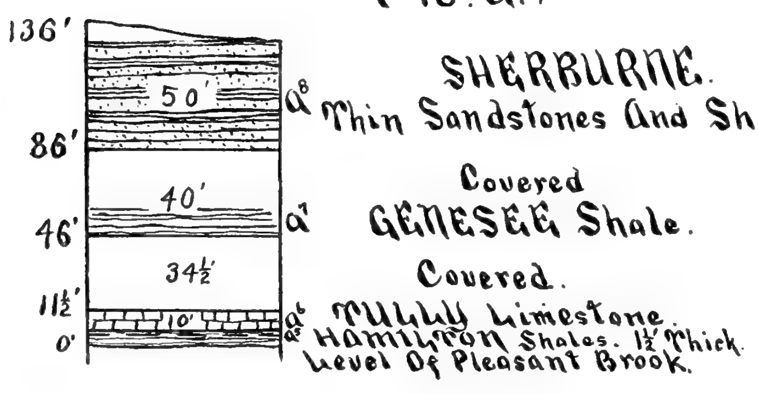
30. *Liopteria*, sp. (rr)
31. *Pleurotomaria capillaria*, Con. (r)
32. *Cyrtolites* (*Cyrtonella*) *pileolus*, Hall (?). (c)

Not well enough preserved to be positively identified. It may be *C. mitella*, Hall.

33. *Bellerophon crenistria*, Hall. (rr)
34. *Bellerophon leda*, Hall. (rr)
35. *Homalonotus DeKayi* (Green), Emmons, fragments. (rr)
36. *Dalmanites* (*Cryphæus*) *Boothi* (Green), Hall. (rr)
37. *Orthoceras*, sp. (fragments). (r)
38. *Crinoid*, sp. (portion of a calyx in several pieces). (rr)
39. *Plant* (a fragment). (rr)

SECTION ON SOUTH BANK OF PLEASANT BROOK, 5½ MILES ABOVE SMYRNA.

(*18. A.)



XVIII A[1]. Pleasant brook flows through the southern part of Smyrna village and along this part of the stream are rocky banks affording excellent exposures of the upper Hamilton rocks. The lowest outcrops studied are a short distance below the New York, Ontario and Western railroad station, and about at its level, or approximately 1,127 feet A. T. Fossils are quite common, the following species having been collected at this locality:

1. *Tropidoleptus carinatus* (Con.), Hall. (c)
2. *Ambocœlia umbonata* (Con.), Hall. (c)

3. *Chonetes coronata* (Con.), Hall. (r)
4. *Chonetes setigera*, Hall. (cc)
5. *Chonetes mucronata*, Hall (?). (r)
6. *Spirifer mucronatus* (Con.), Bill. (c)
7. *Spirifer audaculus* (Con.), Hall and Clarke. (rr)
8. *Spirifer fimbriatus* (Con.), Bill. (rr)
9. *Orthis* (?). (rr)
10. *Discina*. (rr)
11. *Nucula bellistriata* (Con.), Hall. (r)
12. *Nucula corbuliformis*, Hall. (rr)
13. *Nucula lirata* (Con.), Hall. (r)
14. *Palæoneilo constricta* (Con.), Hall. (rr)
15. *Microdon* (*Cypricardella*) *bellistriatus*, Con. (r)
16. *Pholadella radiata* (Con.), Hall. (rr)
17. *Orthonota* (?) *parvula*, Hall. (rr)
18. (?) *Modiella pygmæa* (Con.), Hall. (rr)
19. (?) *Phthonia sectifrons* (Con.), Hall, fragments. (rr)
20. *Tellinopsis subemarginata* (Con.), Hall. (r)
21. *Schizodus appressus* (Con.), Hall. (rr)
22. *Orthoceras*, fragment.
23. *Bellerophon*, fragment.

XVIII A[1]. Along Pleasant brook, above the highway bridge in Smyrna village, is a rather narrow gorge with rocky banks thirty feet or more in height, extending for a quarter of a mile up the brook. The rocks consist of coarse arenaceous shales, alternating with sandstones. All the layers are more or less fossiliferous, and the shales contain abundant fossils. The bottom of the gorge is about twenty-five feet above the level of the railroad station, or with an approximate altitude of 1,150 feet A. T. On account of the considerable number of species contained in these rocks, some time was spent in collecting, and the specimens found in the lower, middle and upper parts of the glen were kept separate. The following lists will give a fair idea of the species contained in thirty or forty feet of upper Hamilton rocks in the Chenango valley region. From the lower part of the glen the following species were collected.

1. *Ambocœlia umbonata* (Con.), Hall. (aa)
2. *Spirifer fimbriatus* (Con.), Bill. (cc)
3. *Spirifer granulosus* (Con.), Hall and Clarke. (a)
4. *Spirifer audaculus* (Con.), Hall and Clarke. (c)

5. *Spirifer mucronatus* (Con.), Bill. (c)
6. *Tropidoleptus carinatus* (Con.), Hall. (aa)
7. *Chonetes coronata* (Con.), Hall. (cc)
8. *Chonetes deflecta*, Hall (?). (r)
9. *Chonetes* sp. (r)
10. *Atrypa reticularis* (Linné), Dal. (r)
11. *Athyris* (*Spirigera*) *spiriferoides* (Eaton), Hall. (rr)
12. *Orthis Vanuxemi*, Hall. (rr)
13. *Stropheodonta perplana* (Con.), Hall. (rr)
14. *Stropheodonta concava*, Hall (?). (rr)
15. *Orthothetes Chemungensis* (Con.), Hall and Clarke. (r)
16. *Liorhynchus multicostus*, Hall. (rr)
17. *Rhynchonella* sp. (rr)
    Possibly *R. prolifica*, H. Very imperfectly preserved.
18. *Productella* sp. (very imperfect specimens). (r)
19. *Cyrtina Hamiltonensis*, Hall (?). (rr)
20. *Cimitaria recurva* (Con.), Hall. (rr)
21. *Paracyclas tenuis*, Hall. (rr)
22. *Palæoneilo emarginata* (Con.), Hall. (r)
23. *Palæoneilo constricta* (Con.), Hall. (rr)
24. *Schizodus appressus* (Con.), Hall. (rr)
25. *Nuculites triqueter*, Con. (c)
26. *Nuculites oblongatus*, Con. (rr)
27. *Pholadella radiata* (Con.), Hall. (r)
28. *Orthonota* (?) *parvula*, Hall. (rr)
29. *Prothyris lanceolata*, Hall. (rr)
30. *Macrodon Hamiltoniæ*, Hall. (r)
31. *Leda diversa*, Hall. (rr)
32. *Nucula bellistriata* (Con.), Hall. (rr)
33. *Microdon* (*Cypricardella*) *tenuistriatus*, Hall. (rr)
34. *Modiomorpha concentrica* (Con.), Hall. (rr)
35. *Modiomorpha mytiloides* (Con.), Hall. (r)
36. *Modiomorpha subalata* (Con.), Hall. (rr)
37. *Goniophora Hamiltonensis*, Hall. (rr)
38. *Goniophora rugosa* (Con.), S. A. Miller (?). (rr)
39. *Grammysia arcuata* (Con.), Hall. (r)
40. *Grammysia* sp. (r)
41. *Leptodesma Rogersi*, Hall. (rr)

42. *Pterinopecten Vertumnus*, Hall. (c)
43. *Orthoceras* sp. (fragment). (rr)
44. *Platyceras carinatum*, Hall. (rr)
45. *Phacops rana* (Green), Hall. (c)
46. *Dalmanites Boothi* (Green), Hall. (rr)
47. *Homalonotus DeKayi* (Green), Emm. (rr)
48. *Crinoid* stems. (rr)

MIDDLE PART OF GLEN.

1. *Spirifer fimbriatus* (Con.), Bill. (c)
2. *Spirifer granulosus* (Con.), Hall and Clarke. (a)
3. *Spirifer audaculus* (Con.), Hall and Clarke. (rr)
4. *Spirifer mucronatus* (Con.), Bill. (c)
5. *Orthis Vanuxemi*, Hall. (a)
6. *Cryptonella planirostra*, Hall. (rr)
7. *Tropidoleptus carinatus* (Con.), Hall. (rr)
8. *Ambocœlia umbonata* (Con.), Hall. (rr)
9. *Chonetes carinata* (Con.), Hall. (rr)
10. *Chonetes setigera*, Hall. (c)
11. *Athyris spiriferoides* (Eaton), Hall. (c)
12. *Cyrtina Hamiltonensis*, Hall. (rr)
13. *Orthothetes Chemungensis* (Con.), Hall and Clarke. (r)
14. *Cypricardinia indenta* (Con.), Hall. (r)
15. *Nucula bellistriata* (Con.), Hall. (rr)
16. *Modiella pygmœa* (Con.), Hall. (rr)
17. *Macrodon Hamiltoniœ*, Hall. (rr)
18. *Schizodus appressus* (Con.), Hall. (rr)
19. *Nuculites triqueter*, Con. (rr)
20. *Goniphora Hamiltonensis*, Hall. (rr)
21. *Modiomorpha concentrica* (Con.), Hall. (r)
22. *Microdon* (*Cypricardella*) *bellistriatus*, Con. (rr)
23. *Microdon* (*Cypricardella*) *tenuistriatus*, Hall. (rr)
24. *Grammysia constricta*, Hall. (rr)
25. *Trilobite* (fragments). (rr)
26. *Orthoceras* (fragment). (rr)
27. *Crinoid* stems (large). (r)

UPPER PART OF GLEN NEAR THE MILL.

1. *Tropidoleptus carinatus* (Con.), Hall. (a)
2. *Crania* (internal impression). (rr)

3. *Stropheodonta perplana* (Con.), Hall. (r)
4. *Orthothetes Chemungensis* (Con.), Hall and Clarke (?). (rr)
5. *Ambocœlia umbonata* (Con.), Hall. (c)
6. *Spirifer granulosus* (Con.), Hall and Clarke. (r)
7. *Spirifer mucronatus* (Con.), Bill. (r)
8. *Spirifer audaculus* (Con.), Hall and Clarke. (rr)
9. *Productella* sp. (rr)
10. *Orthis Vanuxemi*, Hall. (r)
11. *Chonetes coronata* (Con.), Hall. (r)
12. *Chonetes setigera*, Hall (?). (c)
13. *Lingula* sp. (rr)
14. *Nucula bellistriata* (Con.), Hall. (r)
15. *Nucula lirata* (Con.), Hall. (rr)
16. *Nuculites triqueter*, Con. (rr)
17. *Nuculites oblongatus*, Con. (rr)
18. *Palæoneilo constricta* (Con.), Hall. (r)
19. *Palæoneilo emarginata* (Con.), Hall. (rr)
20. *Microdon* (*Cypricardella*) *bellistriatus*, Con. (r)
21. *Paracyclas tenuis*, Hall. (rr)
22. *Prothyris lanceolata*, Hall. (rr)
23. *Leda diversa*, Hall. (rr)
24. *Orthonota carinata*, Con. (rr)
25. *Grammysia arcuata* (Con.), Hall. (rr)
26. *Schizodus appressus* (Con.), Hall. (rr)
27. *Modiomorpha mytiloides* (Con.), Hall. (rr)
28. *Pterinopecten Vertumnus*, Hall. (rr)
29. *Liopteria* sp. (rr)
30. *Phacops rana* (Green), Hall. (c)
31. *Pleurotomaria* sp. (rr)

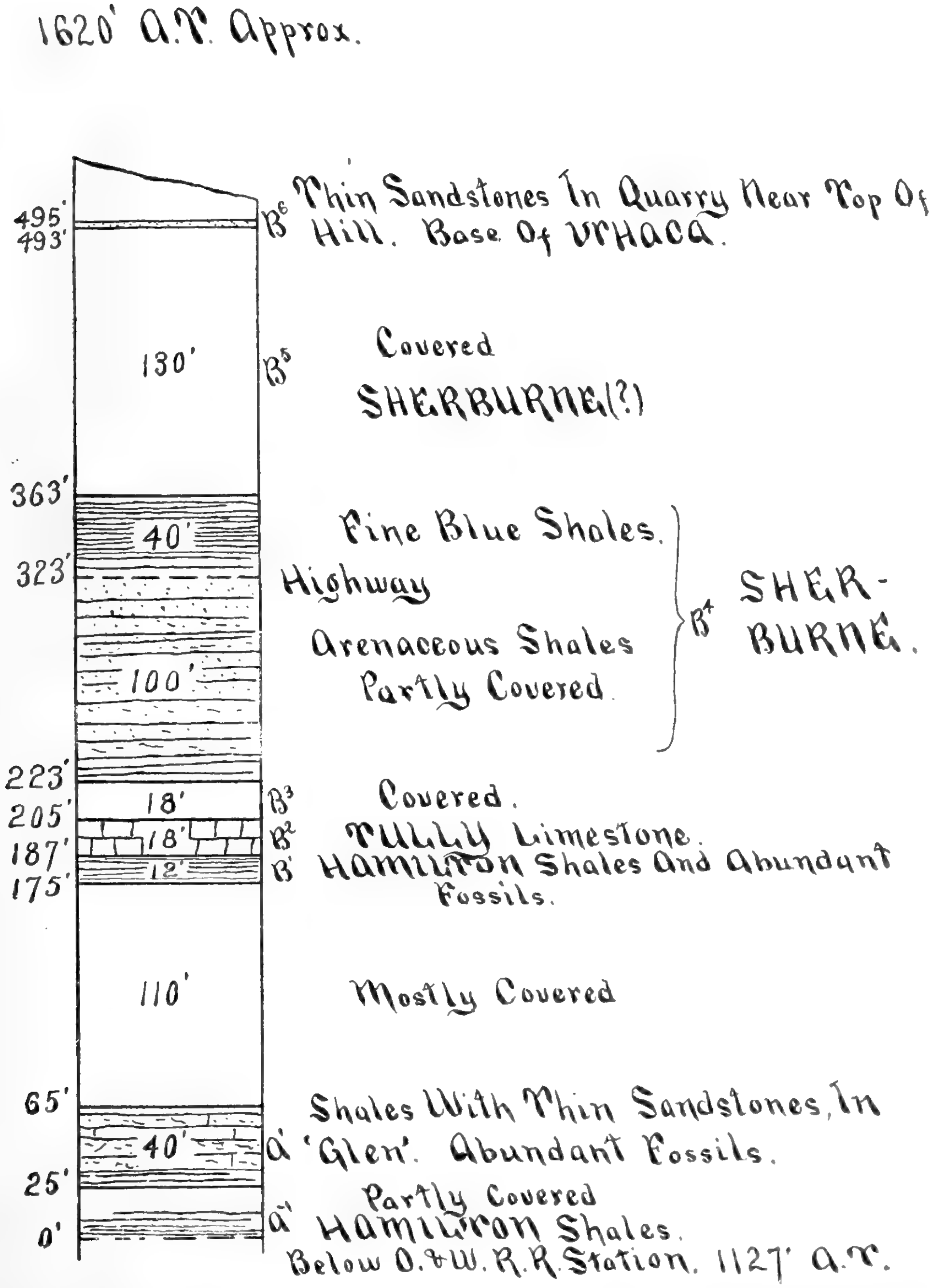
    Specimens too imperfect to decide whether *P. Itys*, H., or *P. capillaria*, Con.

32. *Platyceras* sp.

XVIII B[1]. On the south side of Pleasant brook, less than a mile southwest of Smyrna village, is a steep hill, the summit of which is approximately 500 feet above the Ontario & Western railroad station, or the shales of A[1], exposed along the brook below the station. For some distance above the mill, at the upper end of the village, there are only occasional exposures of rock along the banks of Pleasant brook, while the slope of the hill to the

Section of Pleasant Brook and Hill West of Smyrna.

(#18' a. and B.)



south is largely covered by soil. However, on the "Barber lot," owned by William Wilcox, there is a small brook along whose course the rocks are partly exposed. In the woods at the foot of a cascade about 110 feet above the top of the shales in Pleasant brook at XVIII A[1] is a fair outcrop of shales which contain an abundance of fossils. There is a continuous exposure of twelve feet of these shales which in both faunal and lithologic characters are similar to the Moscow shales of western central New York. Only a few minutes were spent there in collecting, but in that time nineteen species were obtained, all of which, with the exception of *Chonetes mucronata*, Hall, *Cryptonella* (*Eunella*) *Lincklæni*, Hall, and *Liopteria DeKayi*, Hall, occur in the Moscow shales in the vicinity of Moscow and Livonia, Livingston county, New York,[1] which is the typical region for this subdivision of the Hamilton formation. The complete list of species is as follows:

1. *Spirifer mucronatus* (Con.), Bill. (a)
2. *Spirifer granulosus* (Con.), Hall and Clarke. (rr)
3. *Spirifer audaculus* (Con.), Hall and Clarke. (r)
4. *Spirifer Tullius*, Hall. (r)
5. *Vitulina pustulosa*, Hall. (aa)
6. *Tropidoleptus carinatus* (Con.), Hall. (c)
7. *Athyris spiriferoides* (Eaton), Hall. (rr)
8. *Chonetes coronata* (Con.), Hall. (rr)
9. *Chonetes mucronata*, Hall. (rr)
10. *Cryptonella* (*Eunella*), cf. *Lincklæni*, Hall. (r)
11. *Stropheodonta perplana* (Con.), Hall. (rr)
12. *Nuculites triqueter* (Con.). (rr)
13. *Palæoneilo constricta* (Con.), Hall. (rr)
14. *Nucula bellistriata* (Con.), Hall. (rr)
15. *Microdon* (*Cypricardella*) *tenuistriatus*, Hall. (rr)
16. *Goniophora*, cf. *Hamiltonensis*, Hall, and *carinata* (Con.), Hall. (rr)

    The concentric plications are coarse and apparently nearer to to those of *G. carinata* than *G. Hamiltonensis*, but the stratigraphic position of the former is given as higher in the Ithaca group at Oneonta.
17. *Liopteria DeKayi*, Hall. (rr)
18. *Phacops rana* (Green), Hall. (r)
19. *Dalmanites* (*Cryphæus*) *Boothi* (Green), Hall. (c)

[1] See localities mentioned in the distribution of the species in the volumes on the Palæontology of New York, and especially lists of fossils from the Moscow shales of the Livonia salt shaft by J. M. Clarke (Thirteenth Annual Report State Geologist [N. Y.], pp. 134–145).

XVIII B[2]. Immediately above the Hamilton shales which have just been described, is an argillaceous limestone eighteen feet in thickness forming a cascade in the run. In places the limestone is quite shaly and very siliceous, while other portions of the exposure are strongly calcareous. An analysis by Mr. John B. Anderson of a sample from one of the calcareous layers gave the following result:

$Fe_3 O_4$	7.85	per	cent.
Si	32.59	"	"
$Ca\ Co_3$	57.77	"	"
$MgCo_3$	4.28	"	"
Total	102.49	"	"

This is the Tully limestone. It weathers in a manner similar to the outcrops farther up Pleasant brook above Upperville, and in the hills near De Ruyter. This outcrop of the Tully limestone is about two miles southeast of its previously farthest eastern known exposure, which is on the hillside a short distance below Upperville, Smyrna township.[1]

XVIII B[4]. Above the limestone for twenty feet in the brook, there are no outcrops and then grey to bluish, arenaceous unfossiliferous shales appear. There is scarcely any trace of the black Genesee slates along the brook, even as loose pieces. However, that part of the brook without outcrops, between the arenaceous shales above and the limestone below, is the place for the Genesee slate, consequently it may be represented at this locality and be covered by soil. The blue arenaceous shales are fairly exposed along the upper part of the brook on the highway and in the field above, with a thickness of 140 feet. Then for 130 feet higher, forming the upper portion of the slope, there are no outcrops, all the rocks being covered by the soil. The fine blue shales are well exposed for some distance along the highway, on the slope, but a hasty search revealed no fossils. Part of the shales are very smooth and split into thin pieces, and these are well shown in a small brook by the side of the highway on the opposite side of the hill. At this place no fossils were found.

These bluish, unfossiliferous shales, at least 140 feet in thickness, belong in the Portage formation and correspond to the lower part of it, as exposed in

[1] The outcrop near Upperville was described by the writer in 1887. (See Proceedings American Association Advancement of Science, Vol. XXXVI, p. 210.) Also by Prof. S. G. Williams in the Sixth Annual Report State Geologist [New York], p. 18.

The calcareous strata in eastern Pennsylvania which the Pennsylvania geologists correlated with the Tully limestone of New York (see Pennsylvania Geological Survey, Summary Description Geology Pennsylvania, Vol. II, 1892, p. 1313, with map of area on p. 1314), has been shown by the writer to belong considerably lower in the Hamilton formation. (See Bulletin United States Geological Survey, No. 120, 1894, pp. 7, 72.)

the region of Ithaca, N. Y. The picture of Taughannock falls gives an excellent idea of the Lower Portage of the Cayuga lake region. Estimating from other sections in the Chenango and Unadilla valleys, we may safely refer to the Portage, the 130 feet of overlying covered rocks of this station, which would give a thickness of at least 270 feet for the lower Portage near Smyrna. Vanuxem, in 1840, proposed the name "Sherburne flagstone" for this formation, the typical locality being near Sherburne, Chenango county, and described it as composed of "stones * * * of various grades of thickness, alternating with greenish or olive-colored shales; Fucoids resembling the stems of plants are frequent in this rock, and also fragments of plants like the grasses. The flagstone mass extends from Cayuga lake through the district" [Third Geological district, which extended from Cayuga lake eastward to Delaware and Schoharie counties][1]. In the final report on the Third District Vanuxem referred the Sherburne flagstones and shales to the Portage group.[2]

After considering the differences in lithology and fauna between the rocks constituting the Portage formation of western New York and the synchronous formations of eastern New York, it seems advisable to revive Vanuxem's name of Sherburne sandstones as the name of a formation. If we study the sections of the Portage formation in different parts of the State, we will find that in western New York, along the Genesee river, Professor Hall made the following subdivisions of the formation in ascending order: Cashaqua shale, Gardeau shale and Portage sandstones.[3] In Ontario county, along Canandaigua lake, Professor J. M. Clarke divided this formation into the Naples shales and Portage sandstones, regarding the Naples shales as representing the Cashaqua and Gardeau shales of the Genesee valley.[4] For the outcrops along the meridian of Cayuga lake Professor H. S. Williams has used the names Lower Portage, Ithaca group and Upper Portage.[5] In the Chenango valley at the base are Vanuxem's Sherburne flagstones, which are equivalent to the Lower Portage of the Cayuga lake region, and therefore represent only a part of the Portage formation; next above is the Ithaca group, capped by the Oneonta sandstone. The evidence seems to show that at least all of the rocks referred to the three formations just mentioned for the Chenango valley are represented in western New York by the Portage formation. Since in the Chenango valley and eastward, the rocks which are

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[1] Fourth Annual Report, Third Geological District (Assembly Document No. 50, 1840), p. 381.
[2] Geology of New York, Part III., 1842, p. 172.
[3] Geology of New York, Part IV., pp. 226–228.
Bulletin United States Geological Survey, No. 16, p. 36 and p. 67.
[5] Bulletin United States Geological Survey, No. 3, p. 29, and Transactions American Institute of Mining Engineers, Vol. XVI., p. 945.

PLATE I

Taughannock falls, Cayuga lake.
Lower portage with Genesee shale in the lower part of the cliff

synchronous with those of the Portage formation in western New York, differ so strikingly from the Portage in faunal and lithologic characters, there would be an advantage in classifying them in such a way as to make them readily recognizable in the eastern part of the State. The name Oneonta formation is in general use for the upper part; Ithaca formation to some extent for the middle portion; and if Sherburne formation be applied to the lower division, there will then be a complete series of formation names for these terranes, which may be readily followed and mapped half way across New York. Since the Sherburne formation may easily be followed from Sherburne to Ithaca, it is proposed that these rocks at the head of Cayuga lake near Ithaca be called the Sherburne formation.

In this connection it is well to recall the fact that Conrad, in 1841, proposed Sherburne group as the name of a formation [1], for shales found near Smyrna and other localities.[2] The fossils described by Conrad from the Sherburne group are Hamilton species, and this zone was referred correctly by Vanuxem to the Hamilton formation in his final report of 1842.[3]

As the rocks to which Conrad applied the name, "Sherburne group," belong in the upper part of the Hamilton formation, there is little probability that there will ever be occasion to restore the name, and, furthermore Vanuxem's name "Sherburne flagstones" antedates Conrad's by fully one year, so that, according to the law of priority, Conrad's name would be lost.

XVIII B[6]. Near the top of the hill, at an approximate altitude of 1,620 feet A. T., is a small excavation exposing two feet of shaly sandstones. The rock is bluish grey in color, and contains some fossils, especially *Spirophyton*, which occurs abundantly. The following species were collected at this place:

1. *Cyrtina Hamiltonensis*, Hall. (a)
2. *Spirifer mucronatus* (Con.), Bill. (c)
3. *Spirifer mesacostalis*, Hall. (rr)

   Specimens in the form of casts which show clearly the median septum in the sinus of the ventral valve.

4. *Spirifer audaculus* (Con.), Hall and Clarke. (r)
5. *Spirifer*, sp. (rr)

   Fragments of external moulds which show impressions of pustules. The specimens do not have the normal form of *S. granulosus*; cf. *S. fimbriatus* (?).

[1] Fifth Annual Report Palaeontologist, State of New York (Assembly Document No. 150, 1841, p. 31).
[2] *Ibid.*, see lists of fossils on pp. 50-55 for the localities.
[3] Geology of New York, Part III., p. 150. The same correlation appears in Professor Hall's Final Report of 1843 (Geology of New York, Part IV., p. 184)

6. *Liorhynchus mesacostalis*, Hall. (c)
7. *Productella* cf. *speciosa*, Hall. Fragment. (r)
8. *Leptodesma Rogersi*, Hall. (rr)
9. *Aulopora*, sp. (rr)
10. *Crinoid* stems and segments. (r)
11. *Spirophyton*, sp. (rr)
12. *Microdon* (*Cypricardella*) *gregarius*, Hall. (rr)

    Possibly this specimen is not from this locality as the rock is lithologically somewhat different.

13. *Spirifer fimbriatus* (Con.), Bill. (?) (r)
14. *Atrypa reticularis* (Lin.), Dalm. (rr)
15. *Chonetes setigera*, Hall. (rr)
16. *Ambocœlia umbonata* (Con.), Hall. (r)
17. *Phacops rana* (Green), Hall. (rr)

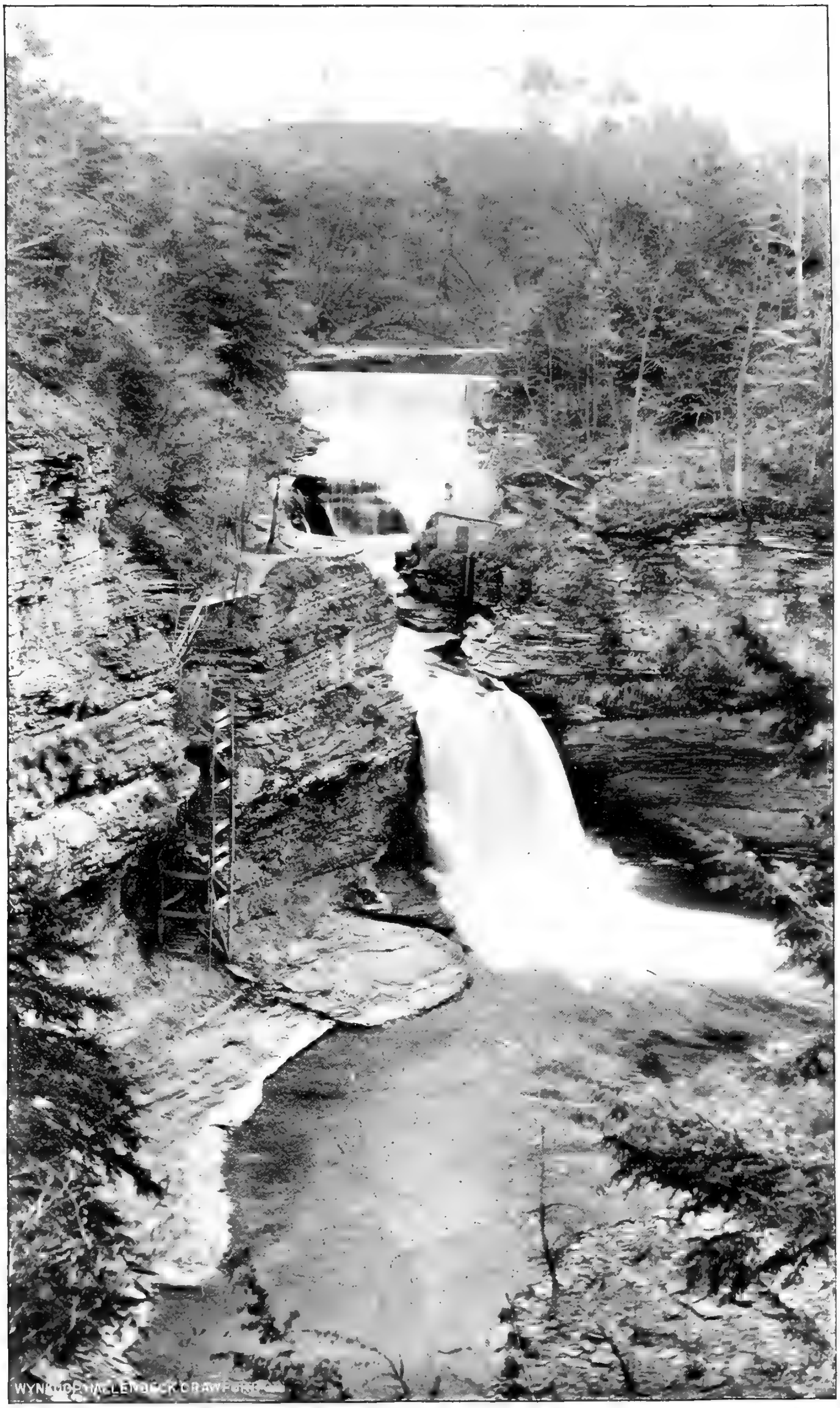
This exposure of fossiliferous rocks is regarded by the writer as containing the early species of the Ithaca epoch of the Chenango valley region. There is no question that on the same hillside about 288 feet lower than this fossiliferous shaly sandstone, is the top of the Tully limestone, while the intervening rocks, as far as exposed, are thin bluish shales in which fossils are very rare; shales that agree in all respects with those of the lower Portage or Sherburne formation of central New York. Near Ithaca, from the base of the lowest rocks referred to the Ithaca group down to the top of the Genesee shales is 250 feet, which is nearly the thickness of the Sherburne formation in the Chenango valley. This section with others near Smyrna and Sherburne clearly show that the fossiliferous beds twelve miles farther south near Norwich and extending along the river valley to Oxford, are not in the Hamilton formation, but are of later date.

The accompanying picture of a portion of the Fall Creek gorge at Ithaca, gives an excellent idea of the lithologic characters of the formation at its typical locality.

XVIII A[2]. Along the bed of Pleasant brook, about one and three-quarter miles above Smyrna village, and three-fourths of a mile below Upperville are excellent exposures of coarse, arenaceous shales which contain fossils in abundance.

Tropidoleptus carinatus (Con.), Hall, is particularly plentiful and there are many specimens of large Lamellibranchs. The species are those of the Hamilton formation, as will be seen from the following list:

PLATE II



Triphammer and Flume falls, Fall creek, Ithaca,
Upper part of the Ithaca group.

1. *Tropidoleptus carinatus* (Con.), Hall. (a)
2. *Chonetes coronata* (Con.), Hall. (c)
3. *Chonetes mucronata*, Hall. (rr)
4. *Spirifer granulosus* (Con.), Hall and Clarke. (a)
5. *Spirifer audaculus* (Con.), Hall and Clarke (?). (r)
   Internal impressions.
6. *Spirifer mucronatus* (Con.), Bill. (rr)
7. *Stropheodonta*, sp. (part of an internal impression). (rr)
8. *Rhynchonella*, sp. (rr)
9. *Orthis*, sp. (rr)
10. *Productella*, sp. (rr)
11. An impression of a *Terebratuloid*. (rr)
12. *Ambocœlia umbonata* (Con.), Hall. (rr)
13. *Athyris* (*Spirigera*) *spiriferoides* (Eaton), Hall. (rr)
14. *Cyrtina Hamiltonensis*, Hall. (rr)
15. *Orthothetes Chemungensis* (Con.), Hall and Clarke. (rr)
16. *Orbiculoidea*, sp. (rr)
   External impression of the dorsal valve.
17. *Nucula bellistriata* (Con.), Hall. (r)
18. *Nuculites oblongatus*, Con. (rr)
19. *Nuculites triqueter*, Con. (r)
20. *Leda rostellata* (Con.), Hall. (rr)
21. *Leda diversa*, Hall. (rr)
22. *Palæoneilo constricta* (Con.), Hall. (c)
23. *Palæoneilo muta*, Hall. (rr)
24. *Palæoneilo emarginata* (Con.), Hall. (rr)
25. *Palæoneilo tenuistriata*, Hall. (rr)
26. *Modiella pygmæa* (Con.), Hall. (rr)
27. *Microdon* (*Cypricardella*) *bellistriatus*, Con. (rr)
28. *Paracyclas tenuis*, Hall. (rr)
29. *Modiomorpha mytiloides* (Con.), Hall. (rr)
30. *Cimitaria*, sp. (rr)
31. *Grammysia arcuata* (Con.), Hall. (rr)
32. *Grammysia obsoleta*, Hall (?). (rr)
   Internal impressions poorly preserved.
33. *Schizodus appressus* (Con.), Hall. (r)
34. *Goniophora rugosa* (Con.), S. A. Miller. (rr)
35. *Phthonia cylindrica*, Hall. (rr)

36. *Mytilarca (Plethomytilus) oviformis* (Con.) Hall. (r)
37. *Liopteria Bigsbyi*, Hall (?). (r)
38. *Phacops rana* (Green), Hall. (r)
39. *Pleurotomaria capillaria*, Con. (r)
40. *Bellerophon*, sp. (rr)
41. *Orthoceras*, sp. (fragments of two species). (r)
42. *Coleolus*, sp. (rr)
43. *Crinoid* stems, large. (c)

XVIII G[1]. The hill on the south side of Pleasant brook between Smyrna and Upperville, is steep and mostly wooded. Not far below Upperville, a small run enters Pleasant brook from the south and the rocks are quite well exposed along its course. At the mouth of the run are shales similar to those of XVIII C[2], containing similar fossils. These shales extend up the hillside for some distance and are about 147 feet above the level of the brook which, at the mouth of the run, is approximately 1,222 feet A. T., and contain numerous fossils, *Tropidoleptus carinatus* (Con.), Hall, being especially abundant. A hasty search afforded the following species:

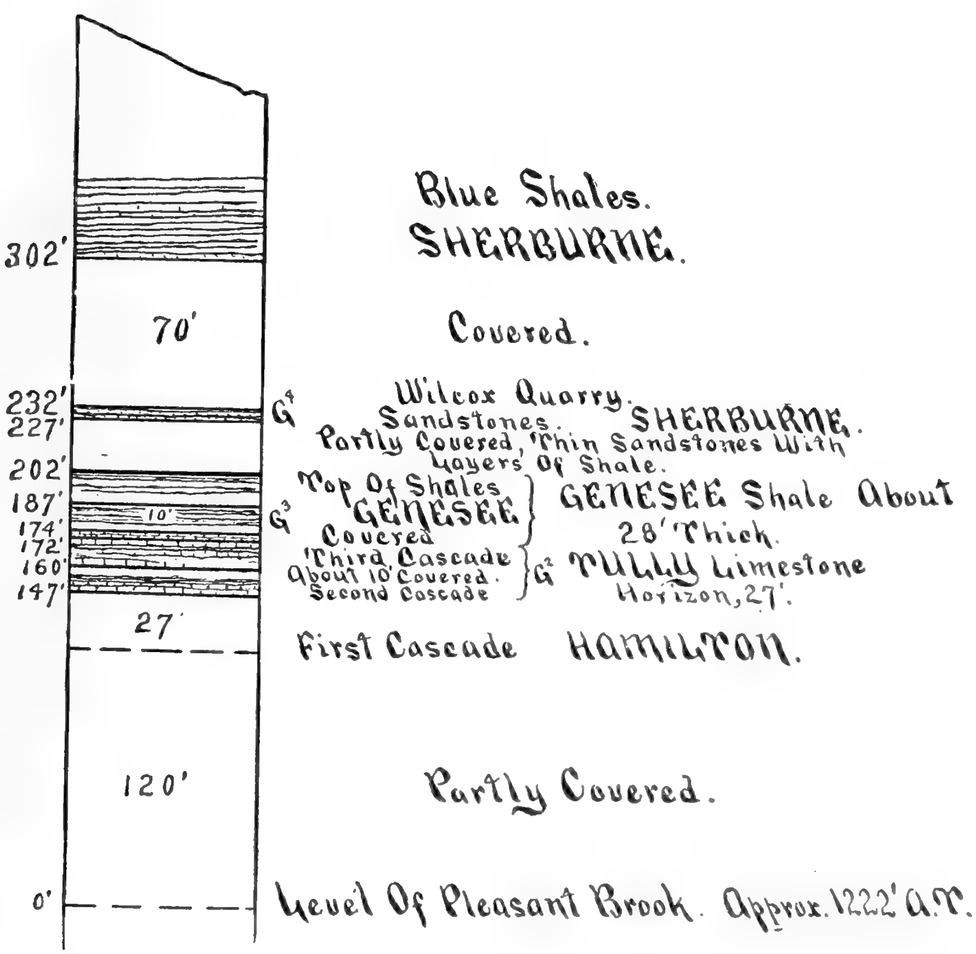
1. *Tropidoleptus carinatus* (Con.), Hall. (a)
2. *Spirifer mucronatus* (Con.), Bill. (rr)
3. *Spirifer granulosus* (Con.), Hall and Clarke, or *S. audaculus* (Con.), Hall and Clarke. (rr)
   Specimen too imperfect for specific identification.
4. *Liorhynchus multicostus*, Hall. (r)
   The lateral plications are very faint.
5. *Orthis Vanuxemi*, Hall. (rr)
6. *Palæoneilo emarginata* (Con.), Hall. (rr)
7. *Nucula lirata* (Con.), Hall. (?) (rr)
   A broken specimen.
8. (?) *Schizodus*, sp., badly broken specimen. (rr)
9. *Crania*, sp., very poorly preserved. (rr)
10. *Phacops rana* (Green), Hall. (rr)

XVIII G[2]. On top of these Hamilton shales, 147 feet above the level of Pleasant brook, is an arenaceous limestone forming the top of the second cascade in the run. The stratum is composed of three layers as it crosses the stream, the lowest, ten inches in thickness, containing quite a large percentage of sand, the upper layer being the purest limestone. A little higher are rather coarse, arenaceous blue shales, and then the rocks are covered for about ten feet. At this point is the third cascade in the stream, at the base of which is an impure limestone, then calcareous shales, and at the top of the cascade are two layers of impure limestone, separated by a shaly parting, the upper

SECTION BELOW UPPERVILLE ON SOUTH SIDE OF PLEASANT BROOK.

(*18. G.)

1524' A.T. Approx.



layer being six inches thick. Resting on this upper limestone are about two feet of calcareous, shaly layers, the distance from the foot of the cascade to its top being fourteen feet. From the base of the lowest calcareous stratum to the top of these calcareous shales is twenty-seven feet, which mass of rock the writer regards as belonging to the same horizon as the Tully limestone of western central New York. This outcrop was first described in 1887 and was the farthest east that the Tully had been traced[1] until the exposure near Smyrna village was discovered, which is described in the present paper. From my observations on the eastern outcrops of the Tully limestone, I ascribe its disappearance to a gradual loss of the calcareous material which is replaced by that of the arenaceous and argillaceous sediments, causing the rock to present a decidedly different lithologic appearance. This is substantially the explanation advanced by Professors S. G. Williams[2] and Henry S. Williams.[3]

XVIII G³. For a short distance above the calcareous shales the rocks are covered, but where the stream forks black fissile shale begins and about ten feet are shown. For forty feet above the black shales the rocks are mostly hidden, but at this point are thin sandstones one-quarter to one-half inch in thickness, with an occasional layer of black shale between them. Fossils were not found in these black, argillaceous shales, which are regarded as belonging to the Genesee slate. As a portion of the rocks is concealed, it is difficult to give their thickness, but from a study of the exposures a little northwest of this locality, it seems probable that they have a thickness of twenty feet or more, perhaps of forty feet, as stated by Professor S. G. Williams.[4]

XVIII G⁴. Just above the thin sandstones of the run already described are thicker sandstones, while the shales change to a blue or olive color; on their upper surface are frequent irregular markings, perhaps partly due to Fucoids, but mainly to mud markings produced by mechanical causes. Above the highway the rocks are mainly blue, smooth shales, which weather to an olive color and split into very thin pieces. In these fine shales no fossils were found. But not far from the run above described another crosses the highway, the first one below Upperville, and in this, about thirty feet above the highway, is the Wilcox quarry, which has been worked for building stone, the heaviest layer being nineteen inches thick. There is an occasional thin flag layer and the sandstones alternate with shales. Fossils are rare, only a very few specimens being found in an hour's search, as the list shows:

[1] See Prosser, Proceedings American Association Advancement of Science, Vol. XXXVI, p. 210; and S. G. Williams, Sixth Annual Report State Geologist [New York], p. 18.

[2] Sixth Annual Report State Geologist [New York], 1887, p. 18.

[3] Bulletin Geological Society of America, Vol I, 1890, p. 490.

[4] Sixth Annual Report State Geologist [New York], p. 18.

1. *Lunulicardium fragile*, Hall. (rr)
2. *Liopteria* sp. (rr)
3. *Crinoid* stems.

A single specimen of *Liorhynchus mesacostalis*, Hall, was found, but it was on a loose piece of stone in the quarry, and may have come from farther up the hillside. On the highway below the quarry are black, argillaceous shales of the Genesee, and in the run below the road is the Tully limestone. The thin sandstones which contain an occasional fossil, and the blue shales that weather to an olive color, belong to the Sherburne formation.

The clear stratigraphic succession of the rocks forming this section; the very fossiliferous shales with abundant Hamilton fossils in the lower part of the run, belonging in the Hamilton formation; followed by twenty-seven feet of calcareous layers, part of which are impure massive limestones, referred to the Tully; succeeded by a black, argillaceous shale similar in all its lithologic characters to the Genesee; capped finally by thin sandstones and blue or olive shales, called the Sherburne, and which contain a few fossils, seem to prove the correlation offered by the writer for the rocks of this region. The stratigraphic order of the rocks just described is shown diagrammatically in the accompanying section.

XVIII A[3]. Gorge and falls in Pleasant brook at Upperville. The water falls over about fifteen feet of coarse, blue, arenaceous shales, in which fossils are common, particularly *Spirifer granulosus* (Con.), Hall and Clarke, and some large Lamellibranchs. Some of the shales which contain many shells are somewhat calcareous, and the outcrop extends along the bed and sides of the brook for some distance below the falls. The rocks belong to the Hamilton formation, and the following species were collected:

1. *Spirifer audaculus* (Con.), Hall and Clarke. (c)
2. *Spirifer granulosus* (Con.), Hall and Clarke. (c)
3. *Spirifer mucronatus* (Con.), Bill. (rr)
4. *Cyrtina Hamiltonensis*, Hall. (c)
5. *Orthis Vanuxemi*, Hall. (r)
6. *Chonetes mucronata*, Hall. (rr)
7. *Palæoneilo fecunda*, Hall. (?) (rr)
8. *Palæoneilo emarginata* (Con.), Hall. (rr)
9. *Modiomorpha concentrica* (Con.), Hall. (rr)
10. *Grammysia arcuata* (Con.), Hall. (rr)
11. *Phacops rana* (Green), Hall. (r)
12. *Bellerophon crenistria*, Hall. (?) (rr)

13. *Orthoceras* (fragment). (rr)
14. *Coleolus tenuicinctum*, Hall. (rr)

XVIII A[4]. Exposures in Pleasant brook below Card's mill, one mile above Upperville. The rocks are blue shales that split into fine, smooth fragments, alternating with calcareous layers which contain fossils in abundance and form layers termed "firestones." Such a calcareous layer six inches in thickness is exposed in the bed of the brook under the highway bridge and contains a large number of fossils, as *Spirifer mucronatus* (Con.), Bill., and other species. In the shales above the calcareous stratum just mentioned are large numbers of *Liorhynchus multicostus*, Hall, which is the most common fossil at this locality. This exposure is about seventy-five feet above the falls at Upperville, and is in the Hamilton formation. The following species were collected:

1. *Liorhynchus multicostus*, Hall. (aa)
2. *Orthothetes Chemungensis* (Con.), Hall and Clarke. (rr)
3. *Athyris (Spirigera) spiriferoides* (Eaton), Hall. (r)
4. *Spirifer consobrinus*, D'Orbigny=*ziczac*, Hall. (rr)
5. *Spirifer granulosus* (Con.), Hall and Clarke. (Imperfect specimen.) (rr)
6. *Spirifer mucronatus* (Con.), Bill. (rr)
7. *Spirifer audaculus* (Con.), Hall and Clarke. (rr)
8. *Atrypa reticularis* (Lin.), Dalm. (rr)
9. *Orthis Vanuxemi*, Hall. (?) (r)
10. *Ambocœlia umbonata* (Con.), Hall. (r)
11. *Stropheodonta*, sp. (very imperfect specimen). (rr)
12. *Tropidoleptus carinatus* (Con.), Hall. (c)
13. *Chonetes scitula*, Hall. (c)
14. *Chonetes setigera*, Hall. (r)
15. *Terebratuloid* shell too imperfect to identify generically. (rr)
16. *Orbiculoidea*, sp. cf. with *O. Seneca*, Hall. (rr)
17. *Nucula bellistriata* (Con.), Hall. (rr)
18. *Nucula lirata* (Con.), Hall. (?) (rr)
19. *Palæoneilo constricta* (Con.), Hall. (rr)
20. *Palæoneilo emarginata* (Con.), Hall. (rr)
21. *Palæoneilo muta*, Hall. (rr)
22. *Modiella pygmæa* (Con.), Hall. (rr)
23. *Tellinopsis subemarginata* (Con.), Hall. (rr)
24. *Modiomorpha subalata* (Con.), Hall. (rr)

25. *Modiomorpha mytiloides* (Con.), Hall. (rr)
26. *Modiomorpha concentrica* (Con.), Hall. (rr)
27. *Phacops rana* (Green), Hall. (rr)
28. *Trilobite*, sp. (fragment). (rr)
29. *Orthoceras*, sp. (fragment). (rr)
30. *Platyceras* (too imperfect to identify specifically). (rr)
31. *Bellerophon*, sp. (two very imperfect specimens). (rr)

XVIII A[5]. On Pleasant brook just above the upper highway bridge, five and one-half miles above Smyrna village, on the Gilbert Tuttle farm, is an exposure of shales and limestone. Below the limestone are one and one-half feet of black, argillaceous shales that are quite fossiliferous, containing numerous specimens of typical *Spirifer mucronatus* (Con.), Bill., *Vitulina pustulosa*, Hall, and other Hamilton fossils. This outcrop is some 275 feet by the barometer above the New York, Ontario and Western railroad station in Smyrna, or approximately 1,400 feet A. T., and is at the top of the Hamilton formation. The following species were collected:

1. *Spirifer mucronatus* (Con.), Bill. (a)
2. *Vitulina pustulosa*, Hall. (a)
3. *Tropidoleptus carinatus* (Con.), Hall. (rr)
4. *Chonetes*, sp., probably *C. setigera*, Hall. (rr)
5. *Modiella pygmæa* (Con.), Hall. (rr)
6. *Nuculites oblongatus* (Con.). (rr)
7. *Orthonota undulata* (Con.). (rr)
8. *Palæoneilo emarginata* (Con.), Hall. (rr)
9. *Dalmanites Boothi* (Green), Hall. (r)
10. *Bellerophon*, sp. (rr)
11. Internal impression of a large *Orthoceras* from a loose slab of sandstone in the creek.

XVIII A[6]. On top of the shales are three and a half feet of somewhat impure limestone, separating into two or three layers, the upper being the purer. Above the limestone, part of which is dark in color and strongly calcareous, with the lithologic characters of the Tully, the rocks are covered by soil. A little farther up the brook is another outcrop of rather impure limestone five feet in thickness, which is apparently higher than the former. It seems probable that there are fully ten feet of the impure limestone at this locality, and the actual thickness is no doubt somewhat greater, but is obscured by the soil.[1] So far no fossils have been found in this limestone

[1] Professor S. G. Williams, in describing this locality, stated the indications were that "the limestone is at least fifteen feet thick." (Sixth Annual Report State Geologist [New York], p. 18).

along Pleasant brook, but none of the outcrops are favorable for collecting, and it is very likely if the rocks were opened to any extent that fossils would be found.

This is supposed to be the most eastern locality of the Tully limestone observed by Vanuxem, for he said, in describing the localities of this rock: "The first point going west is on the turnpike from Sherburne to De Ruyter, about eight miles from the former village. It appears in a low side hill, forming the bank of the creek where the road crosses it. About four layers are exposed, ranging by the side of the creek."[1] Again, in describing the geology of Chenango county, Vanuxem wrote: "The Tully limestone was seen in but one locality at the northwestern part of Smyrna, on the road to De Ruyter village, where the road crosses the west branch of the Chenango."[2]

XVIII A[7]. In Pleasant brook and along its bank, about one-half mile above the first outcrop of Tully limestone, are black argillaceous shales, which form a bluff fifteen feet in height on the south bank of the creek. The shales weather to very thin pieces, and in lithologic characters resemble closely the Genesee slates as exposed on Cayuga and the other lakes of western central New York. The shale is so black that some years ago an excavation was made in the hope of finding coal. No fossils were found by me. Between the Tully limestone and the lowest layers of the shale on the creek the rocks are covered for some distance, the shales being about thirty-five feet above the last outcrop of the limestone; then there are at least fifteen feet of black shales, and next, following a small stream up the hill to the south of Pleasant brook for about twenty-five feet, the rocks are covered and sandstones and shales occur.

XVIII A[8]. The sandstones, which are of a dark gray color, weathering to a rather brownish tint, alternate with greenish shales. Fifty feet of the shales and sandstones occur along the run and reach the brow of the hill. Along the upper part of Pleasant brook the hills are much lower than in the vicinity of Smyrna village. The thin sandstones of these rocks show on the upper surfaces numerous specimens of *Fucoides graphica*, Van., and in general lithologic characters are similar to the shales and sandstones constituting the Sherburne formation in Cortland and Tompkins counties. The base of these Sherburne rocks is about seventy-five feet above the top of the Tully limestone, or barometrically 360 feet above the New York, Ontario and Western railroad station at Smyrna, making the altitude approximately 1,485 feet A. T.

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[1] Geology of New York, Part III., p. 164.
[2] *Ibid.*, p. 292.

These three sections along Pleasant brook and up the hill to the south through the central part of Smyrna township are regarded by the writer as very important in deciding where the line of separation between the Hamilton and Chemung series should be drawn. It is nearly, if not quite, the most eastern locality at which the lithologic characters of the Tully limestone and Genesee shale agree closely with those of their typical localities in the more western portions of New York. Above the black shale occur thin sandstones and olive to bluish shales which agree well lithologically with the lower part of the Sherburne formation, as shown along Cayuga lake, while on the top of the high hills occur sandstones and shales containing fossils which compose the lowest fauna of the Ithaca group, as developed in Chenango county.

Sherburne.

The next township to the east of Smyrna is Sherburne, which also belongs to the northern tier of townships in Chenango county, and as the Chenango river flows from north to south entirely across the western half, it forms one of the townships of the Chenango river valley. To the north is Hamilton township, on the east is Columbus which extends east to the Unadilla river.

The valley of the Chenango river in central New York is noted for its beauty. Rather narrow in general, from one-half to two miles in width, there are steep hills rising on one and usually both sides of the valley. In places the hills are so steep that numerous exposures of the rocks along their sides are seen, but usually the best sections are afforded by the small runs and brooks that have trenched more or less deeply the hills that bound the river valley. These hills extend from the northern line of Chenango county for forty-five miles to the southwest until the Susquehanna is reached near Binghamton.

These sections occur in the Middle and Upper Devonian of southern central New York. In order to bring out clearly the character and succession of these formations, a series of sections with their fossils will now be described approximately in the order of their occurrence from Sherburne on the north to the vicinity of Binghamton on the south.

XIX A[1]. To the southeast of Smyrna, between the New York, Ontario and Western and the Delaware, Lackawanna and Western railroads, is a hill on whose eastern side, about two miles southwest of Sherburne village, and just west of the turn in the highway approaching the village, is an old quarry of shaly sandstone. The back of the quarry shows a ledge eleven feet thick, in which Hamilton fossils are common, and from which the following species were obtained:

1. *Spirifer mucronatus* (Con.), Bill. (a)
2. *Tropidoleptus carinatus* (Con.), Hall. (rr)
3. *Chonetes scitula*, Hall. (c)
4. *Athyris spiriferoides* (Eaton), Hall (?). (rr)
   Imperfectly preserved internal impression.
5. *Grammysia (Sphenomya) cuneata*, Hall. (rr)
6. *Microdon (Cypricardella) tenuistriatus*, Hall. (rr)
7. *Tellinopsis subemarginata* (Con.), Hall. (rr)
8. *Actinopteria decussata*, Hall. (rr)
9. *Orthoceras*, sp. (poorly preserved fragment). (rr)
10. *Dalmanites (Cryphæus) Boothi* (Green), Hall. (rr)

The Hamilton arenaceous shales, with plenty of fossils, extend at least sixty feet higher than the quarry, where an outcrop was found which is barometrically 175 feet above the Delaware, Lackawanna and Western railroad station at Sherburne, or approximately 1,220 feet A. T.

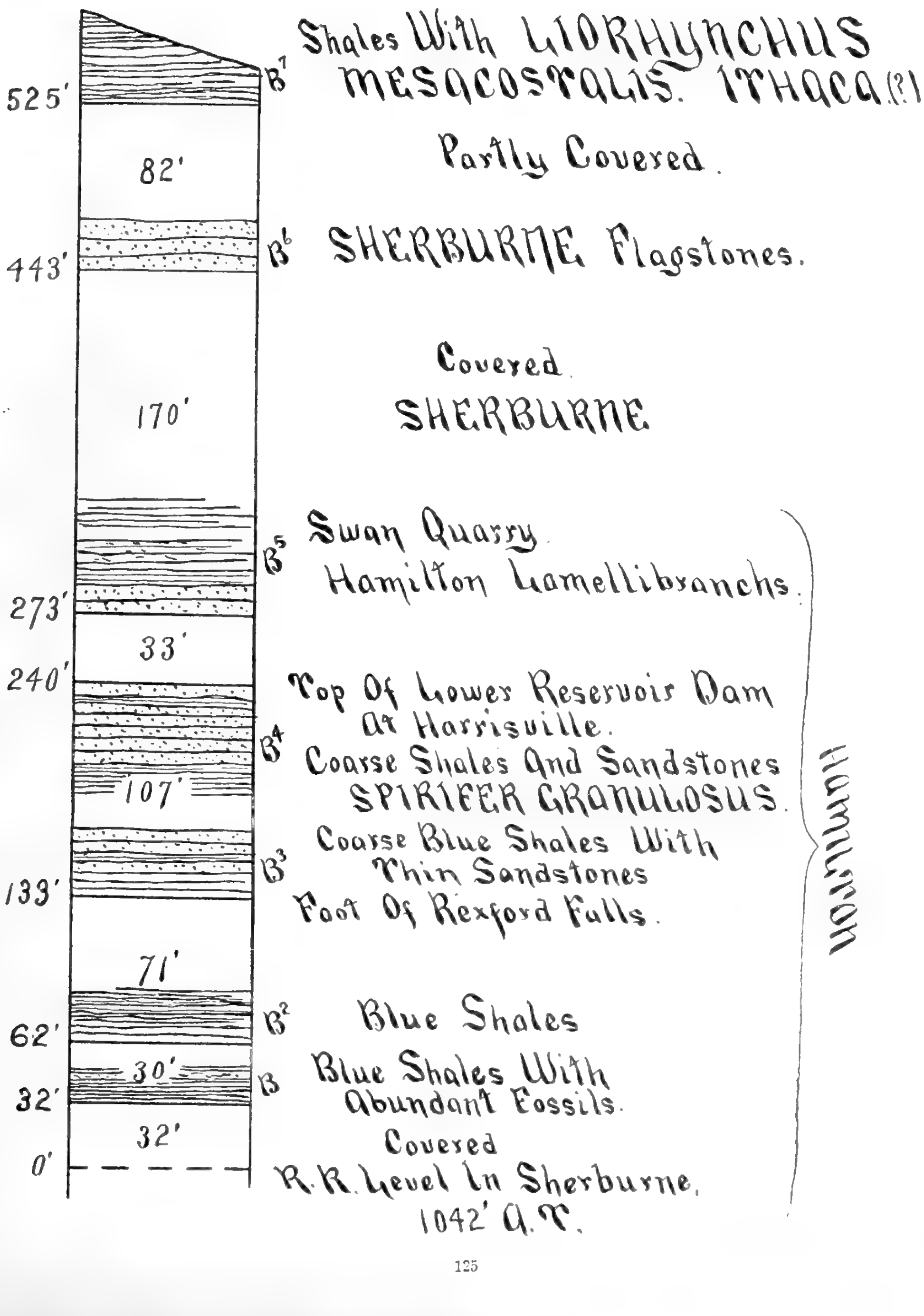
*XIX A*². Above the Hamilton outcrop just mentioned the rocks are covered for about sixty-three feet, when another old quarry is reached, in which there are thin, bluish sandstones alternating with thin, bluish, fissile, argillaceous shales, and this outcrop may be followed for some distance along the side of the hill to the north. No fossils were found except fucoidal markings similar to *Fucoides graphica*, Van. The quarry is barometrically 238 feet above the Delaware, Lackawanna and Western railroad station at Sherburne. The rocks belong to the Sherburne formation, and the upper portion of this hill has been so indicated on the accompanying geologic map.

*XIX F*¹. In the northern part of Sherburne township, about two and one-half miles northeast of the village, on the Powers farm, two excavations were made some years ago in search of coal, and the place is known locally as the "coal mine." The rocks are mostly thin, fissile, black, argillaceous shales, containing abundant Hamilton fossils. Some of the layers are composed very largely of *Spirifer mucronatus* (Con.), Bill. and *Tropidoleptus carinatus* (Con.), Hall. The most abundant species are *Spirifer mucronatus* (Con.), Bill., *Tropidoleptus carinatus* (Con.), Hall, and *Ambocœlia umbonata* (Con.), Hall, and the rocks belong in the upper part of the Hamilton formation, probably the zone termed in western New York, the Moscow shale. Barometrically the locality is 266 feet above the Sherburne railroad station, or approximately 1,308 feet A. T.

MAD BROOK SECTION EAST OF SHERBURNE

(*19. B.)

1567' A.T. Approx.



XIX F². On the western side of the small valley formed by Herrington brook and to the northwest of the "coal mine" is a steep hill 200 feet higher. Near the top of the hill is Mulligan's quarry, from which bluish, fine-grained, thin flagstones are produced. Most of the layers are only from one-half to two inches thick, but the workmen claim that if well bedded they do not break easily, and the flags have been used to some extent in the village for sidewalks. Above the flags in the quarry are rather coarse, irregular shales, which contain fossils; *Liorhynchus mesacostalis*, Hall, and *Spirifer* are common. This quarry is barometrically about 455 feet above the railroad station in Sherburne, or approximately 1,500 feet A. T., and is considered as belonging to the lower part of the Ithaca group. The hill is composed of the Sherburne and Ithaca formations, and has been so represented on the geologic map.

XIX B¹. In the eastern part of Sherburne village is a stream known as Mad brook, which has rocky banks for a mile or more. At the head of the glen is Sherburne or Rexford falls, a local summer resort and picnic ground. The rocks along the side of the brook contain numerous fossils, making an excellent locality for collecting species found in the upper part of the Hamilton formation. The lowest exposures of rocks in Mad brook are in the edge of the village, only thirty-two feet, by the level, above the railroad, or with an altitude of 1,074 feet A. T. They are thin, blue shales, that split very finely, contain numerous fossils and some calcareous layers, composed principally of fossils. The observed fauna is as follows:

1. *Orthis Vanuxemi*, Hall.	(c)
2. *Athyris* (*Spirigera*) *spiriferoides* (Eaton), Hall.	(r)
3. *Stropheodonta perplana* (Con.), Hall.	(r)
4. *Stropheodonta inequistriata* (Con.), Hall.	(a)
5. *Spirifer mucronatus* (Con.), Bill.	(a)
6. *Spirifer granulosus* (Con.), Hall and Clarke.	(rr)
7. *Spirifer audaculus* (Con.), Hall and Clarke.	(rr)
8. *Spirifer fimbriatus* (Con.), Bill.	(rr)
9. *Orthothetes Chemungensis* (Con.), Hall and Clarke.	(rr)
10. *Chonetes coronata* (Con.), Hall.	(r)
11. *Centronella impressa*, Hall. (?)	(r)
12. *Tropidoleptus carinatus* (Con.), Hall.	(c)
13. *Orbiculoidea* sp.	(rr)
14. *Lingula* (portion of a valve).	(rr)
15. *Nucula bellistriata* (Con.), Hall.	(rr)
16. *Macrodon Hamiltoniæ*, Hall.	(c)

17. *Palæoneilo constricta* (Con.), Hall. (r)
18. *Goniophora Hamiltonensis*, Hall. (r)
19. *Microdon* (*Cypricardella*) *bellistriatus*, Con. (rr)
20. *Mytilarca* (*Plethomytilus*) *oviformis* (Con.), Hall. (r)
21. (?) *Liopteria* (very imperfect specimen). (rr)
22. *Phacops rana* (Green), Hall. (r)
23. *Loxonema delphicola*, Hall. (rr)
24. *Gomphoceras*, sp. (rr)
25. Portion of a *Crinoid* stem. (rr)

*XIX B*². The shales farther east by the side of Mad brook, just above the highway bridge, are sixty-two feet by level above the railroad. The rocks are blue, argillaceous (somewhat arenaceous) shales, containing abundant fossils, generally small forms of lamellibranchs and brachiopods, with an occasional large lamellibranch and trilobite. The following species were collected:

1. *Chonetes coronata* (Con.), Hall. (aa)
2. *Chonetes setigera*, Hall. (aa)
3. *Chonetes scitula*, Hall. (?) (r)
4. *Chonetes lepida*, Hall. (rr)
5. *Spirifer mucronatus* (Con.), Bill. (aa)
6. *Spirifer granulosus* (Con.), Hall and Clarke. (rr)
7. *Spirifer fimbriatus* (Con.), Bill. (rr)
8. *Spirifer Tullius*, Hall. (?) (rr)
   (A single internal impression of a ventral valve.)
9. *Ambocœlia umbonata* (Con.), Hall. (r)
10. *Athyris spiriferoides* (Eaton), Hall. (r)
11. *Orthis Vanuxemi*, Hall. (r)
12. *Stropheodonta*, sp. (internal impression of large valve). (rr)
13. *Orbiculoidea*, sp. (rr)
14. *Lingula*, sp. (rr)
   It has the same proportions as *L. ligea*, H., though slightly larger
15. *Lingula*, sp. (rr)
   A broken specimen resembling *L. complanata*, Williams.
16. *Nuculites triqueter*, Con. (aa)
17. *Nuculites oblongatus*, Con. (r)
18. *Palæoneilo constricta* (Con.), Hall. (a)
19. *Palæoneilo emarginata* (Con.), Hall. (r)
20. *Palæoneilo muta*, Hall. (r)

21.	*Nucula bellistriata* (Con.), Hall.	(c)
22.	*Nucula corbuliformis*, Hall.	(r)
23.	*Nucula lirata* (Con.), Hall.	(r)
24.	*Paracyclas tenuis*, Hall.	(rr)
25.	*Schizodus*, sp. (?), (imperfect specimen).	(rr)
26.	*Macrodon Hamiltoniæ*, Hall.	(rr)
27.	*Modiella pygmæa* (Con.), Hall.	(c)
28.	*Orthonota* (?) *parvula*, Hall.	(r)
29.	*Orthonota carinata*, Con.	(r)
30.	*Orthonota undulata*, Con. (?)	(r)
31.	*Lunulicardium fragile*, Hall (?).	(rr)
32.	*Cimitaria elongata* (Con.), Hall (?).	(r)
33.	*Pholadella radiata* (Con.), Hall.	(aa)
34.	*Prothyris lanceolata*, Hall.	(rr)
35.	*Grammysia arcuata* (Con.), Hall.	(c)
36.	*Grammysia bisulcata* (Con.), Hall.	(a)
37.	*Modiomorpha mytiloides* (Con.), Hall.	(rr)
38.	*Sphenotus solenoides*, Hall.	(rr)
39.	*Sphenotus truncatus* (Con.), Hall (?).	(rr)
40.	*Goniophora*, sp. (probably *G. Hamiltonensis*, H.).	(rr)
41.	*Tellinopsis subemarginata* (Con.), Hall.	(rr)
42.	*Cypricardinia indenta* (Con.), Hall.	(rr)
43.	*Microdon* (*Cypricardella*) *bellistriatus*, Con. (fragments).	(rr)
44.	*Liopteria*, sp.	(r)
	With poorly preserved specimens it is difficult to make specific identifications when the species of this genus differ so slightly.	
45.	*Pterinopecten Vertumnus*, Hall (?). cf. *P. intermedius*, H.	(c)
46.	*Glyptocardia speciosa*, Hall.	(rr)
47.	*Dalmanites Boothi* (Green), Hall.	(c)
48.	*Phacops rana* (Green), Hall.	(r)
49.	*Homalonotus DeKayi* (Green), Emm.	(rr)
50.	*Bellerophon Leda*, Hall.	(r)
51.	*Bellerophon acutilirata*, Hall.	(rr)
52.	*Cyrtolites* (*Cyrtonella*), sp.	(rr)
53.	*Pleurotomaria capillaria*, Con.	(r)
54.	*Loxonema delphicola*, Hall.	(a)
55.	*Coleolus tenuicinctum*, Hall.	(r)

56. *Tentaculites*, sp. (a single impression). (rr)
57. *Orthoceras*, sp. (fragments of two species). (r)
58. *Crinoid* stems. (rr)

XIX B[3]. Sherburne or Rexford falls, one mile east of Sherburne village. The foot of the falls is 133 feet by level above the railroad, or 1,175 feet A. T. The shales are coarser than those farther down the brook, quite blue, and alternate with blue sandstone, some of the strata of which are two feet thick. In the glen below the falls is a sulphur spring, and the place is well known locally as a picnic ground. The following species were here collected:

1. *Spirifer granulosus* (Con.), Hall and Clarke. (r)
2. *Spirifer fimbriatus* (Con.), Bill. (r)
3. *Spirifer mucronatus* (Con.), Bill. (rr)
4. *Spirifer Tullius*, Hall. (rr)
5. *Tropidoleptus carinatus* (Con.), Hall. (r)
6. *Orthis Vanuxemi*, Hall (?). (r)
7. *Orthothetes Chemungensis* (Con.), Hall and Clarke. (rr)
8. *Ambocœlia umbonata* (Con.), Hall. (c)
9. *Chonetes coronata* (Con.), Hall. (rr)
10. *Chonetes mucronata*, Hall. (rr)
11. *Chonetes setigera*, Hall. (rr)
12. *Chonetes scitula*, Hall. (rr)
13. *Palæoneilo constricta* (Con.), Hall. (rr)

XIX B[4]. Mad creek, just below the Sherburne reservoir at Harrisville, one and one-half miles east of Sherburne village. The lower dam at the top of these shales is about 240 feet above the railroad by surveyor's leveling, making the altitude of this locality about 1,282 feet A. T. The rocks are coarse, arenaceous Hamilton shales, alternating with shaly sandstones, and characteristic Hamilton fossils are abundant, as for example, *Spirifer granulosus* (Con.), Hall; *Tropidoleptus carinatus* (Con.), Hall; *Spirophyton velum* (Van.), Hall, mingled with some of the larger lamellibranchs. The rocks form a small fall just below the lower reservoir dam, and at its base finer shales occur. The coarse, shaly sandstones contain large numbers of perfect specimens of the *Spirophyton velum* (Van.), Hall, making an excellent locality for collecting specimens of this interesting fossil. The complete list is as follows:

1. *Spirifer granulosus* (Con.), Hall. (aa)
2. *Spirifer audaculus* (Con.), Hall.=*S. medialis*, H. (c)
3. *Spirifer mucronatus*, (Con.), Bill. (c)

4. *Tropidoleptus carinatus* (Con.), Hall. (a)
5. *Cyrtina Hamiltonensis*, Hall. (r)
6. *Grammysia arcuata*, (Con.), Hall. (rr)
7. *Grammysia bisulcata* (Con.), Hall. (rr)
8. *Crinoid* segments.
9. *Spirophyton velum* (Van.), Hall. (c)

XIX B[5]. On the south side of the highway and the south branch of Mad brook, opposite the reservoir, is the Swan quarry, which is only about ten feet higher than the top of the upper reservoir dam or some 273 feet above the railroad at the village, or 1,315 feet A. T. At the bottom of the quarry is a bluish sandstone from one and one-half to two feet thick, which has been quarried to some extent, capped by about eight feet of rather arenaceous shales that contain plenty of small Hamilton lamellibranchs. During a hasty search the following species were collected:

1. *Spirifer mucronatus* (Con.), Bill. (a)
2. *Liorhynchus multicosta*, Hall. (aa)
3. *Tropidoleptus carinatus* (Con.), Hall. (r)
4. *Spirifer Tullius*, Hall. (rr)

   The shell has distinctly the form of this species and near the front of the valves are apparently traces of striae on the plications. There are several very small specimens of *Spirifer* which may possibly belong to this species.

5. *Palæoneilo constricta* (Con.), Hall. (r)
6. *Nucula lirata* (Con.), Hall. (c)
7. *Nucula bellistriata* (Con.), Hall. (rr)
8. *Nuculites triqueter*, Con. (rr)
9. *Palæoneilo emarginata* (Con.), Hall. (rr)
10. *Phthonia cylindrica*, Hall. (rr)
11. *Modiomorpha mytiloides* (Con.), Hall (?). (rr)

   The striae are of this species but the shape at the anterior end is nearer that of *M. concentrica* (Con.), Hall.

12. *Liopteria DeKayi*, Hall (?). (rr)
13. *Orthothetes Chemungensis* (Con.), Hall and Clarke, var. *perversa*, Hall. (rr)
14. *Grammysia (Sphenomya) cuneata*, Hall. (rr)

   Crushed specimen agreeing closely with the description of this species.

XIX B[6]. Above the Swan quarry is a steep hill with but few outcrops. On the highway up this hill, at an elevation of 170 feet above the Swan quarry, is a clear outcrop of the Sherburne flagstones, but these thin sandstones appear lower on the highway, and it is probable that the Swan quarry is near the top of the Hamilton formation.

XIX B[7]. Along a small run on the western side of the highway, near the brow of the hill, are shales. This outcrop is barometrically 252 feet above the base of the Swan quarry or approximately 1,567 feet A. T. Fossils are rare with the exception of *Liorhynchus mesacostalis*, Hall, fourteen specimens of which were collected. The list is as follows:

1. *Liorhynchus mesacostalis*, Hall. (a)
2. *Chonetes setigera*, Hall (?). (rr)
   Imperfectly preserved.
3. *Nucula corbuliformis*, Hall (?). (rr)
   Very imperfect specimen.
4. *Crinoid* segments. (r)

This outcrop probably contains the first of the Ithaca fauna, though it is lower than its appearance in force, and below it are perhaps some 240 feet of shales and sandstones of the Sherburne formation.

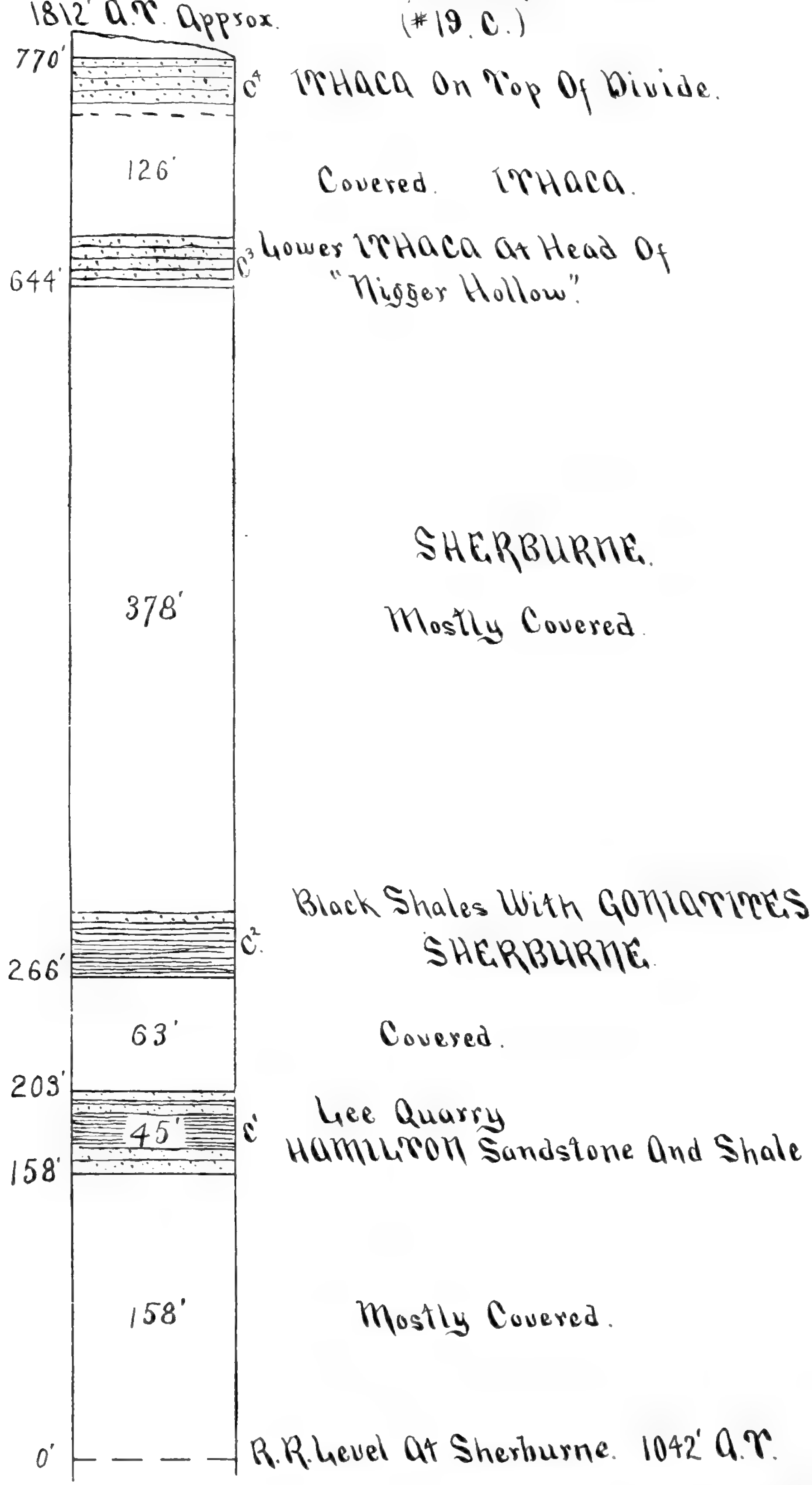
XIX G[1]. Section along a small stream and up a steep hill about three-fourths of a mile southeast of Sherburne village and some twenty-five feet above the railroad. In the stream are arenaceous blocky shales in which Hamilton fossils are abundant, especially small *Chonetes*.

XIX G[2]. About fifty-five feet higher, near the foot of the steep hill, are coarser shales. The fossils are not so abundant as in G[1], but the species are larger, as for example, *Spirifer granulosus* (Con.), Hall.

XIX G[3]. Above comes the steep slope of the hill, completely covered by soil to near the brow on the western side, 440 feet above G[2], where occurs a ledge composed of coarse arenaceous shales alternating with thin blue flagstones. Some of the thin layers contain a few fossils, as *Liorhynchus mesacostalis*, Hall; *Atrypa reticularis* (Lin.), Dalm.; *Palæoneilo emarginata* (Con.), Hall; *Paracyclas lirata* (Con.), Hall; *Orthis*, sp.; *Spirifer*, sp., and a few others. This ledge is in the lower part of the Ithaca formation and barometrically 520 feet above the railroad, or at an approximate altitude of 1,582 feet A. T.

XIX C[1]. One and one-half miles south of Sherburne village, Nigger brook enters the Chenango river from the east. For two miles its course is almost directly west, and it has cut a deep valley bordered by steep sides

SECTION OF "NIGGER HOLLOW" CREEK, IN S.E. SHERBURNE.



through the elevated tract of land which follows the eastern side of the Chenango river for some miles. Locally, the narrow part of this valley is known as "Nigger Hollow." Up this valley, one and one-quarter miles from the river road and in a straight line about two and one-half miles southeast of Sherburne village, is the Lee quarry which was formerly worked for a blue sandstone at its bottom, and above this are blue argillaceous shales containing abundant Hamilton fossils. This quarry is undoubtedly in the upper part of the Hamilton formation as may be inferred from the accompanying list of fossils from the blue shales on top of the sandstone:

1. *Spirifer mucronatus* (Con.), Bill. (c)
   Normal Hamilton type.
2. *Spirifer Tullius*, Hall. (rr)
3. *Liorhynchus multicosta*, Hall. (c)
   Some of the small specimens show scarcely any plications on the sides of the shell, yet they are nearer in general appearance to this species than to *L. mesacostalis*, H.
4. *Orthis Vanuxemi*, Hall. (rr)
5. *Athyris spiriferoides* (Eaton), Hall. (rr)
6. *Nucleospira concinna*, Hall (?). (rr)
7. *Modiomorpha concentrica* (Con.), Hall. (rr)
8. *Modiomorpha mytiloides* (Con.), Hall. (rr)
9. *Modiomorpha subalata* (Con.), Hall (?). (rr)
10. *Palæoneilo constricta* (Con.), Hall. (rr)
11. *Nucula corbuliformis*, Hall. (rr)
12. *Chonetes mucronata*, Hall (?). (rr)
13. *Grammysia bisulcata* (Con.), Hall. (rr)
14. *Tellinopsis subemarginata* (Con.), Hall. (rr)
15. *Bellerophon acutilira*, Hall. (r)
16. *Orthoceras*, sp. (fragment). (rr)

This quarry is barometrically 158 feet above the railroad at Sherburne. The Hamilton shales continue at least forty-five feet higher than at the Lee quarry, as may be seen in an outcrop of fine shales having the characteristic lithologic appearance and fossils, by the side of the road that crosses Nigger brook just below the forks. This outcrop is 203 feet above the railroad and has an approximate altitude of 1,245 feet A. T., and the rocks are near the top of the Hamilton formation as the description of those overlying will indicate. The locality is one and four-tenths miles due south of the Swan quarry which is regarded as near the top of the Hamilton formation on the northern side of this hill; and if this exposure at the creek be at about the top of the Hamilton, we would have a dip of fifty feet per mile to the south.

*XIX C*². About sixty-three feet above the Hamilton shales at the fork of Nigger brook, on its south branch on the Ertz farm, are blackish shales. This locality is hardly one mile above the Lee quarry, and barometrically 108 feet higher. The rocks which are well exposed along the bed and side of the brook are even-layered argillaceous shales, part of which are decidedly blackish in color. The shales contain a few fossils, the following species having been obtained:

1. *Glyptocardia speciosa*, Hall. (r)
2. *Leptodesma Rogersi*, Hall. (r)
3. *Coleolus aciculum*, Hall (?). (c)
   Slender tapering specimens without surface markings, and very near the figures of this species.
4. *Orthoceras* cf. *subulatum*, Hall (?). (r)
5. *Goniatites* cf. *discoideus*, Hall. (c)
   Very imperfectly preserved.

These shales are considered to belong in the Sherburne formation, and in lithologic characters are quite similar to the darker shales of the Portage formation in western New York.

*XIX C*³. Along the south branch of Nigger brook are but few outcrops of any importance after passing the black shales of the Ertz farm. However, at the head of the valley, two and eight-tenths miles east of the river road and 378 feet above the black shales of C², is a ledge of thin shaly sandstones on the G. S. Sherdin farm. These shaly sandstones form a ledge on the south side of the highway and contain a considerable number of fossils. *Spirifer mesastrialis*, Hall, is common, several specimens preserving the external surface of the shell and showing clearly the markings of the fine striae which characterize this species. Two specimens are very broad, like that shown in figure 18, plate XL, Vol. IV of the Palæontology of New York, and there can be no doubt as to the correctness of the identification of this species. Professor Clarke has suggested that the appearance of the above species is evidence of a change from the Hamilton to the Ithaca formation.[1] I would also state that this species is generally above the first species of this fauna, and is not present until the Ithaca fauna is fairly well represented. A search of twenty minutes in these thin sandstones furnished the following:

[1] Thirteenth Annual Report State Geologist [New York], p. 554.

1. *Spirifer mesastrialis*, Hall. (c)

    Several specimens of the exterior clearly show the striae, so there can be no doubt as to the species.

2. *Spirifer mucronatus*, Hall. (c)

    These specimens are small and mucronate with few plications. In the interior of one is a small septum showing the beginning of that character. These are like many of the Ithaca specimens, and probably it would be better to call them varieties of this species.

3. *Spirifer granulosus* (Con.), Hall and Clarke. (rr)

    Two external impressions which have distinct pits that must have been made by pustules, and the impression of the dorsal valve shows a small furrow along the center of the fold.

4. *Cyrtina Hamiltonensis*, H. (?). (rr)

    Broken and poorly preserved specimen.

5. *Chonetes scitula*, H. (a)
6. *Chonetes setigera*, Hall. (c)

    Smaller specimens with fewer and coarser striae having form of this species and spines at the same angle from the hinge line.

7. *Rhynchonella* (*Camarotœchia*) *Stevensi*, Hall. (c)

    Two or three specimens approach the *R.* (*C.*) *eximia* type.

8. *Tropidoleptus carinatus* (Con.), Hall. (r)
9. *Atrypa reticularis* (Lin.), Dalm. (r)
10. *Stropheodonta perplana* (Con.), Hall (?). (rr)

    Poorly preserved.

11. *Orthis*, sp. (rr)

    Not poorly preserved but apparently nearer in form to *O. Vanuxemi*, H., than to *O. impressa*, H.

12. *Palæoneilo emarginata* (Con.), Hall. (rr)
13. *Modiomorpha mytiloides* (Con.), Hall. (rr)
14. *Modiomorpha concentrica* (Con.), Hall. (rr)
15. *Paracyclas lirata* (Con.), Hall. (rr)
16. *Palæoneilo constricta* (Con.), Hall. (rr)

From the above fauna this ledge is referred to the Ithaca formation, but it is probably fully 100 feet above its base. The approximate altitude of the ledge is 1,686 feet A. T., and the altitude of the lowest Ithaca fossils on the top of the hill above the Swan quarry is 1,544 feet. This locality is two miles southeast of Swan hill, so that, making an allowance for dip, it is probable that C^3 is nearer 150 than 100 feet above the base of the Ithaca formation.

XIX C⁴. One mile farther east, in the southwestern corner of Columbus, rocks are seen by the side of the road. This place is on top of the divide between the Chenango and Unadilla rivers, from which a beautiful view of the surrounding country may be obtained. These rocks are the highest of this region, by the barometer 126 feet higher than C^3, 567 feet above the Hamilton at the Nigger brook crossing, and 770 feet above the railroad in Sherburne village, giving an approximate altitude of 1,812 feet A. T. They consist of micaceous and arenaceous shales and shaly sandstones, part of the layers containing plenty of fossils, and others scarcely any except an occasional lamellibranch. The following species were collected in fifteen minutes:

1. *Spirifer mucronatus* (Con.), Bill. var. *posterus*, Hall and Clarke. (aa)

   These specimens in general seem to be like figures 28 and 30, (plate XXXIV, Palaeontology of New York, Vol. VIII., Brachiopoda II.) of this variety, although some might possibly be referred to the species itself. The internal impressions in the umbonal region of two or three specimens show a small groove which looks as though they might have possessed a small septum and these should be compared with *Sp. mesacostalis*, although I have seen *Sp. mucronatus* with a septum in the Hamilton (Moscow) shales of Cayuga lake.

2. *Spirifer granulosus* (Con.), Hall (?). (rr)

   Part of an external impression that shows very clearly the impressions of pustules.

3. *Liorhynchus mesacostalis*, Hall. (rr)
4. *Paracyclas lirata* (Con.), Hall. (rr)
5. *Nucula corbuliformis*, Hall. (rr)
6. *Palaeoneilo* cf. *filosa* (Con.), Hall. (r)

   Impressions that do not preserve any of the surface markings except near the outline of the species.

7. *Modiomorpha* cf. *subalata* (Con.), Hall, var. *Chemungensis*, Hall. (rr)
8. *Leptodesma Rogersi*, Hall (?). (r)
9. *Actinopteria perstrialis*, Hall. (rr)
10. *Schizodus* cf. *appressus* (Con.), Hall. (rr)

   The upper 300 feet of this ridge, which includes the highest rocks of the divide, belong in the Ithaca formation.

North Norwich.

XL A[1]. The next township south of Sherburne is North Norwich, in the northwestern portion of which is a steep and high hill, known locally as Pratt's mountain. On its eastern side is the Chenango river, and on the western the Fly brook valley, which is followed by the Delaware, Lackawanna and Western railroad from the North Norwich station to Sherburne village. On the eastern side of the hill, two and four-tenths miles south of Sherburne, and immediately above the lock on the abandoned Chenango valley canal, are rather coarse, arenaceous shales in which Hamilton fossils are common. This exposure is about on a level with the station in Sherburne.

XL A[2]. This part of the hill side is very steep, and near its top, 345 feet above the canal, is a ledge composed of thin arenaceous shales alternating with thin sandstones, an inch or more in thickness. Fossils are very rare, only a few specimens of *Liorhynchus* being found. The outcrop is probably in the Sherburne formation, although not far from the base of the Ithaca, and it has an approximate altitude of 1,387 feet A. T.

XL B[1]. The southern end of Pratt's mountain is about one-half mile north of the village of North Norwich, and near the brow of the hill are coarse, arenaceous shales that split into thin, somewhat even pieces. Fossils are very rare, an occasional *Liorhynchus* and *Spirifer* with fragments of plant stems constituting all that were found. This is probably the base of the Ithaca formation. The New York, Ontario and Western railroad station at North Norwich is 1,005 feet A. T., but probable inaccuracy in the readings of the barometer on account of rain gave this ledge as 265 feet higher than the station, which would indicate an altitude of 1,270 feet A. T.

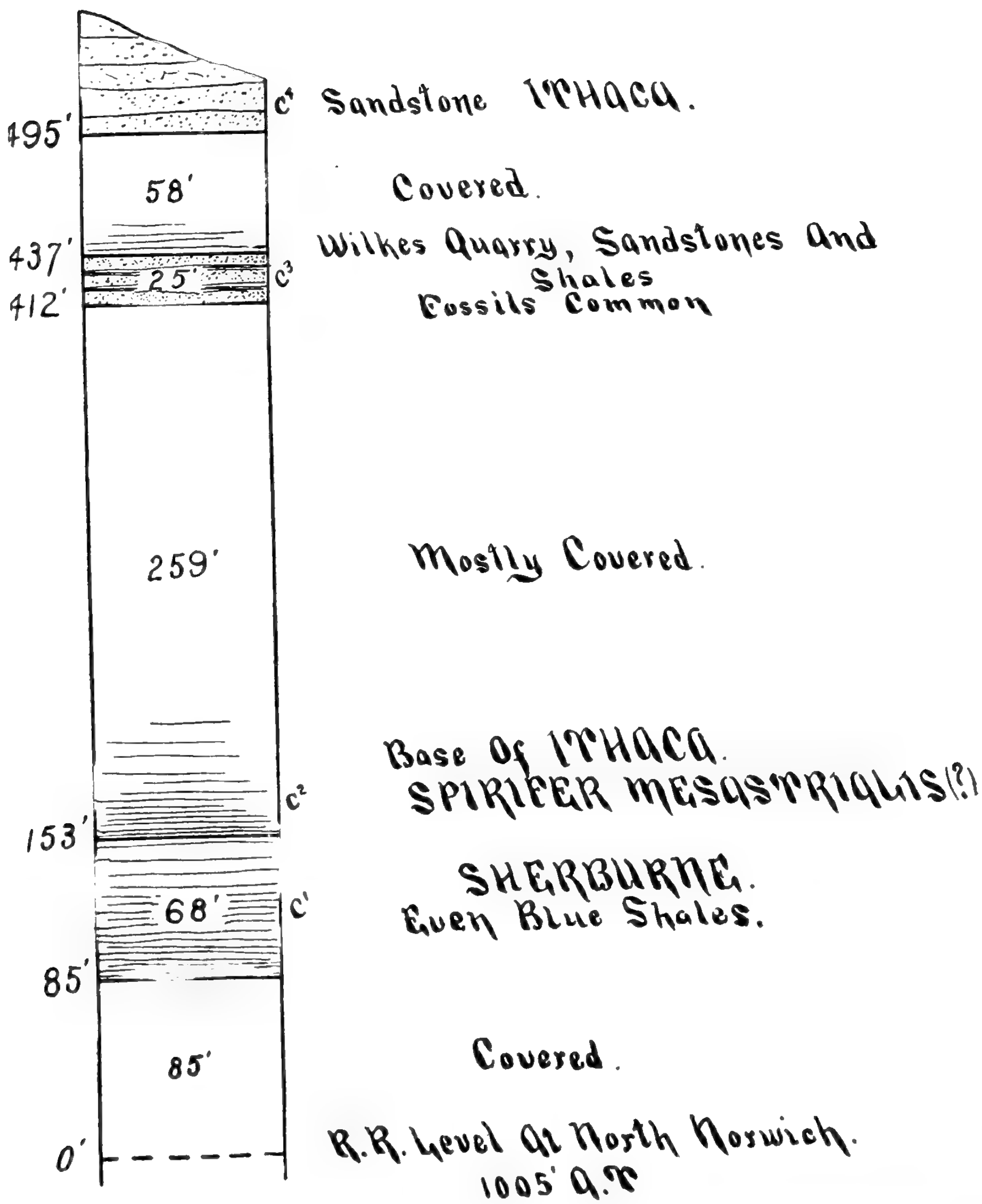
XL C[1]. Along Cold brook, about one mile southwest of North Norwich, are bluish arenaceous shales that split into regular pieces of uniform thickness. No fossils were found except fragments of plant stems. The first exposure of these shales was at eighty-five feet above the station, and they continue with practically the same characters for 153 feet and belong in the Sherburne formation.

XL C[2]. Along a small stream that enters Cold brook from the west are rocky cliffs, and at an elevation of 153 feet above the railroad, or approximately 1,158 feet A. T., is a layer, about two inches thick, containing fossils, mostly brachiopods, as *Liorhynchus mesacostalis*, Hall; *Spirifer mesastrialis*, Hall (?); *Spirifer mucronatus* (Con.), Bill. (Ithaca variety); *Cyrtina Hamiltonensis*, Hall; *Nucula* sp. and Crinoid stems. This exposure is clearly the first of the Ithaca fauna, and may be considered the base of the Ithaca forma-

COLD BROOK SECTION, SOUTH WEST OF NORTH NORWICH.

(#40. C.)

1500' A.T. Approx.



tion which, on top of the high hill southwest of Smyrna village, is seven miles northwest of this locality. The approximate altitude of the Smyrna locality above sea level is 1,620 feet, and that at North Norwich is 1,158 feet, making a dip of sixty-six feet per mile to the southeast between these two localities, which is greater than had been given in previous estimates.

*XL C*³. About one and one-half miles southwest of North Norwich, in the edge of Plymouth township, is the Horace Wilkes quarry which, fifty years ago, was worked under the name of the Harris quarry. It is about 412 feet above the railroad, or 1,417 feet A. T. The back of the quarry shows about twenty-five feet of blue sandstones alternating with shales. A small amount of the stone is quarried for flagging, but most of it for building purposes. The sandstone contains specimens of *Spirophyton velum*, Van., of large size, and other fossils are common. The list is as follows:

1. *Spirifer mucronatus* (Con.), Bill. (c)
2. *Atrypa reticularis* (Linné), Dalm. (cc)
3. *Liorhynchus mesacostalis*, Hall. (c)
4. *Chonetes scitula*, Hall (?). (a)

    This species is abundant, but in the condition of impressions which renders identification difficult. Some of the specimens approach *C. setigera*, Hall, in form, though they are not so convex near the umbo as those found at Ithaca.

5. *Chonetes lepida*. Hall. (rr)
6. *Cyrtina Hamiltonensis*, Hall. (rr)
7. *Stropheodonta* sp. (rr)

    Two imperfect impressions which are similar to *S. perplana* (Con.), Hall.

8. *Productella*, sp. (c)
9. *Microdon* (*Cypricardella*) *bellistriatus* (Con.), Hall, or *M. tenuistriatus*, Hall. (rr)

    A single specimen that has the proportions of *M. bellistriatus*, as well as those of the elongated form of *M. tenuistriatus*, Hall (see plate 73, figure 28, Palaeontology of N. Y., Vol. V., Part I.). It is impossible to determine whether the specimen has the fine striae of *M. tenuistriatus* or the coarse striae of *M. bellistriatus*.

10. *Paracyclas lirata*, (Con.), Hall. (rr)
11. *Cimitaria recurva* (Con.), Hall. (r)
12. *Palæoneilo emarginata* (Con.), Hall. (rr)
13. *Goniophora carinata* (Con.), Hall (?). (r)

This species is reported from Copley's quarry at Oneonta.[1] A comparison of specimens from the two localities fails to prove them precisely similar; but the North Norwich specimens are nearer this species than any of the others figured in this work.

14. *Modiomorpha*, sp. (a broken specimen). (rr)
15. *Glossites depressus*, Hall. (rr)

A single specimen that apparently belongs to this genus and species.

16. *Palæoneilo constricta* (Con.), Hall. (rr)
17. *Orthis*, sp. (rr)
18. *Leptodesma* cf. *Rogersi*, Hall. (r)

These specimens do not have as mucronate ears as most of those figured; but some of them resemble closely the one figured on plate 21, figure 9 (Palaeontology of New York, Vol. V., Part I., Lamell. I.), which is stated to be from the Hamilton shales at Norwich, N. Y.

19. *Orthothetes Chemungensis* (Con.), Hall. (r)
20. *Actinopteria Boydi* (Con.), Hall. (rr)
21. *Phacops rana* (Green), Hall. (rr)
22. *Spirophyton*, sp.

The quarry is of course in the Ithaca formation, and some 260 feet above its base. Vanuxem mentioned the quarry, referring the rocks to the Ithaca group and called it the second best locality for the "*Fucoides velum*, or *Curtain fucoid*" = *Spirophyton*, and stated that "fossils are somewhat numerous."[2]

XL C[4]. On top of the hill, above the Wilkes quarry to the west of Cold brook, is an outcrop of sandstone in the South Plymouth road, which is, perhaps, 495 feet above the North Norwich railroad station, making its altitude approximately 1,500 feet A. T. The sandstone weathers to a brownish color, contains large numbers of Spirifers, and is in the Ithaca formation, which gives a thickness of 340 feet to this formation in the hill southwest of North Norwich.

Norwich.

XXXV C[1]. South of North Norwich is Norwich township which has been carefully described by J. M. Clarke,[3] and those interested in the geology of the Chenango valley are referred to that report for the description of this

[1] Palaeontology of New York, Vol. V., Part I., Lamell. II., p. 302; see plate 44, figure 7, for figure of form similar to the North Norwich specimen.

[2] Geology of New York, Part III., 1842, pp. 178, 293.

[3] Thirteenth Annual Report State Geologist [New York], pp. 533–539.

township as well as those of Oxford and Greene to the south. A few localities were studied by the writer that are not mentioned by Clarke, and a brief description of them may add something to our knowledge of the geology of the township.

About one-quarter of a mile north of the Delaware, Lackawanna and Western railroad station in Norwich village, is a railroad cut through bluish shales and shaly sandstones. The base of the cut is not more than ten or fifteen feet higher than the railroad station, which is given as 1,001 feet A. T.[1] Fully five feet of rocks in which fossils are common, are exposed in the cut, some of the layers containing large numbers of *Liorhynchus mesacostalis*, Hall; *Chonetes setigera*, Hall, and *Spirifer mucronatus* (Con.), Bill. The following species were collected:

1. *Liorhynchus mesacostalis*, Hall. (aa)
2. *Chonetes scitula*, Hall. (a)
3. *Chonetes setigera*, Hall. (aa)

   This narrower species with the smaller number of striae is by far the most abundant specimen from the railroad cut. Some of the specimens show a tendency towards *C. lepida*, Hall, in the character of two stronger striae near the center of the shell and finer ones between them.

4. *Spirifer mucronatus* (Con.), Bill. (aa)

   These specimens agree fairly well with figures of this species, as figures 1, 4, 19 and 20 of plate 34 (Palaeontology of New York, Vol. IV.), and are undoubtedly the same as the forms listed by Clarke from Norwich as this species (Thirteenth Annual Report, p. 533, etc.); but there are specimens from Ithaca that are difficult to separate from some of these. There are both mucronate and rounded forms.

5. *Spirifer granulosus* (Con.), H. and C. (?). (rr)

   One impression which shows very clearly the numerous pittings produced by the pustules.

6. *Atrypa reticularis* (Linné), Dalm. (rr)
7. *Tropidoleptus carinatus* (Con.), Hall. (c)
8. *Productella*, sp. (c)

   Poorly preserved and broken specimens, possibly nearer *P. dumosa*, H., than *P. speciosa*, H.

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[1] The profile of the New York, Ontario and Western railroad gives the Norwich station as 987 feet A. T., and it seems hardly possible that there is a difference of fourteen feet between the two railroad stations in the village.

9. *Stropheodonta*, sp. (r)

I have compared these with *S. mucronata*, (Con.), H., and *S. perplana* (Con.), H., without coming to a decision as to their specific character. They seem to be rather too convex for the former and too much variation in the size of the striae for the latter.

10. *Palæoneilo fecunda*, Hall. (rr)

The specimen seems to be nearer to this species than to *P. filosa* (Con.), Hall. The geatest length is not on the hinge line.

11. *Cyrtina Hamiltonensis*, Hall. (rr)

This locality is, of course, in the Ithaca formation and some distance above its base.

XXXV A[1]. Clarke described an interesting section on the western side of Canasawacta creek along the road northwest from Norwich toward Preston,[1] and the writer studied one beginning on the Canasawacta creek in the western part of the village, and following the road up the steep hill directly west. This hill affords a section of 550 feet, and on account of its close agreement with the one described by Clarke, it is considered sufficiently interesting to merit a description. On the bank of Canasawacta creek, immediately below the bridge at the western side of the village, are thin, irregular sandstones and coarse, arenaceous shales. Some clay pebbles are found in the rocks. Fossils are common in some of the layers, as *Tropidoleptus carinatus* (Con.), Hall; *Chonetes scitula*, Hall; *Spirifer mesastrialis*, Hall (?); *Rhynchonella* sp., and lamellibranchs. This outcrop is sixteen feet below the highway bridge, or approximately 985 feet A. T., and is in the Ithaca formation, though somewhat above its base. The base of the Ithaca formation on the branch of Cold brook, one mile southwest of North Norwich is five and four-tenths miles north of the above locality, with an altitude of 1,158 feet A. T., which indicates that the dip between these two places is greater than thirty-two feet to the mile; how much greater is not known, as the base of the Ithaca formation has not been noted in the vicinity of Norwich.

XXXV A[2]. This is an old quarry a little beyond the forks in the road and 155 feet above the creek level, in which forty feet of rocks are exposed, consisting of blue sandstones alternating with shales, some of the layers containing clay pebbles. The sandstones are of irregular thickness, some of them about two feet thick but generally much thinner. Fossils in general are not numerous though some layers are composed largely of a few species forming what might be called a firestone. The most abundant fossils are: *Paracyclas*

[1] Thirteenth Annual Report State Geologist [New York], pp. 534-539, with section on p. 538.

lirata (Con.), Hall; *Chonetes scitula*, Hall; *Atrypa reticularis* (Lin.), Dalm.; *Palæoneilo maxima* (Con.), Hall; and *Spirifer*, sp. The top of this quarry is 208 feet above the creek level, which brings it in an approximate horizon with stations B and B_1, described by Clarke,[1] who gave a list of nineteen species. For about eighteen feet the rocks are covered and then arenaceous and rather smooth shales that weather to a greenish tint are exposed by the roadside. The base of these shales is 226 feet above the creek and they show a thickness of nineteen feet on the road. At 239 feet above the creek in thin blocky shales a few fossils were found, *Paracyclas lirata* (Con.), Hall, and *Microdon* (*Cypricardella*) *bellistriatus* (Con.), Hall. In a thin sandstone layer are plenty of crinoid segments. These were the last fossils noted until the red and grey rocks were reached above at an elevation of 491 feet.

*XXXV A*³ is used to designate the shales and rather coarse sandstones after fossils become very rare. At 277 feet above the creek are very fine, smooth and micaceous shales that break up into small pieces about an inch square. At 386 feet rather coarse-grained sandstones begin to appear.

*XXXV A*⁴. These coarse sandstones with a little shale continue to an elevation of 426 feet where a stratum of concretionary coarse-grained sandstone weathering to a greenish tint, crosses the road, below which are thin shales without fossils. Fifty feet higher a prominent, coarse-grained grey sandstone crosses the road.

*XXXV A*⁵. At 491 feet above the creek level is the first outcrop of red argillaceous shale, below which is fissile, argillaceous, olive shale. About three feet above the base of the red shale is a slightly calcareous layer that contains clay pebbles with flat, black fish scales and fragments of fish bones. The red shales were not noticed on the road section above 517 feet. It is interesting to note that Clarke described an outcrop of "about three feet of soft red and green sandy shales with minute fish bones and entomostraca" on the Norwich-Preston road about one mile northwest of this locality.[2] The altitude of this red shale above the river level is, according to Clarke, 495 feet. This agrees very closely with that of the fossiliferous red shale described by the writer at an altitude of 491 feet above the level of Canasawacta creek, which can differ but slightly from the river level at this locality.

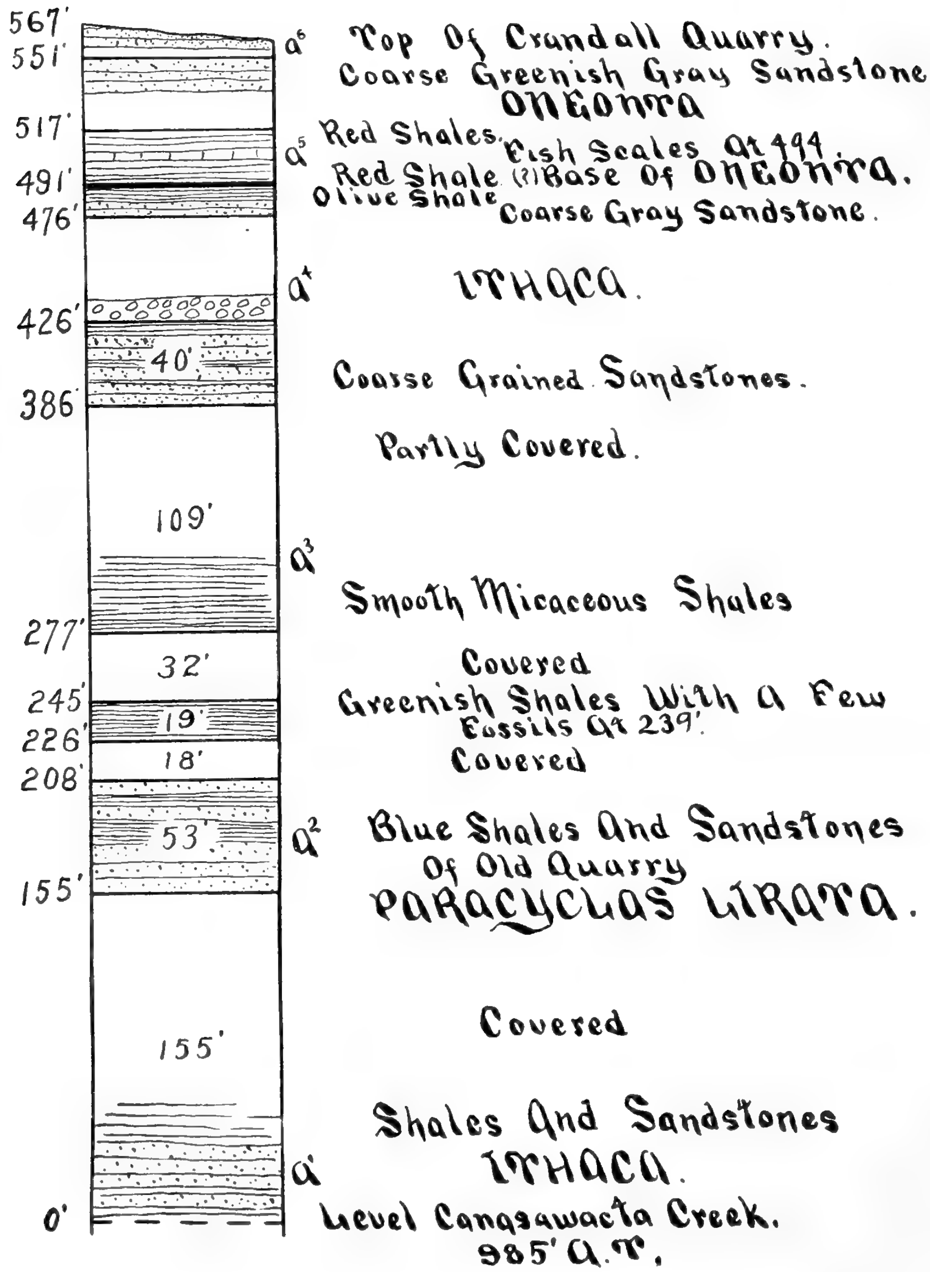
*XXXV A*⁶. Near the brow of the hill is the Crandall quarry, no longer worked, the top of which is 551 feet above the creek level, or approximately 1,536 feet A. T. The rock is a coarse-grained, greenish-grey sandstone, whose

[1] Thirteenth Annual Report State Geologist [New York], pp. 534 and 535.
[2] *Ibid.*, p. 536.

SECTION WEST OF NORWICH.

(*35. Q.)

1552' A.T. Approx.



layers are separated by shales. One layer in the upper part of the quarry is two feet thick, and another near the bottom is a finer-grained stone twenty-seven inches in thickness. Similar greenish-grey sandstones continue to the top of the hill some fifteen feet higher, 567 feet above the creek level or approximately 1,557 feet A. T. Below the base of the red shales, 491 feet above the creek, in the above section, fossils are very rare for a thickness of 252 feet, in that portion of the section that is indicated as A^4 and A^3. Professor Clarke observed that in the Crandall quarry, the base of which is 465 feet above the river, "fossils are exceedingly and remarkably rare throughout," but he was fortunate in finding a few in one of the flagstones, and they are here listed: "*Palæoneilo emarginata*, small form; *Nuculites lirata*, small form, and *Leda diversa*. After a long search the soft green shales produced a single specimen of a small *Orthoceras* or *Coleolus*."[1] This outcrop is less than twenty-five feet below the fossiliferous red shale. These sections show very clearly the gradual transition from the fossiliferous blue shales and sandstones of the Ithaca formation to the coarser greenish-grey sandstones and argillaceous red and green shales of the Oneonta formation, the conditions of which were unfavorable to marine life. Farther east these conditions began at an earlier period so that it is almost impossible to draw a synchronous line of separation between the Ithaca and Oneonta formations when followed from the Chenango valley eastward into Schoharie and Albany counties.

The first heavy greenish-grey sandstones have been considered the base of the Oneonta formation by some geologists, while others have placed the lowest red shales there. It seems probable that in either case the line will be a somewhat variable one. Apparently Clarke considered the base of this formation defined by the "light grey-green sandstone" of the Hale quarry,[2] northwest of Norwich, which is 510 feet above the river level. Possibly it might be as well to regard the red shales with the fossil fish remains eighteen feet lower as the base, although, as previously stated, the line will vary in position when followed for some distance. If these red shales are called the base of the Oneonta formation, then in the high hill west of Norwich and the Canasawacta creek, the Ithaca formation has a thickness of 490 feet, showing its entire thickness to be greater than 500 feet for the Chenango valley. It is to be recalled that a thickness of 450 feet has been assigned to the rocks of the latter formation in the vicinity of Ithaca.[3]

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[1] Thirteenth Annual Report State Geologist [New York], p. 536.

[2] *Ibid.*, p. 536, 537. Darton states that in Albany county he assumed the base of the Oneonta formation to be "at the bottom of the lowest red shale member;" *ibid.*, p. 240.

[3] Transactions American Institute of Mining Engineers, Vol. XVI., p. 945.

XXXV B[1]. Quarry three miles northwest of Norwich, in the southeastern corner of Plymouth, and on the western side of the Canasawacta creek above the former DeRuyter branch of the New York, Ontario and Western railroad. This quarry is in the Ithaca formation and is between ninety and one hundred feet higher than the Norwich railroad station. About twenty feet of blue sandstone and shales are exposed. Fossils are common in the lower layers, but few were seen in the upper part of the quarry. *Tropidoleptus carinatus* (Con.), Hall; *Spirifer mucronatus* (Con.), Bill.; *Liorhynchus mesacostalis*, Hall; *Productella*, sp.; *Palæoneilo*, sp., and some other species are common. A church in Norwich was built of stone from this quarry.

XXXV D[1]. The lowest rocks in Ransford creek, about one and one-quarter miles northeast of Norwich and some forty feet above the railroad station, consist of thin blue sandstones and shales. *Liorhynchus mesacostalis*, Hall, and *Spirifer mucronatus* (Con.), Bill., are abundant. A little farther up the creek is a quarry in blue sandstone alternating with shales. There is no flagging, and the stone is used for building purposes only. Fossils are quite common, *Tropidoleptus carinatus* (Con.), Hall, and *Productella*, sp., are most abundant. One good specimen of *Cimitaria recurva* (Con.), Hall, was found.

XXXV D[2]. On Ransford creek, two miles northeast of Norwich, is the reservoir, the top of the dam being 160 feet above the railroad station, or 1,160 feet A. T. In the creek, just below the dam, are shales and sandstones which in places contain abundant fossils, especially *Liorhynchus mesacostalis*, Hall; *Paracyclas lirata* (Con.), Hall; *Spirifer*, sp., and *Rhynchonella*, sp. Above this locality, at about the same level as the dam, is a quarry that was opened when the reservoir was built. The rocks are blue shales and sandstones in which fossils are common, *Chonetes* and *Spirifer* being the most numerous. These exposures described along Ransford creek are in the strongly fossiliferous portion of the Ithaca formation.

All the recent writers in describing the geology of the Norwich region have noted the great similarity between the fauna of the Ithaca, as exposed in the Chenango valley, and that of the Hamilton formation. Professor H. S. Williams, in 1886, stated that "the fauna A[1] [which he called the *Paracyclas lirata* stage of the Hamilton faunas occurring above the horizon of the Genesee shale], underlying the greys which initiate and terminate the reds [the Oneonta formation] was composed of Hamilton species with scarcely any exception—that is, species that are known to occur below the second black Devonian shale."[1]

The writer referred to this fact in 1893,[2] and Clarke, in 1894, stated it very clearly. In describing the faunas near Norwich, Clarke wrote: "If, however, there exists a palpable difference between the faunas at B and B_1 [quarries one mile northwest of Norwich], and that of the typical upper Hamilton shales in regions where the Tully limestone is present, they may be reduced to the existence in the former of *Actinopteria zeta*, and the not infrequent occurrence of *Spirifer mesastrialis*;"[3] and again "the predominant traits of the fauna are Hamilton; its extra-Hamilton species are rare, especially in the lower parts of the series."[4]

As will be seen from the above statement, the rocks near Norwich contain a considerable number of species that occur in the Hamilton formation, but have not yet been reported from the Ithaca formation as exposed at its typical locality, Ithaca. Since this fauna is more decidedly Hamilton than the typical Ithaca, which is the general condition at least from the Chenango valley eastward, the question may arise whether eventually it may not be better to designate this formation by a name that will refer to a locality at which the faunal and stratigraphic conditions are more nearly representative for the eastern and greater extent of the formation.

While considering this portion of the Chenango valley section it is important to remember that in most of the recent papers relating to the geology of this valley, the Sherburne formation has been overlooked. As described above in Nigger brook, in the southern part of Sherburne township (XIX C^2), in the lower part of the Sherburne formation is a *Goniatites* fauna that is probably an eastern extension of the *Cephalopod* stage (C^1) described by Dr. H. S. Williams as occurring in the lower Portage.[5] The writer called attention to this formation in 1887,[6] although at that time, on account of insufficient data, its thickness was underestimated, and again in 1893.[7] The Sherburne formation in the Chenango valley is 250 feet in thickness and the Ithaca formation at least 500 feet, making a total thickness, for the rocks, from the top of the Hamilton formation to the base of the Oneonta, of more than 750 feet. This gives a thickness of some 1,250 feet for the Sherburne,

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1 Proceedings American Association for the Advancement of Science, Vol. XXXIV., p. 229; also see the plate of "Meridional sections of the Upper Devonian deposits of New York, Pennsylvania and Ohio," section IX.

2 American Journal of Science, Third series, Vol. XLVI., p. 225.

3 Thirteenth Annual Report State Geologist [New York], p. 535.

4 *Ibid.*, p. 554.

5 Proceedings American Association Advancement of Science, Vol. XXXVI., p. 226.

6 *Ibid.*, p. 210.

7 American Journal of Science, Third Series, Vol. XLVI., pp. 221, 222, 224.

Ithaca and Oneonta formations of the Chenango valley, which is only fifty feet less than the thickness of the lower Portage, Ithaca and upper Portage in the vicinity of Ithaca, consequently the position of the Oneonta formation is nearly in line with the upper Portage of the Ithaca section, and the Portage sandstones of the Naples and Genesee sections. Clarke has advanced this correlation and stated "that these Oneonta beds (including the barren grey sands and flags lying beneath the red and green shales and sands) are the eastern representative of the upper sandstones and flags originally designated by Professor Hall as the 'Portage sandstones,' and are hence the sedimentary equivalent of the typical Portage."[1]

Oxford.

Along the Chenango river valley to the southwest of Norwich is Oxford township. Except along the immediate valley of the Chenango river in the northern part of the township where the Ithaca formation occurs and in the southeastern part where the Chemung is found, the township is covered by rocks of the Oneonta formation, and its geology was so fully described by Professor Clarke in the Thirteenth Annual Report, that little remains to be said.

XLI A[1]. The farthest south that the Ithaca formation was noticed, is a characteristic outcrop of shales containing plenty of fossils along the side of Fly Meadow creek, near the highway one and one-half miles northeast of Oxford village.

XLI B[1]. Nearly three miles northeast of Oxford village in the northeastern corner of the township is Lyon brook, across which is the noted Lyon brook bridge of the New York, Ontario and Western railroad. The bridge is 161 feet above the bed of the stream, and has an altitude of 1,197 feet A. T. In the bed of the brook beneath the bridge, as well as north of the highway to the east of the bridge, are bluish shales, in which a few rather poorly preserved fossils occur. Small lamellibranchs are the most common. This locality was studied by Dr. C. E. Beecher, Dr. J. W. Hall, and Mr. C. E. Hall, who reported "*Spirifer mesastrialis, Paracyclas lirata,* and *Palæoneilo muta*" from these shales, which were stated to be "below the red shales which occur about two hundred feet higher in the series."[2] This outcrop is in the upper part of the fossiliferous portion of the Ithaca formation. On the south side of the brook and about sixty feet higher, a quarry

[1] Thirteenth Annual Report State Geologist [New York], p. 557. See also similar statement near the middle of p. 555 and the section on p. 556

[2] Fifth Annual Report State Geologist [New York], 1886, p. 11; see page 4 for credit.

in bluish-grey to buff sandstones was opened by Mr. Burns, but the stone did not prove valuable.

XLI B[2]. Still higher than the Burns quarry is one that was opened during the construction of the railroad and furnished stone for the abutments of the bridge. At the bottom of the railroad quarry are grey sandstones, then red sandstones that are capped by red shale. The red rocks are about thirty feet below the railroad track, or 1,167 feet A. T. If these reds correspond to the lowest reds in the hill west of Norwich, and they seem to have that position, then they will give the dip along almost a direct north and south line. The red shales west of Norwich are 1,476 feet A. T., and the distance between the two places four and eight-tenths miles, giving us a dip to the south of 64^+ feet per mile.

To the south of the bridge there are railroad cuts through coarse-grained, greenish-grey sandstones, alternating with red shales, which show clearly enough that these rocks are in the Oneonta formation. In these shales specimens of a fern—*Archæopteris* sp.—were found. Farther south, near the middle of a cut through the coarse grey sandstone, just north of the 218th New York mile post, are numerous fragments of plants, among which is *Lepidodendron Gaspianum*, Dn. In the same cut, specimens of the characteristic fossil of the Oneonta sandstone, *Amnigenia Catskillensis* (Van.), Hall, occur, and an unusually good specimen of *Holonema rugosa* (Claypole), Newb., was found. This specimen of a fossil fish has been described by Professors H. S. Williams,[1] Claypole[2] and Cope,[3] while the last edition of Dana's Manual of Geology contains a figure showing the restored ventral plates of the species.[4] In addition to the above species, *Leptodesma Rogersi*, Hall, was reported, probably from this cut.[5]

XLI C[1]. A railroad cut on the New York, Ontario and Western railroad, about two and one-half miles southeast of the Oxford station and one-quarter of a mile north of the 214th New York mile post. The cut is through red and greenish shales, alternating with thin grey sandstones. The dip is at least sixty feet to the mile, twenty degrees west of south. A layer of the nature of a conglomerate, containing an occasional quartz pebble, was noticed. Fucoidal markings occur in the grey sandstones, while in thin layers quite a number of fossil shells are preserved. The following species from this cut are listed in the Fifth Annual Report of the New York State Geologist:

[1] Proceedings American Association Advancement of Science, Vol. XXXIX., p. 337.
[2] American Geologist, Vol. VI., pp. 255–257.
[3] Proceedings United States National Museum, Vol. XIV., p. 456.
[4] Fourth edition, 1895, fig. 963 on p. 616; see also p. 618.
[5] Fifth Annual Report State Geologist [New York], p. 11, 2d paragraph.

"*Macrodon Hamiltoniæ*, *Actinopteria Boydi* (?), *Actinopteria* sp. (?), *Modiomorpha subalata* (?), *Leptodesma* sp., *Strophodonta perplana*."[1] The altitude of this cut, taken from the profile of the New York, Ontario and Western railroad, is approximately 1,560 feet A. T. This locality is three and one-half miles west of south of Lyon brook bridge, and the difference in altitude between the base of the red shale and this cut is 348 feet. If the dip for the distance is sixty feet per mile, then the thickness of the rocks is 558 feet, all of which may be regarded as belonging in the Oneonta formation.

XLI C². One-fourth mile southeast of Summit station, or five miles from Oxford station, is another railroad cut, through greenish and olive shales and sandstones, which reveals a thick concretionary stratum. Fossils are not uncommon in these rocks, the most abundant species being *Atrypa reticularis* (Lin.), Dal., while "*Productella hirsuta*, *Spirifer mesacostalis*, and other species" have been reported.[2] From the railroad profile the altitude is 1,616 feet A. T., or fifty-six feet higher than the cut at C¹, which is probably near the top of the Oneonta formation, for at C² no red or coarse greenish-grey rocks were seen, and the Summit beds have been referred to the "Lower Chemung group."[3]

The extensive stone quarries of the F. G. Clark Company, at Oxford, in which specimens of *Amnigenia Catskillensis* have been found, and the Miller quarry at South Oxford are both in the Oneonta formation, and were fully described by Clarke in the Thirteenth Annual Report, to which the reader is referred for an account of the excellent flagging stones of this formation.[4] The picture of the Clark quarry shows the massive character of this sandstone.

Greene.

To the southwest of Oxford is the township of Greene, which is crossed diagonally from the northeast to the southwest by the Chenango river. The Oneonta formation follows the river valley as far south as the village of Greene, but the remaining and greater portion of the township is covered by rocks which, on the new Geological Map of New York, are placed in the Chemung formation. The northern half of this township was fully described by Clarke,[5] who referred the greenish fossiliferous shales and sandstones overlying the Oneonta formation to the Chemung. Southeast of Greene

[1] *Loc. cit.*, p. 11, 3d paragraph.
[2] *Ibid.*, p. 11, 4th paragraph.
[3] *Ibid.*, and compare the section at the bottom of the page
[4] *Ibid.*, pp. 539–542.
[5] Thirteenth Annual Report State Geologist [New York], pp. 542–546

village is Juliand hill, whose summit is some 300 feet above the river level, and whose upper half is mainly composed of greenish argillaceous shales. Clarke, in describing this hill, stated that "fossils are abundant throughout these shales, and are of typical Chemung expression, viz:

Atrypa reticularis, large, rugose; common.
Orthis impressa, large form; abundant.
Liorhynchus globuliformis, common.
Spirifer mesacostalis.
Productella lachrymosa.
Stropheodonta perplana var. *nervosa*.
Cryptonella, sp."[1]

In the lower part of the greenish or Chemung rocks, near the northwestern corner of the corporation of Greene village, is a sandstone containing coarse quartz pebbles which, some years ago, the writer designated as the *Greene conglomerate*. This stratum contains fragments of fossil fish, as stated by Clarke, who writes that the lower part "contains *Holonema* cf. *rugosa*, Claypole, undetermined plates, scales and teeth."[2] In the same exposure, but a little higher, Clarke noted "fish remains common," and "*Lingula* cf. *Cuyahoga*, *Leptodesma* cf. *sociale* (single specimen)".[3] To the southwest of the village is the old Cameron quarry. The lowest rocks of this quarry contain scarcely any fossils except *Tentaculites* sp. and large Crinoid segments, while the shaly layers of the upper part of the exposure contain fossils, but of only a few species. This quarry was described by Vanuxem, who stated that it was the "only opening noticed in the hills at Greene," and referred it to the Chemung group.[4]

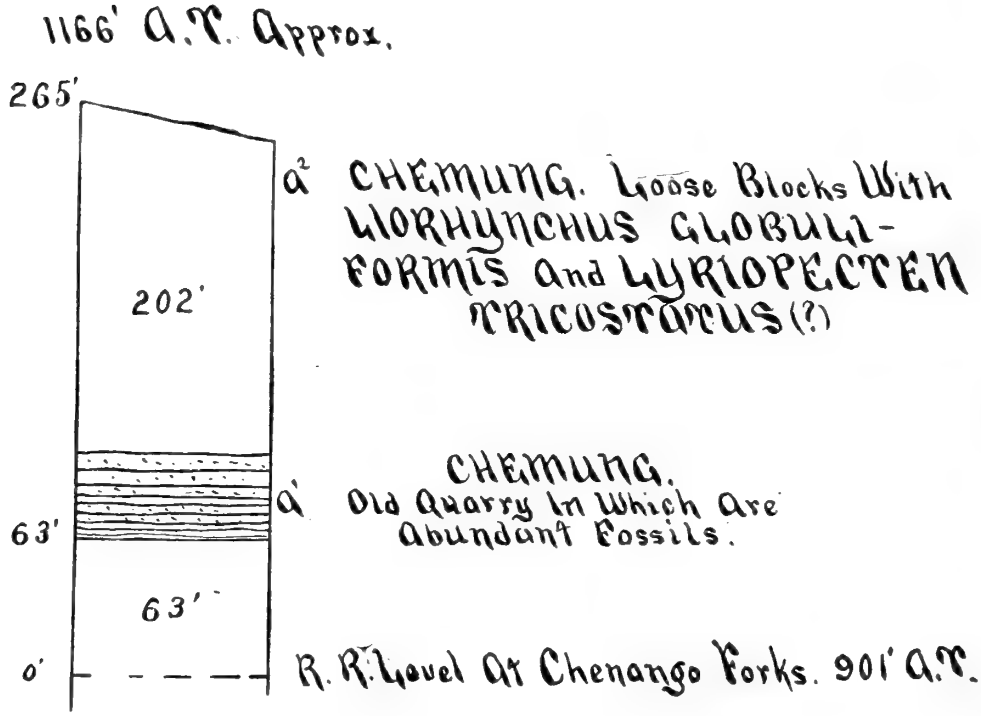
XXXVI A[1]. In the extreme southwestern corner of Greene township are the villages of Williards and Chenango Forks. On the hillside west of the Utica division of the Delaware, Lackawanna and Western railroad, between Chenango Forks and Williards, is an old quarry that was opened during the construction of the Chenango canal and is not worked at present, the base of which is about sixty-three feet above the railroad track. The rocks consist of blue, argillaceous, thin or shaly sandstones, separated by blue shales, all of which weather to an olive tint.

Fossils are common in most of the rock and abundant in layers. *Productella lachrymosa* (Con.), Hall; *Spirifer mucronatus* (Con.), Bill., var.

[1] Thirteenth Annual Report State Geologist [New York], p. 543.
[2] *Ibid.*, p. 545.
[3] *Ibid.*
[4] Geology of New York, Part III., 1842, p. 293.

SECTION BETWEEN WILLIARDS AND CHENANGO FORKS.

(#36. A.)



posterus, Hall and Clarke; *Orthis impressa*, Hall, and *Crinoid* segments are the most abundant species. The complete list is:

1. *Orthis impressa*, Hall. (aa)

   Large form as reported by Clarke from southeast of Greene (Thirteenth Annual Report, p. 543).

2. *Productella lachrymosa* (Con.), Hall. (aa)

   Probably some of these specimens should be cf. *P. speciosa* of Ithaca, but the pustules are coarser than in this species. So identified by Clarke in Thirteenth Annual Report, p. 543.

3. *Spirifer mucronatus* (Con.), Bill., var. *posterus*, Hall and Clarke. (aa)

   Many of these specimens agree exactly with the figures of the mucronate forms of this species. These are undoubtedly the same as those from Chenango identified as *Sp. mucronatus* var. by Professor H. S. Williams and figured in Bulletin Geological Society of America Vol. I., pl. 12, f. 13.

4. *Spirifer mesacostalis*, Hall (?). (rr)
5. *Liorhynchus globuliformis* (Van.), Hall. (c)
6. *Atrypa reticularis* (Lin.), Dal. (r)
7. *Rhynchonella* (*Pugnax*) *pugnus* (Martin), Dav. (r)

   Specimens rather small and poorly preserved, but pretty clearly of this species.

8. *Cyrtina Hamiltonensis*, Hall. (rr)
9. *Stropheodonta demissa* (Con.), Hall. (rr)
10. *Palæoneilo filosa* (Con.), Hall. (c)
11. *Palæoneilo* cf. *constricta* (Con.), Hall. (rr)

    One specimen better preserved approaches this species in markings and form.

12. *Mytilarca carinata*, Hall (?). (rr)
13. *Schizodus* cf. *appressus* (Con.), Hall. (r)

    The specimens are nearer to figure 8, plate 75 (Palaeontology of New York, Vol. V., Part I.), of the above species than to any other form.

14. *Lyriopecten* cf. *tricostatus* (Van.), Hall. (rr)

    A left valve that agrees quite well in its plications with *L. macrodontus* H. of the Hamilton.

15. *Actinopteria Boydi* (Con.), Hall (?). (rr)

    Crushed, but much like this species.

16. *Crinoid* segments. (a)

The Chenango Forks railroad station is at 901 feet, which makes the altitude of the quarry approximately 964 feet A. T.

XXXVI A². Near the top of the hill above A¹ are loose blocks of stone containing plenty of specimens of *Liorhynchus globuliformis* (Van.), Hall, and *Rhynchonella* (*Camarotœchia*) *Stevensi*, Hall, which are probably from the next fauna above that of the lower exposures at Chenango Forks. The following species were noted in these loose blocks:

1. *Liorhynchus globuliformis* (Van.), Hall. (c)
2. *Rhynchonella* (*Camarotœchia*) *Stevensi* (Hall), Hall and Clarke. (c)
3. *Rhynchonella* (*Camarotœchia*) *eximia* (Hall), Hall and Clarke. (c)

   It is probable that these specimens should be carefully compared with *R. congregata* (Con.), Hall, of the Hamilton, which seems to be a closely allied species.

4. *Lyriopecten tricostatus* (Van.), Hall (?). (rr)

The plications are of three sizes, giving the shell the surface ornamentation of this species.

5. *Palæoneilo,* sp. (r)

Very poorly preserved.

6 *Actinopteria* cf. *Theta,* Hall. (rr)

Imperfectly preserved, but like figure 19, plate 84 (Palaeontology of New York, *loc. cit.*) of this species.

This hill forms the divide between the Chenango and Tioughnioga rivers above their junction, and its top is about two hundred and sixty-five feet above the railroad.

Fenton and Chenango.

Greene is the southwestern township of Chenango county. To the south is Fenton township, Broome county, which is on the eastern side of the Chenango river, and on the western side of the river is Chenango township.

In the southern part of Fenton township is the small village of Port Crane, formerly a port on the Chenango canal, but now reached by the Susquehanna division of the Delaware and Hudson railroad, the station of which is on the hill side, considerably higher than the village. The geology of this region was a puzzle to Vanuxem, on account of the presence here of Hamilton species. In describing the Chemung group, Vanuxem referred to this difficulty and said: "These rocks appear [at Port Crane], having similar fossils to those of the lower rocks which are quarried around the village of Norwich, and those exposed in the sides of the brook to the west of the village of Oneonta. There are three fossils at these localities also, which are the same with those of the Hamilton group, the Posidonia lirata [*Paracyclas lirata* (Con.), Hall], Strophomena carinata [*Tropidoleptus carinatus* (Con.), Hall], and Atrypa plebeia [this is not recognized]; showing that localities existed which favored the continuance of certain species long after their total destruction in others; a subject which requires thorough investigation, and without which the value of fossils as a character will not be as deservedly esteemed as they should."[1] Also, in describing the geology of Broome county, Vanuxem mentioned the same difficulty and wrote: "There are several openings in the hillside at Port Crane, not far from the level of the canal, where some of the same fossils which exist at the quarries near Norwich, and near the canal also, are found. These fossils belong to

[1] Geology of New York, Part III., p. 180.

the Hamilton group and, unless they have a high range, which I am disposed to believe, would bring the Hamilton and the Chemung groups together in two or more localities. They are anomalies which further observations are required to explain or remove."[1] Vanuxem's difficulty in reference to the range of certain species in the vicinity of Port Crane and the bearing of the above quotations will be appreciated after a description of the rocks exposed near that village. At this locality the Chenango river makes a decided bend to the west. On the eastern side of the river is a very steep hill and on the western side a lower one.

XLII A[1]. About a mile north of Port Crane exposures were found from near the level of the canal extending for a considerable distance up the hill. In the lowest rocks the following species were collected:

1. *Liorhynchus globuliformis*, (Van.), Hall.
2. (?) *Lingula spatulata*, Hall.
3. *Sphenotus rigidus* (White and Whitfield), Hall (?).
4. *Nucula corbuliformis*, Hall (?).
5. (?) *Goniophora*, sp.

In an old quarry near the village, C^1, quite an extensive fauna was secured, as is shown by the following list:

1. *Rhynchonella* (*Camarotœchia*) *eximia*, Hall.
2. *Spirifer*, (?).
   See *S. mesacostalis* with middle septum; H. S. W.
3. *Spirifer sculptilis*, Hall (?).
4. *Spirifer granulosus* (Con.), Hall and Clarke.
5. *Chonetes setigera*, Hall.
6. *Chonetes scitula*, Hall (?).
   Wider forms than the common one, *C. setigera*, H.
7. *Ambocœlia umbonata* (Con.), Hall.
   Possibly this may be *A. umbonata* var. *gregaria*, H.
8. *Liopteria DeKayi*, Hall (?).
   There are two specimens and they are doubtfully referred to the above species.
9. *Liopteria*, sp. (small specimen).
10. *Grammysia nodocostata*, Hall.
11. *Grammysia subarcuata*, Hall.

[1] Geology of New York, Part III., pp. 294–295.

12. *Modiomorpha mytiloides* (Con.), Hall.

    Two specimens are rather short, in this respect resembling *M. alta* (Con.), H., but their umbonal slope is not sharp enough for that species. Another specimen is much elongated and very ventricose along the region of the umbonal slope.

13. *Modiomorpha macilenta*, Hall (?).
14. *Microdon (Cypricardella) bellistriatus*, Con.
15. *Palæoneilo plana*, Hall.
16. *Leptodesma*, sp.
17. Small lamellibranch shell, possibly *Modiomorpha*.
18. *Goniophora*, sp.
19. *Sphenotus*, sp.
20. *Coleolus tenuicinctum*, Hall.
21. *Bellerophon*, sp.
22. *Cyclonema multilira*, Hall.
23. *Loxonema Hamiltoniæ*, Hall.
24. *Pleurotomaria Itys*, Hall.
25. *Orthoceras*, sp. (fragments).

XLII B[1]. About one and one-half miles southwest of Port Crane a section was made extending from the canal level to the top of the high hill. At the base of the hill, only a few feet above the river and canal level, are olive, argillaceous shales in which fossils are rare, *Spirifer mesastrialis*, Hall, and *Rhynchonella (Camarotœchia) Stevensi*, Hall (?), being the most common species. The complete list is:

1. *Spirifer mesastrialis*, Hall. (c)

    Mostly broken specimens, but they show clearly the fine striae on the plications and sinus.

2. *Spirifer mesacostalis*, Hall. (rr)

    The type of *S. acuminata*, Hall, 1843. Another specimen seemed to be similar, but it has very fine striae on the plications, like *S. mesastrialis*.

3. *Tropidoleptus carinatus* (Con.), Hall. (rr)
4. *Rhynchonella (Camarotœchia), Stevensi* (H.), H. and C. (c)
5. *Chonetes setigera*, Hall (?). (rr)

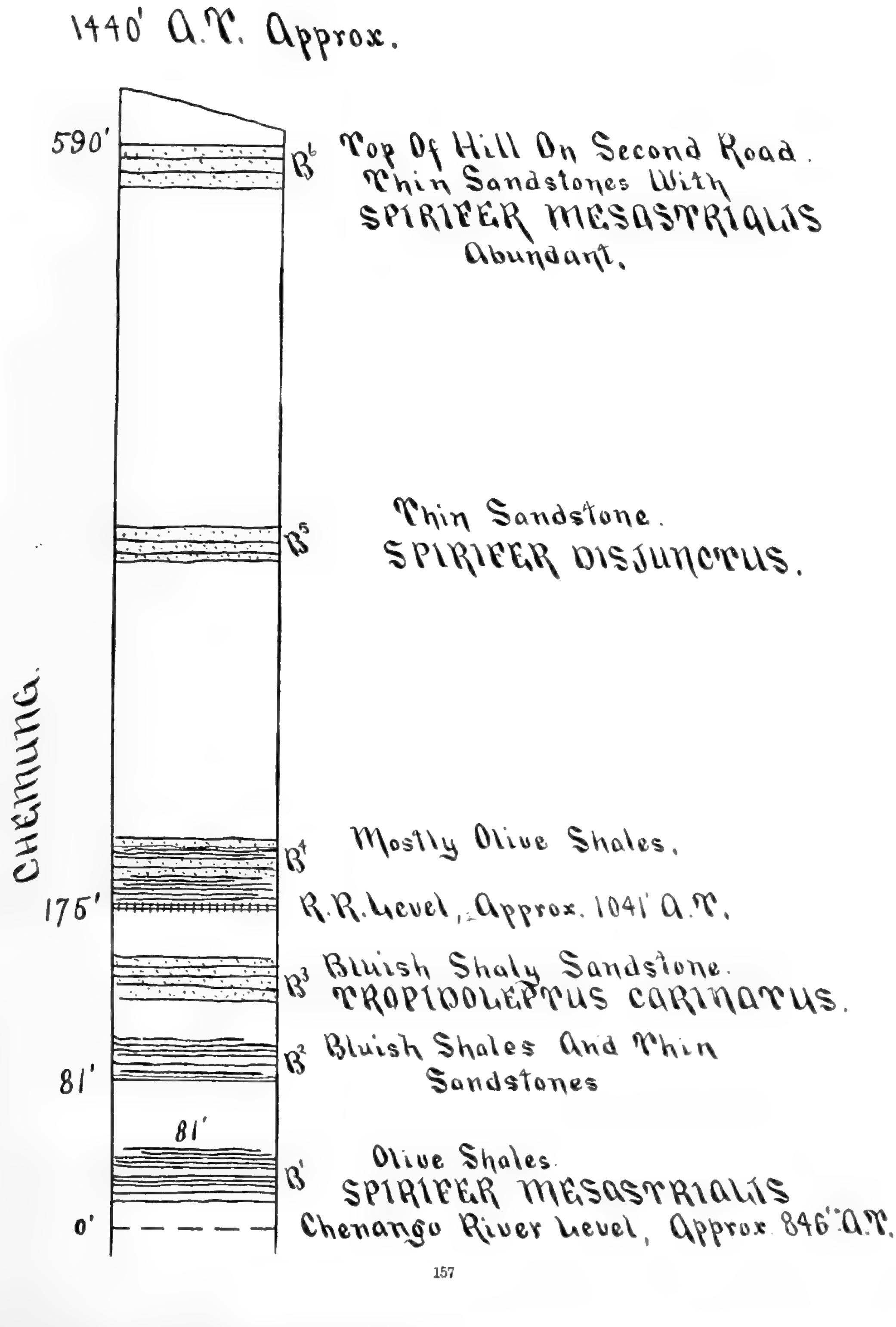
    Imperfectly preserved, with thirty to forty striae.

6. *Modiomorpha subalata* (Con.), Hall, var. *Chemungensis*, Hall (?). (rr)

    Not clearly preserved.

SECTION 1½ MILES SOUTH-WEST OF PORT CRANE.

(#42. B.)



7. *Palæoneilo brevis*, Hall (?). (rr)
8. *Palæoneilo plana*, Hall (?). (rr)
9. *Schizodus* cf. *appressus* (Con.), Hall. (rr)

In form similar to figure 8, of plate LXXV (Palaeontology of New York, *loc. cit.*), which is described as "a small right valve of rotund form."

XLII B². About eighty feet above the river level on the very steep hillside is a small excavation in bluish shales and shaly sandstones. Fossils are somewhat abundant, the most common species being *Microdon* (*Cypricardella*) *complanatus*, Hall, and *Palæoneilo constricta*, (Con.), Hall. The following species were obtained:

1. *Spirifer mesastrialis*, Hall. (rr)
2. *Microdon* (*Cypricardella*) *complanatus*, Hall. (a)
3. *Microdon* (*Cypricardella*) *gregarius*, Hall. (rr)
4. *Palæoneilo constricta* (Con.), Hall. (c)

The specimens are external impressions of poorly preserved shells, but they agree closely in form and general appearance with figure 1 of this species on plate XLVIII (Palaeontology of New York, *loc. cit.*).

5. *Nucula corbuliformis*, Hall. (rr)

Form and proportions agree well with those of this species.

6. *Paracyclas* (?) *pauper*, Hall (?). (r)

The specimens are not sufficiently well preserved to show much of the markings, but they seem to agree more nearly with the figures of this species than with those of any other.

7. *Palæoneilo plana*, Hall. (rr)
8. *Bellerophon*, sp. (rr)

This may be compared with *B. Mæra*, H., of the Chemung, but it is so poorly preserved that it is difficult to determine.

9. Fragment of *Bryozoa*. (rr)
10. (?) *Edmondia*, sp. (rr)

XLII B³. In the slope somewhat above the quarry in bluish shaly sandstones, fossils are common, as the list indicates:

1. *Tropidoleptus carinatus* (Con.), Hall. (r)
2. *Rhynchonella* (*Camarotœchia*) *eximia* (H.), Hall and Clarke. (a)

See *R. Stevensi* (H.), H. and C. The smaller specimens have proportions nearer those of *R. eximia*, while the larger are more like *R. Stevensi*.

3. *Spirifer mesacostalis*, Hall. (c)

One ventral impression distinctly shows the median plication which is supposed to define this species. Another specimen is almost the same as figure 3, plate XL, Pal. IV., except that it shows a distinct sinus on the fold. This form was originally described as *S. acuminata* which, in Vol. VIII., II. is stated to be probably *S. mucronatus* (Con.), Bill., var. *posterus*, H. and C. It it possible that some of these specimens belong to this species, but they all clearly show a sinus on the fold, or fold in the sinus, which is characteristic of *S. mesacostalis*.

4. *Ambocœlia umbonata* (Con.), Hall. (c)
5. *Chonetes setigera*, Hall (?). (r)
6. *Microdon* (*Cypricardella*) *gregarius*, Hall. (c)

XLII B[4]. Exposures in the cuts along the Delaware and Hudson railroad, 175 feet above the river level. The rocks are mostly olive shales, but there are some of a bluish color that are iron stained and these contain most of the fossils; interbedded are thin shaly sandstones. *Rhynchonella* (*Camarotœchia*) *Stevensi*, Hall; *Spirifer mesacostalis*, Hall, and *Microdon* (*Cypricardella*) *gregarius*, Hall, are the most common species. The list is as follows:

1. *Rhynchonella* (*Camarotœchia*) *Stevensi* (H.), Hall and Clarke. (a)

Some of the specimens may be compared with *R. eximia* (H.), H. and C., as they are broad and similar in outline.

2. *Spirifer mesacostalis*, Hall. (a)

The impressions of two ventral valves show very distinctly the median septum in the sinus.

3. *Spirifer mesastrialis*, Hall (?). (rr)

A large specimen with twenty or more plications on each side of the sinus.

4 *Ambocœlia umbonata* (Con.), Hall. (rr)
5. *Chonetes setigera*, Hall. (rr)
6. *Microdon* (*Cypricardella*) *gregarius*, Hall. (a)
7. *Microdon* (*Cypricardella*) *complanatus*, Hall (?). (r)

A few specimens are not dissimilar to figure 23, plate LXXIII (Palaeontology of New York, *loc. cit.*), of *M. tenuistriata* and perhaps should be referred to that species.

8. *Orthoceras*, sp. (fragments). (rr)

9. *Leptodesma* cf. *sociale*, Hall. (rr)

The specimens do not show the strong concentric markings of this species, but fine striae as in *L. Rogersi*, Hall, to which species perhaps they should be referred. The form is similar to that of the small specimens of *L. Rogersi* or *L. sociale*.

XLII B[5]. By the roadside at the top of the hill above the railroad are thin, very much weathered sandstones that contain fossils. The following were collected:

1. *Spirifer mesastrialis*, Hall.
2. *Spirifer disjunctus*, Sowerby.
3. (?) *Aviculopecten*, sp.
4. *Crinoid* segments.

This is the first place in the Chenango valley where *Spirifer disjunctus* was found, and the occurrence of this characteristic Chemung fossil conclusively proves that the rocks near the top of the high hill south of Port Crane are in the Chemung formation.

B[6]. On top of the high hill along the second road south of the river, and about two miles south of Port Crane, are thin sandstones in which *Spirifer mesastrialis*, Hall, is abundant. There is only a slight exposure by the roadside, but the following species were collected:

1. *Spirifer mesastrialis*, Hall. (a)
2. *Mytilarca carinata*, Hall. (rr)
3. *Palæoneilo*, sp. (rr)

   An elongated specimen which is narrower than any of the figured forms.

4. (?) *Schizodus*, sp. (rr)
5. *Crinoid* segments. (a)

This fauna is about 590 feet above the river level or with an approximate altitude of 1,440 feet A. T., and it is in the highest rocks found in the vicinity of Port Crane.

XLIII A. Two miles east of Port Crane is Osborne Hollow, in the western part of Colesville township. The railroad station is 1,115 feet A. T. The country about this place is gently rolling, with few extensive rock exposures. The species in the following list were obtained from an outcrop along the brook near the village:

1. *Modiomorpha*, sp.
2. *Leptodesma*, sp.
3. *Microdon* (*Cypricardella*) *bellistriatus*, Con., var.

4. *Spirifer mesacostalis*, Hall (?).
5. *Spirifer mesastrialis*, Hall.
6. *Rhynchonella (Camarotœchia) Stevensi*, Hall.
7. *Productella*, sp.
8. *Palæoneilo constricta* (Con.), Hall (?).
9. *Palæoneilo plana*, Hall (?).
10. (?) *Palæoneilo*, sp.
11. *Schizodus gregarius*, Hall.
12. *Nuculites*, sp.
13. *Liopteria Rafinesquii*, Hall.
14 *Liopteria Bigsbyi*, Hall.
15. *Grammysia bisulcata* (Con.), Hall.
16. *Goniophora Chemungensis* (Van.), Hall.
17. (?) *Sphenotus*, sp.
18. *Chonetes scitula*, Hall (?).
19. *Chonetes setigera*, Hall.
20. *Chonetes*, sp.
21. *Crinoid* stem and segments.
22. *Plant* stems.
23. *Platyceras*.
24. *Coral* remains

XLIII B. Some years ago three shafts were sunk to quite a depth near the village, in search of galena. From the rocks remaining on the dump heaps of these shafts the species enumerated below were collected:

1. *Tropidoleptus carinatus* (Con.), Hall.
2. (?) *Rhynchonella*, sp
3. *Bryozoa*.
4. *Rhynchonella (Camarotœchia) Stevensi*, Hall.
5. *Spirifer mesacostalis*, Hall (?).
6. *Grammysia bisulcata* (Con.), Hall.
7. *Nucula*, sp.
8. *Sphenotus*, sp.
9. *Liopteria*, sp.
10. *Chonetes scitula*, Hall (?).
11. *Leptodesma*, sp.
12. *Microdon (Cypricardella) gregarius*, Hall.
13. *Palæoneilo*, sp.
14. (?) *Goniophora Chemungensis* (Van.), Hall.

15. *Loxonema delphicola*, Hall.

16. *Crinoid* segments.

17. Fragments of fish bones like *Holonema rugosa* (Claypole), Newb.

XLII D[1]. On the hillside west of the Chenango river, opposite Port Crane, is an old quarry that was opened during the construction of the Chenango canal. It is in the eastern part of Chenango township, and the bottom is some seventy-five or more feet above the river. The wall of the quarry shows fifteen feet of bluish shales and shaly sandstones that weather to an olive color. Some of the thin sandstones and slightly calcareous layers contain fossils abundantly, especially *Rhynchonella* (*Camarotœchia*) *Stevensi*, Hall, and *Tropidoleptus carinatus* (Con.), Hall. The species in the list were gathered in one half hour:

1. *Tropidoleptus carinatus* (Con.), Hall. (aa)

   Typical specimens of this species such as occur in the Hamilton.

2. *Rhynchonella* (*Camarotœchia*) *Stevensi* (H.), Hall and Clarke (?). (aa)

   The ventral valves of a number of specimens show clearly the dental lamellæ described in this species, and the dorsal valves, the septum about one-third the length of the shell. However, the plications are less than given for this species, and in form many of them are about the same as *R. eximia* with which they must be compared.

3. *Chonetes scitula*, Hall. (rr)

   One specimen shows over fifty striae and is clearly of the form of this species.

4. *Orthonota* (?) *parvula*, Hall. (r)

5. *Microdon* (*Cypricardella*) *gregarius*, Hall. (c)

6. *Palæoneilo plana*, Hall (?). (rr)

7. *Goniophora*, cf. *Chemungensis*, (Van.), Hall. (rr)

8. *Grammysia elliptica*, Hall (?). (rr)

   Imperfectly preserved.

9. *Grammysia circularis*, Hall. (rr)

   The posterior portion of the shell is not complete, but in all the characters preserved it agrees well with this species.

10. *Crinoid* stems and segments. (c)

11. *Liopteria DeKayi*, Hall (?). (c)

    The specimens resemble quite closely figure 6, plate LXXXVIII (Pal., N. Y.), which is a large specimen from Schoharie county.

XLII E[1]. Along the bank of the Chenango river, about two and one-half miles below Chenango Forks and opposite Kattle Hill, are quite fossiliferous shales. There is one layer that is quite calcareous, forming a "fire stone," which contained these species:

1. *Spirifer mesacostalis*, Hall (?).
2. *Productella speciosa*, Hall (Ithaca variety).
3. *Rhynchonella* (*Pugnax*) *pugnus* (Martin), Dav.
4. *Liorhynchus globuliformis* (Van.), Hall.
5. *Cyrtina Hamiltonensis*, Hall.
6. *Crania* (*Craniella*) *Hamiltoniæ*, Hall (?).

The shales contained the succeeding:

1. *Orthis* (*Schizophoria*) *impressa*, Hall.
2. *Liorhynchus globuliformis*, (Van.), Hall.
3. *Spirifer mesacostalis*, Hall (?).
4. *Stropheodonta demissa* (Con.), Hall.
5. *Rhynchonella* (*Camarotœchia*) *Stevensi*, Hall.
6. *Productella speciosa*, Hall.
7. *Palæoneilo constricta* (Con.), Hall (?).
8. *Lyriopecten tricostatus* (Van.), Hall.
9. *Microdon* (*Cypricardella*) *bellistriatus*, Con. (?).
10. *Sphenotus*, sp.

Liorhynchus globuliformis (Van.), Hall, is the most abundant species in both of the preceding lists.

XLII E[2]. Two miles below Chenango Forks is a long cut on the Delaware, Lackawanna and Western railroad, furnishing a good locality to study the *Liorhynchus globuliformis* fauna. The rocks are principally sandstones and shales which, on weathering, are of an olive color. Above the railroad cut is the highway along the steep eastern face of Kattle Hill, where the rocks are not very fossiliferous except in thin layers. These layers are somewhat calcareous, often at the bottom of a four to six inch sandstone, and contain a mass of fossils, principally *Liorhynchus globuliformis* (Van.), Hall, mixed with a few other species. This *Liorhynchus*, under the name of *Atrypa globuliformis*, was figured by Vanuxem, who said: "This cast is given, because it exists in myriads as such in this group [the Chemung], numerous localities abounding in it."[1] Professor H. S. Williams has termed this horizon "the *Liorhynchus globuliformis* stage" of the faunas succeeding the Oneonta formation in the Chenango valley.[2]

[1] Geology of New York, Part III., p. 182 See fig. 2 of No. 49 on same page.
[2] Proceedings American Association Advancement of Science, Vol. XXXIV., 1886, p. 226.

To indicate the base of the Chemung formation across Chenango and Otsego counties is a matter of some difficulty. There is a difference of opinion among working geologists as to where it occurs in this region, and possibly as yet insufficient study has been given to these higher rocks to enable the determination of this point. Vanuxem's interpretation of this region is of little value on account of his failure to separate the Oneonta from the Catskill formation, as will be seen by reference to the Geological Map of the State of New York, of 1842. Professor James Hall has given careful attention to the classification of these rocks and mentioned them in numerous publications, among which might be cited his paper before the National Academy of Sciences, in which he clearly stated his interpretation when he said: "The fossiliferous beds of the Chemung are found lying upon that formation [the Oneonta] between Norwich and Oneonta, and to the east of Sidney Plains, and at or near Franklin, where they apparently pass beneath the great red-sandstone formation of the Catskills."[1] Professor Henry S. Williams placed the base of the Chemung considerably higher, beginning above the *Tropidoleptus carinatus* fauna near Port Crane, apparently with the *Spirifer mesastrialis* zone well toward the top of the hill south of Port Crane.[2] Mr. Darton evidently followed Professor Hall's classification and stated that: "From Franklin, westward, the Oneonta-Chemung boundary is clearly marked by the abrupt change from red beds to grey shales and soft sandstones."[3] Finally, Professor Clarke, as a result of his studies in the vicinity of Greene, concluded that the fossils in the shales and sandstones overlying the Oneonta formation "are of typical Chemung expression,"[4] and consequently referred the rocks to the Chemung formation.

Professor Williams described the lowest Chemung fauna of the Cayuga lake meridian as found on the high hill south of Ithaca in Danby township in the southern part of Tompkins county "stratigraphically 1,300 feet or more above the Genesee shale."[5] The following fauna from this locality is given by Professor Williams:

"*Productella lachrymosa*,
Ambocœlia umbonata var. *gregaria*,
Orthis impressa (second variety, wide and large),
Atrypa reticularis,
and a few other imperfect fossils."[6]

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[1] Science (old series), Vol I.. Dec. 11, 1880, p. 290.
[2] Proceedings American Association Advancement of Science, Vol. XXXIV., section IX. of Chart.
[3] American Journal of Science, third series, Vol. XLV., 1893, p. 207.
[4] Thirteenth Annual Report State Geologist [New York], p. 543; also see section on p. 556.
[5] Bulletin United States Geological Survey, No. 3, 1884, p. 21.
[6] *Ibid.*, p. 21.

It will be noticed that in the above fauna *Spirifer disjunctus*, Sow., is not reported; but above the fauna just cited occur shales that contain a fauna "very similar to that in the dark shale at the base of the Ithaca group, but mingled with other species. * * * The most northern exposure, at which the typical Chemung fauna was found in abundance, was high up in the hills in the northeastern part of Chemung county, near Park station,"[1] and at this place *Spirifer disjunctus*, Sow., and *Orthis Tioga*, Hall, were found, some 300 or 400 feet stratigraphically above the lowest fauna in Danby.

On comparing the list of fossils reported by Professor Williams from the lowest Chemung in Danby[2] with the list given by Professor Clarke for Greene,[3] or the fauna reported in this paper from Chenango Forks, it will be seen that all the species listed by Professor Williams from Danby, except *Ambocœlia umbonata* var. *gregaria*, occur in these localities in Chenango county. Again it will be found that the thickness of the formations from the top of the Genesee slates to the base of the fauna overlying the Oneonta of the Chenango valley, and the similar fauna above the Upper Portage of the Cayuga lake region is about the same. Professor Williams reports it as "1,300 feet or more"[4] for Tompkins county, and in the Chenango valley it is fully 1,300 feet from the top of the Hamilton to the base of the fauna immediately above the Oneonta formation. Finally Professor Williams described a fauna containing *Tropidoleptus carinatus* near Owego[5] at about the same altitude as the *Tropidoleptus carinatus* zone near Port Crane, which is in the midst of a typical Chemung fauna, at least 200 feet above the first occurrence of *Spirifer disjunctus*, Sow. It is thought that possibly the Owego zone of *Tropidoleptus* represents the same general part of the section as that at Port Crane, except that the *Tropidoleptus* fauna is being replaced by the regular Chemung fauna near Owego, consequently it is not so conspicuous as in the sections farther east.

After reviewing the results obtained by different investigators of this problem of the separation of the Chemung and Portage and the Chemung and Oneonta formations in the central part of southern New York, the facts seem to justify the conclusion that the Chemung begins with the *Orthis impressa* fauna overlying the Oneonta formation.

The thickness of the formations composing the Chenango valley section, ranging from the base of the Marcellus shale in Sangerfield township, Oneida

[1] Bulletin United States Geological Survey, No. 3, 1884, p. 22.
[2] *Ibid.*, p. 21.
[3] Thirteenth Annual Report State Geologist [New York], p. 543.
[4] Bulletin United States Geological Survey, No. 3, p. 21.
[5] *Ibid.*, p. 24.

county, up into the Chemung on top of the high hill in Fenton and Kirkwood townships, Broome county, to the northeast of Binghamton, is approximately as follows: estimating the dip for the northern part of the Chenango valley to be sixty feet to the mile, we would have a thickness of about 1,500 feet for the Marcellus and Hamilton formations. To the east of Smyrna there are, perhaps, twenty-five feet representing the Tully limestone and Genesee slate. The Sherburne formation is 250 feet, the Ithaca 500 feet, or more, and the Oneonta 550 feet thick; while for the Chemung from Greene to the top of the hill south of Port Crane, calling the dip 60 feet per mile, there are 1,225 feet, which result agrees quite well with the record of the well drilled at Binghamton.[1]

The thickness of these formations may be more clearly and concisely expressed in tabular form, as shown on the accompanying generalized section of the Chenango valley.

THE UNADILLA VALLEY SECTION.

The courses of the Chenango and the first river to the east, the Unadilla, are approximately parallel, and are, on the average, ten miles apart. For a considerable distance the Unadilla river serves as the dividing line between Chenango and Otsego counties. The general topographic features of the two valleys are very similar, and they cross the same formations.

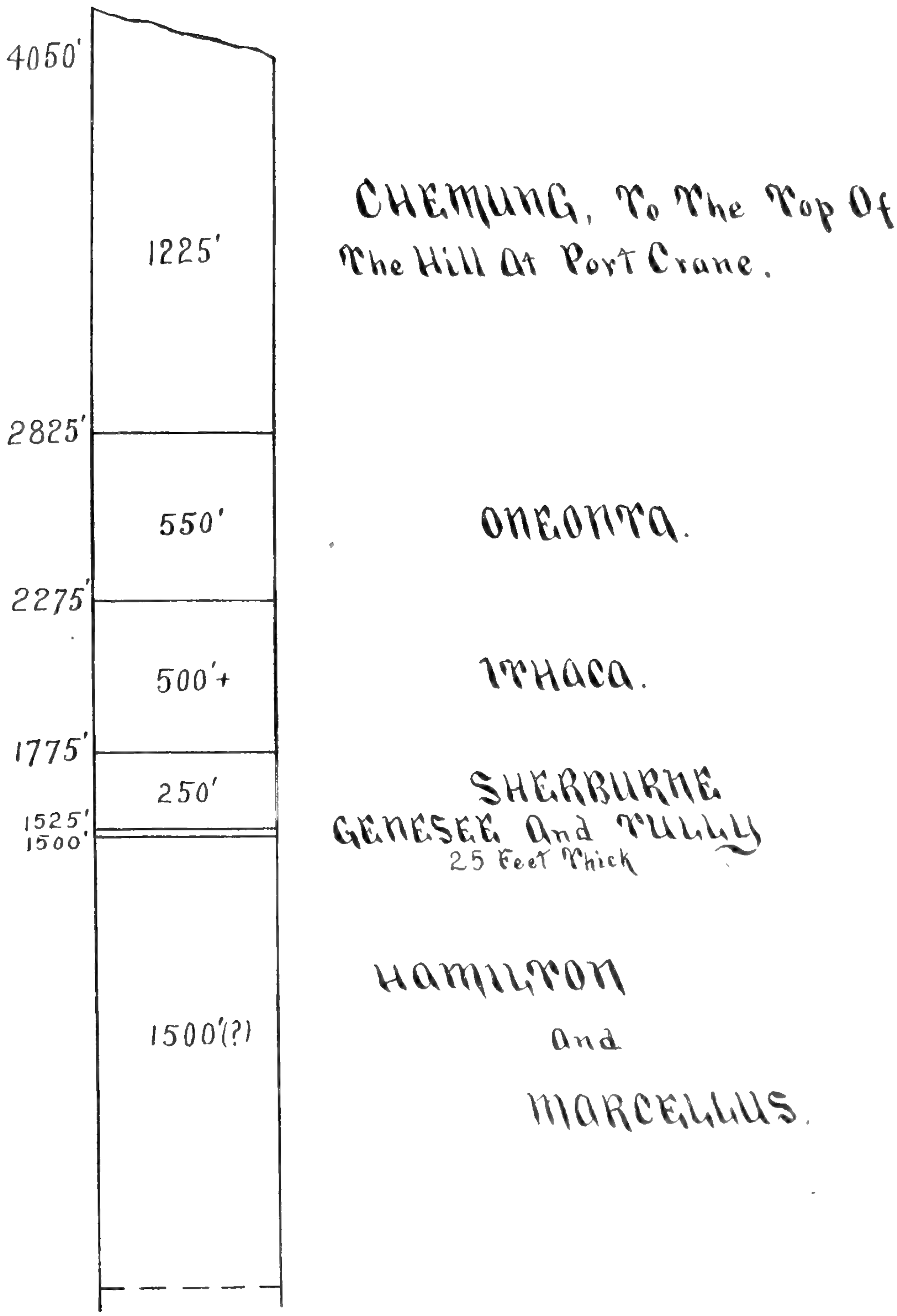
Columbus.

Columbus is the northeastern township of Chenango county, being directly east of Sherburne, south of Brookfield, Madison county, and separated by the Unadilla river on the east from Edmeston, Otsego county. In describing the exposures of this township, we begin with those directly east of the outcrops described near Harrisville, Sherburne township and, continuing eastward, follow somewhat closely the line of separation between the Hamilton and Sherburne formations.

XIX B[8]. East of Harrisville, along the main road from Sherburne to Columbus, are occasional outcrops. By the roadside, on the divide at the head of Mad brook, are shaly layers containing fossils; *Liorhynchus mesacostalis*, Hall, being abundant, while *Productella speciosa*, Hall (?), and *Cyrtina Hamiltonensis*, Hall, are common. The locality is just east of the Sherburne and Columbus township line, about two miles east of Harrisville, and barometrically 485 feet higher than the lower reservoir dam at Harris-

[1] Bulletin Geological Society of America, Vol. IV, pp. 93, 94.

GENERALIZED SECTION GIVING THICKNESS OF THE CHENANGO VALLEY FORMATIONS.



ville, or approximately 725 feet above the railroad level in Sherburne village, which makes its altitude about 1,767 feet A. T. This outcrop belongs in the Ithaca formation. A rather hasty search revealed the following fossils:

1. *Liorhynchus mesacostalis*, Hall. (a)
2. *Spirifer granulosus* (Con.), Hall (?). (rr)
3. *Spirifer*, probably *Sp. mucronatus* (Con.), Bill. (rr)
4. *Cyrtina Hamiltonensis*, Hall. (c)
5. *Chonetes scitula*, Hall. (rr)
6. *Productella speciosa*, Hall (?). (c)

   Very similar to specimens identified as this species at Ithaca.
7. *Nucula corbuliformis*, Hall. (rr)

XIX D[1]. At the corner of the second east and west road, north of the Sherburne and Columbus turnpike, and one and one-half miles northwest of XIX B[8], is the head of the northeast branch of Mad brook. Beginning immediately below the road, and appearing at intervals down the brook, are blackish shales containing abundant fossils. An anticlinal roll crosses the brook some distance below the road. These shales are on the Andrews farm, two miles northeast of the Sherburne reservoir at Harrisville, and the upper part of them is some 590 feet above the railroad at Sherburne. The abundant fossils are all Hamilton species, and the shales are apparently in the upper part of the Hamilton formation. The following species were obtained:

1. *Spirifer mucronatus* (Con.), Bill. (a)
2. *Spirifer granulosus* (Con.), Hall. (c)
3. *Spirifer Tullius*, Hall. (rr)
4. *Vitulina pustulosa*, Hall. (rr)
5. *Tropidoleptus carinatus* (Con.), Hall. (c)
6. *Chonetes scitula*, Hall. (c)

   These resemble somewhat *C. setigera*, H., but are probably rather short forms of the above.
7. *Lingula punctata*, Hall. (rr)
8. *Nucula corbuliformis*, Hall. (rr)
9. *Palæoneilo maxima* (Con.), Hall (?). (rr)
10. *Liopteria*, sp. (rr)
11. *Dalmanites* (*Cryphæus*) *Boothi* (Green), Hall. (rr)
12. *Phacops rana* (Green), Hall. (rr)

On the hill south of the creek and 150 feet higher, are arenaceous iron-stained shales that contain an occasional small lamellibranch and *Liorhynchus*.

Interstratified with the shales are also thin, smooth sandstones. The rocks probably belong in the Sherburne formation.

On the first road turning to the east about one-fourth of a mile north of the Andrews farm and eighty-five feet above the Hamilton shales at XIX D^1, are fine bluish, argillaceous shales which belong in the Sherburne formation. These shales form the upper part of the northern end of the steep hill along the Sherburne and Columbus township line. On the eastern side of the steep hill, fossils were found about seventy feet below the exposure of the Sherburne shales, just described, which are regarded as near the top of the Hamilton. This outcrop is about 600 feet above the railroad level at Sherburne or approximately 1,642 feet A. T.

XIX E^1. In a branch of Howard creek, at the foot of this hill, is a blue sandstone, above which are coarse arenaceous shales. The outcrop is on the Thomas Mulligan farm, three miles northwest of Columbus village, and is 155 feet lower than the stratum with fossils on the hillside, or approximately 1,487 feet A. T. The shales are blocky, split into irregular pieces, and contain plenty of Hamilton fossils. The following species were collected :

1. *Tropidoleptus carinatus* (Con.), Hall. (c)
2. *Orthis*, sp. (rr)
3. *Spirifer granulosus* (Con.), Hall. (rr)
4. *Orthothetes Chemungensis* (Con.), H., var. *arctostriata*, H. (rr)
5. *Microdon* (*Cypricardella*) *tenuistriatus*, Hall. (rr)
6. *Pholadella radiata* (Con.), Hall. (rr)
7. *Nucula bellistriata* (Con.), Hall. (rr)
8. *Grammysia bisulcata* (Con.), Hall. (rr)
9. *Grammysia* cf. *G. alveata* (Con.), Hall. (rr)
10. *Coleolus tenuicinctum*, Hall. (rr)
11. *Cyclonema multistriata*, Hall (?).
12. *Leptodesma*, sp. (rr)

XIX F^1. At the foot of a small glen one and two-tenths miles southwest of the above exposure, are coarse arenaceous shales, containing plenty of Hamilton fossils. Then, for about twenty feet, the rocks are covered, while in the glen above is an excellent exposure of the Sherburne shales and sandstones (F^2). The glen is cut out of rocks belonging to this formation, and on the road above, in front of Mr. Pultz's house, the thin argillaceous shales are well exposed. This locality is but a short distance east of the Sherburne and Columbus township line, and 150 feet of the Sherburne formation are shown.

New Berlin.

New Berlin township is directly south of Columbus, its eastern boundary being the Unadilla river, its western Norwich and North Norwich, while Sherburne forms a part of its northern boundary. West brook rises in the southern part of Columbus and flows southeasterly across the northeastern part of New Berlin and through New Berlin village into the Unadilla river. In the southwestern corner of Columbus, to the northwest of the head of West brook, is the high divide which runs north and south along the Sherburne-Columbus township line and for some distance south into New Berlin. On top of this divide in the southwestern part of Columbus, are the rocks (XIX C^4) which were referred to the Ithaca formation when describing the exposures along "Nigger brook" in Sherburne township.[1]

XX A^7. Commencing about one-half of a mile east of XIX C^4, are exposures of rocks, and at intervals there are small outcrops for one and one-half miles along the highway to the southeast when the upper part of West brook is reached. Along the brook there are plenty of exposures from near its head to New Berlin village. The exposure A^1 consists of arenaceous shales by the side of the highway nearly five miles northwest of New Berlin village. This outcrop is 670 feet higher than the New Berlin railroad station, or approximately 1,758 feet A. T.[2] Only a few minutes were spent in collecting fossils, but a number of species were obtained, among which occurs *Spirifer mesastrialis*, H. The fauna and stratigraphic position of the layer show it to be in the Ithaca formation. Below is the complete list of fossils:

1. *Spirifer mucronatus* (Con.), Bill., var. *posterus*, H. and C. (c)
   One of these specimens is quite like the form of *S. mesacostalis*, H. (as figure 10 plate 40, Palaeontolgy of New York, Vol. IV.).
2. *Spirifer mesastrialis*, Hall. (rr)
3. *Chonetes scitula*, Hall. (c)
4. *Rhynchonella* (*Camarotœchia*) *eximia*, Hall (?). (rr)
5. *Liorhynchus mesacostalis*, Hall. (rr)
6. *Atrypa reticularis* (Linné), Dalm. (rr)
7. *Stropheodonta demissa* (Con.), Hall. (rr)
8. *Actinopteria*, sp. (rr)
9. *Grammysia* cf. *elliptica*, Hall. (rr)

XX A^5. About three-fourths of a mile southeast of the locality just described, near the head of West brook and 180 feet lower, fossiliferous arenaceous shales occur by the roadside and the following species were collected:

[1] See *supra*, p. 131.
[2] On profile N. Y., O. & W. railroad New Berlin is given as 1,088 feet.

1. *Spirifer mucronatus* (Con.), Bill., var. *posterus*, H. and C. (r)
2. *Liorhynchus mesacostalis*, Hall (?). (rr)
3. *Modiomorpha* cf. *subalata* (Con.), Hall. (rr)

No umbonal ridge is shown and so it departs from the form of this species. The umbonal slope being rounded, the specimen may belong to the genus *Elymella*.

On the hillside, eighty feet above the road, are thin, apparently unfossiliferous sandstones (A^6). These two exposures are in the Ithaca formation.

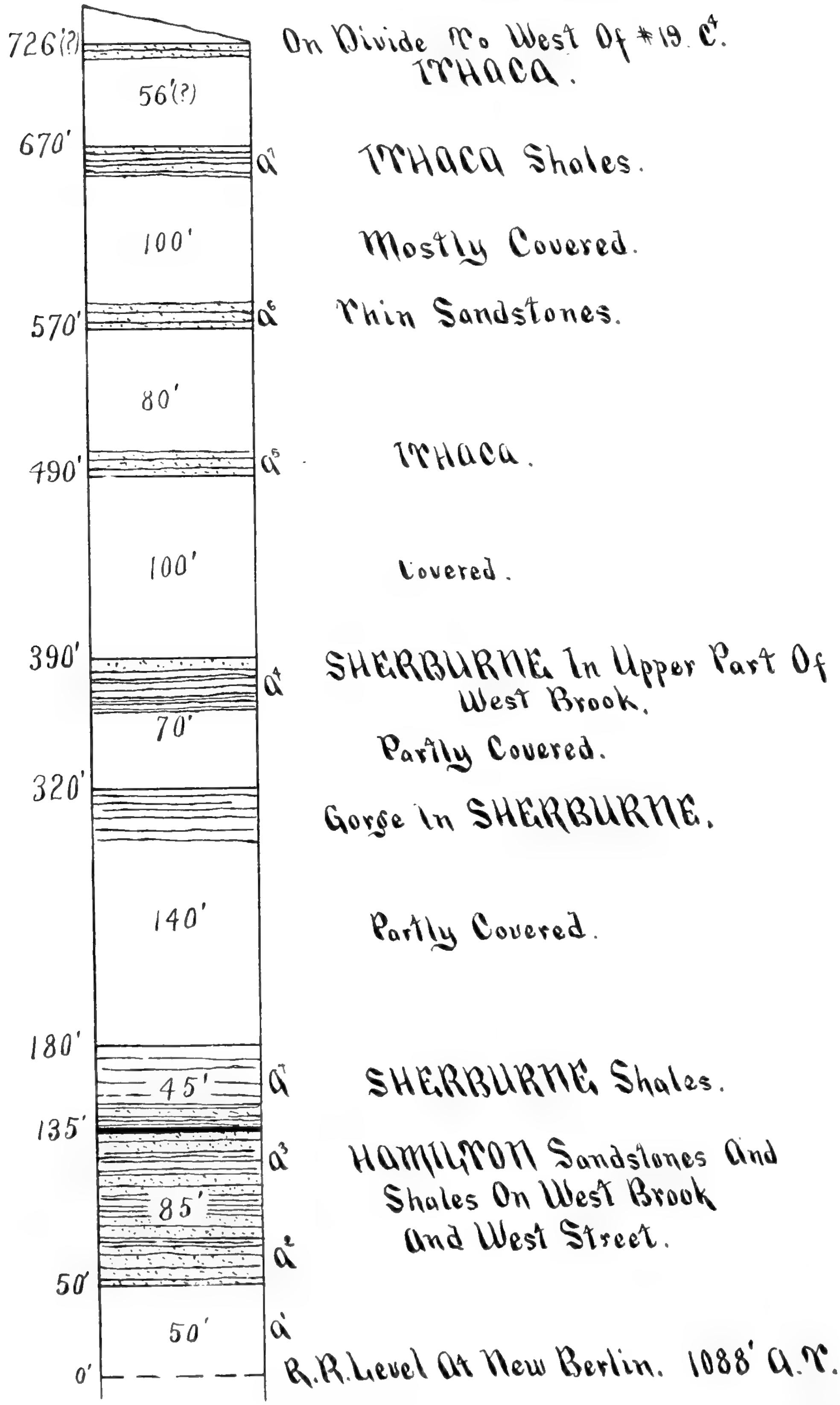
XX A⁴. One hundred feet lower than A^5, thin, micaceous sandstones alternating with shales, are well exposed along West brook. The surface of the thin sandstones is usually shiny, but some specimens have a glazed, blackish surface in which specimens of *Fucoides graphica*, Van., occur. These rocks are in the Sherburne formation, the top of which is probably not much above this outcrop. This ledge is 390 feet above the railroad station in New Berlin, or approximately 1,478 feet A. T. The thickness of the rocks from this outcrop down to the top of the Hamilton formation, as exposed on the banks of West brook in the edge of New Berlin village, is 255 feet, which is approximately the thickness that we have assigned to the Sherburne formation of Chenango county. Farther down the brook and some seventy feet lower is a rocky glen which gives an excellent idea of the Sherburne shales. The rocks are mostly bluish or blackish shales, forming steep banks on each side of the brook, with only sufficient space between them for the stream and highway. This formation continues down the brook into the edge of New Berlin village.

XX A^3. The base of the Sherburne formation occurs in West brook at the beginning of the former mill race and upper dam, just above the old brewery. This locality is now on the farm of Thomas Lowe, at which place the thin, bluish-grey, smooth sandstones and shale of the Sherburne formation are clearly shown resting directly on the bluish-black, coarser arenaceous shales of the Hamilton. There is apparently no representation of characteristic Tully limestone and Genesee slate. Fossils appear in the Hamilton shales just below the dam and, a little lower, the creek has cut a narrow gorge through these rocks with walls from twenty to twenty-five feet high. The top of the Hamilton is about 135 feet above the railroad level at New Berlin station, or approximately 1,223 feet A. T. These upper shales of the Hamilton are quite fossiliferous, but the number of species is small. The following were found in the shales just below the dam and above the gorge:

1. *Spirifer mucronatus*, (Con.), Bill. (c)
2. *Spirifer Tullius*, Hall. (c)

SECTION ALONG WEST BROOK IN NORTHERN NEW BERLIN AND SOUTHERN COLUMBUS. (*20. a)

1812' A.T. Approx.



3. *Leptodesma Rogersi*, Hall (?). (c)

Rather imperfectly preserved, but more like this than any other fossil figured.

*XX A*². In the lower part of the gorge of West brook in New Berlin village are coarse arenaceous shales alternating with those that are somewhat argillaceous. This exposure begins in the brook only a few rods above the Eagle hotel and about fifty feet above the railroad level. These upper Hamilton rocks are excellently shown in this gorge of West brook along West street in New Berlin village. Fossils are very abundant in layers, the following list giving a good idea of the fauna of this part of the formation:

1. *Spirifer audaculus* (Con.), Hall (?).

   It is possible that these specimens are all *S. granulosus* (Con.), Hall. The surface markings are not preserved and they are largely internal impressions.

2. *Spirifer granulosus* (Con.), Hall. (c)
3. *Spirifer mucronatus*, (Con.), Bill. (rr)
4. *Atrypa reticularis* (Linné), Dalm. (rr)
5. *Tropidoleptus carinatus* (Con.), Hall. (rr)
6. *Nucula lirata* (Con.), Hall. (rr)
7. *Modiomorpha mytiloides* (Con.), Hall. (rr)
8. *Ambocœlia umbonata* (Con.), Hall. (rr)
9. *Chonetes coronata* (Con.), Hall. (rr)
10. *Palæoneilo constricta* (Con.), Hall. (r)
11. *Pleurotomaria capillaria*, Con. (rr)
12. *Spirophyton velum* (Van.), Hall (?). (rr)

*XX B*¹. A brook enters the Unadilla river from the west, one and one-fifth miles south of New Berlin village, which affords a good exposure of the rocks just west of the river road. The lowest rocks, which are coarse, arenaceous shales containing an abundance of Hamilton species, form a small fall, above which is a short gorge and second fall. The fauna is as follows:

1. *Spirifer mucronatus* (Con.), Bill. (a)

   Typical mucronate forms of this species as in figure 15, plate 34, Vol. IV, Palaeontology of New York.

2. *Tropidoleptus carinatus* (Con.), Hall. (rr)
3. *Spirifer granulosus* (Con.), Hall. (rr)

   Or *S. audaculus* (Con.), H. Very much weathered external impressions.

4. *Spirifer Tullius*, Hall (?). (c)

Form of this species, but not well enough preserved to show the fine striae.

5. *Leptodesma Rogersi*, Hall. (rr)

XX B². Less than five feet above the top of the first fall are blue shales alternating with thin sandstones which form the rocky sides of the narrow gorge. These rocks have the typical lithologic characters of the Sherburne, and from their stratigraphic position undoubtedly belong at the base of that formation. This is one of the best localities found in the Unadilla valley for the purpose of illustrating the transition from the Hamilton to the Sherburne formation. It indicates that the conditions under which the Tully limestone and Genesee slate were formed had nearly ceased and that the lithologic characters of those formations are scarcely represented in the Unadilla valley. Vanuxem mentioned the occurrence of the Genesee slate at North New Berlin (now New Berlin)[1], but it was probably some of the rather darker shales of the Sherburne which he considered the Genesee, and, in fact, under his description of the formation it is stated that "The Genesee slate was not distinctly recognized east of the town of Smyrna in Chenango county."[2]

Fossils are very rare in these shales, only two fragments of a *Goniatites* and another of a different shell being found. In this glen the top of the Hamilton, according to barometric readings, is approximately 140 feet lower than it is at XX A³, in West brook, New Berlin village, scarcely two miles farther north, which would give, approximately, a dip to the south of seventy feet per mile. Although this dip is considerably greater than former estimates, still it agrees closely with the estimates in the earlier part of this report for the exposures ten miles farther west along the Chenango valley. The base of the Marcellus shale is north of Bridgewater in the upper part of the Unadilla valley, twenty miles north of XX B, and, providing the dip is as great for the entire distance as in the vicinity of New Berlin, we would have a thickness along the Unadilla valley of over 1,300 feet for the Marcellus and Hamilton formations. The lithologic characters and fauna of the Hamilton and Marcellus formations as shown along the Unadilla river valley from New Berlin to Bridgewater have been described in a former paper.[3] About one mile south of XX B is a smaller brook which exposes shales and thin sandstones of the Sherburne formation.

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[1] Geology of New York, Part III., p. 292.

[2] *Ibid.*, p. 169.

[3] Prosser: The Devonian section of central New York along the Unadilla river. Twelfth Annual Report State Geologist [New York], 1893, pp. 110–142.

XX C^1. About three and one-fourth miles south of New Berlin is the small hamlet of New Berlin Center. To the west of the Unadilla is a steep hill which rises between 400 and 500 feet above the river level. This hill was studied north of New Berlin Center and opposite the schoolhouse of District No. 4.

SECTION OF XX C, NORTH OF NEW BERLIN CENTER.

344′		Brow of hill.
	130′	Thin sandstones and arenaceous shales. *Ithaca.*
214′		C^2.
	162′	*Sherburne.*
52′		C^1. Fine blue shales.
	37′	Covered.
15′		Railroad level.
	15′	Covered.
0′		River level.

As the above section shows, the valley and lower part of the hill do not exhibit outcrops of rocks, but at C^1, fifty-two feet above the river, is a small exposure of thin blue shales which clearly belong in the Sherburne formation. Its base is probably below the bed of the river at this locality and the formation continues for about 214 feet up the hillside.

XX C^2. At 214 feet above the river level the rocks are coarser and consist of thin sandstones with arenaceous shales, the lower part containing but few fossils, which increase in abundance in the higher layers. These shales and sandstones are in the Ithaca formation, 130 feet of which occur before the brow of the steep part of the hill is reached. The fauna is as follows:

1. *Chonetes scitula*, Hall. (c)
2. *Chonetes setigera*, Hall. (c)
3. *Rhynchonella (Camarotœchia) eximia*, Hall.
4. *Spirifer mucronatus* (Con.), Bill. (r)
5. *Tropidoleptus carinatus* (Con.), Hall.
6. *Paracyclas lirata* (Con.), Hall. (rr)
7. *Nucula corbuliformis*, Hall. (rr)
8. *Modiomorpha subalata* (Con.), H., var. *Chemungensis*, H. (rr)
9. *Actinopteria* cf. *Theta*, Hall. (rr)

Morris.

Morris township, Otsego county, lies on the eastern side of the Unadilla river, directly east of the southern part of New Berlin township.

XX D^1. The hill on the eastern side of the river is steeper than the one on the western side, but unfortunately does not afford frequent exposures of the rocks. The road crossing the river south of schoolhouse No. 4 and section C, continues almost due south for over one mile until it reaches the east and west road on top of the divide. There are but few exposures along the steep road, most of the rocks being concealed by drift. At 305 feet above the river are rather thin sandstones, and loose pieces from apparently near this horizon contain some fossils. The species below were obtained from the loose blocks:

1. *Orthothetes Chemungensis* (Con.), Hall. (a)
   Abundant in the few blocks of stone found at this place.
2. *Phacops rana* (Green), Hall. (rr)
3. *Modiomorpha subalata* (Con.), Hall, var. *Chemungensis*, H. (rr)
4. *Actinopteria*, *sp.* (rr)

The greater part of the hill probably belongs in the Ithaca formation, with a hundred feet or so of the Sherburne formation at its base.

XX D^2. On the east and west road of the divide just east of the corners in the western part of Morris township are red, thin-bedded sandstones which alternate with those that are thin, green and coarse-grained. This outcrop is apparently near the base of the Oneonta formation. In the field to the north of the highway, some ten feet higher, is a ledge of grey, thin-bedded, coarse-grained sandstones, above which are red sandstones of similar texture. This is a characteristic outcrop of the Oneonta sandstone. The accompanying sketch gives an idea of the divisions of section D.

SECTION OF XX D, SOUTH OF NEW BERLIN CENTER.

665′		Heavy ledge of red and grey sandstone.
		Oneonta.
655′		Red and greenish thin sandstones.
	350′	*Ithaca.*
305′		D^1. Sandstones.
	305′	Covered. *Sherburne.*
0′		Unadilla river level.

On the "Preliminary Geologic Map of New York," published in 1896, the northern point of the Oneonta sandstone is represented as some two miles farther south; but the formation clearly forms the summit of the divide in this locality.

Two miles to the east is another four corners, where the road crosses the valley of Morris creek in the northern part of Morris. Near the corners, approximately 220 feet lower than the ledge of Oneonta sandstone at D^2, are thin arenaceous shales which contain the small form of *Spirifer mucronatus* (Con.), Bill. These rocks belong in the Ithaca formation, which continues northward and encloses the small glacial lake on the line of Morris and Pittsfield townships well toward the summit of the divide known as Matteson's lake.

XX E^1. At the top of the hill, northwest of Matteson's lake and overlooking the Unadilla valley, are thin arenaceous Ithaca shales, this formation continuing for at least 350 feet below the summit of the hill. An outcrop of these shales about fifty feet below the summit contains plenty of Ithaca fossils. The lower part of the hill belongs in the Sherburne formation which extends along the river road to north of the four corners above Silver lake.

Pittsfield.

Pittsfield township, Otsego county, is on the eastern side of the Unadilla river and lies east of the northern part of New Berlin and the southeastern corner of Columbus.

The line of division between the Hamilton and Sherburne formations runs in a northeasterly direction along the side of the hill east of the Unadilla river and Wharton creek to about two miles northeast of Pittsfield village, when it takes a more easterly course across the divide between Wharton and Butternut creeks. This line is twelve miles due north of that represented as the top of the Hamilton formation on the "Preliminary Geologic Map of New York"; but this difference, which will be found across Otsego county and still farther eastward, is due to the fact that the Sherburne and Ithaca formations were mapped as the upper part of the Hamilton in eastern New York.

Fossiliferous Hamilton shales and sandstones on the eastern bank of the Unadilla river in the northwestern part of Pittsfield, as well as the barren Sherburne shales and sandstones forming the long Pittsfield hill southeast of New Berlin, crossed by the New Berlin and Morris road, the top of which is capped by the Ithaca formation, were described by the writer several years ago.[1]

The lower part of the hill east of Wharton creek and New Berlin village shows ledges of arenaceous shales and thin sandstones which contain plenty of characteristic Hamilton fossils. Above, and approximately 135 feet higher than the railroad crossing below New Berlin, are thin, blue, unfossiliferous sandstones and shales that belong in the Sherburne formation. This indicates that the base of the Sherburne occurs at about the same elevation east of the Unadilla river as in West creek in New Berlin village.

XX F[1]. On the hillside east of Wharton creek, one-fourth mile northeast of Pittsfield village and about 180 feet above the railroad level of New Berlin, are rough arenaceous shales containing numerous Hamilton fossils. Ten feet higher are thin unfossiliferous sandstones which are perhaps in the base of the Sherburne. The fauna of F[1] is as follows:

1. *Spirifer granulosus* (Con.), Hall. (a)
2. *Tropidoleptus carinatus* (Con.), Hall. (aa)
3. *Cyrtina Hamiltonensis*, Hall. (rr)
4. *Ambocœlia umbonata* (Con.), Hall. (r)

[1] Twelfth Annual Report State Geologist [New York], pp. 133-136.

5. *Modiomorpha concentrica* (Con.), Hall. (rr)
6. *Palæoneilo emarginata* (Con.), Hall. (rr)
7. *Mytilarca* (*Plethomytilus*) *oviformis* (Con.), Hall. (r)
8. *Crinoid* segments and part of stems. (c)

XX F[2]. On top of the hill, one and one-half miles northeast of Pittsfield and near the township line between Pittsfield and Edmeston, are thin, rather irregular arenaceous shales containing Hamilton fossils. The top of the hill is barometrically 370 feet above the railroad at New Berlin, but it is two and one-half miles northeast of the locality at which the top of the Hamilton was found at an altitude of 135 feet above the railroad, and if the dip remains seventy feet or more per mile it would bring the top of the Hamilton near the summit of this hill. The nature of the rocks and fauna seems to favor the above conclusion and shows that the entire hill is composed of Hamilton rocks. Eighty feet below its summit are very coarse shales grading into sandstones that form rather prominent ledges containing an abundance of Hamilton fossils. *Spirifer granulosus* (Con.), Hall, is abundant; *Tropidoleptus carinatus* (Con.), Hall, common; *Pleurotomaria capillaria*, Con., rare. A careful search would yield considerable numbers of characteristic Hamilton species.

For some distance along the first brook entering Wharton creek from the east, one and one-half miles above Pittsfield, the fossiliferous Hamilton shales are found. To the south on the hillside the shales and sandstones of the Sherburne occur, while on the high hill to the south, 500 feet above the Hamilton shales in the brook, are those containing the fossils of the Ithaca formation. This exposure occurs on the high hill to the north of Ketchum. However, on account of the thick deposit of drift covering the rocks of the divide between the Wharton and Butternut creeks, it is difficult to describe very closely the geological formations of the region.

GEOLOGY OF SOUTHERN OTSEGO COUNTY.

The southern part of Otsego county is covered by rocks belonging to the Hamilton, Sherburne, Ithaca and Oneonta formations. In tracing the line of division between the Hamilton and Sherburne formations across this county, the geology of its southern part was quite carefully studied and will now be described.

New Lisbon.

XX H[3]. In the northwestern part of the township, one and one-half miles northwest of Garrattsville, is a small glacial lake known as Turtle lake. The ground is marshy about the lake, but along its outlet and in a small run which enters the brook from the south are rocky ledges. The arenaceous shales on the outlet of Turtle lake are apparently in the Hamilton formation, fossils being common, as the following list will show:

1. *Tropidoleptus carinatus* (Con.), Hall.	(a)
2. *Spirifer mucronatus* (Con.), Bill.	(rr)
3. *Spirifer granulosus* (Con.), Hall.	(rr)
4. *Spirifer Tullius*, Hall.	(rr)
5. *Cyrtina Hamiltonensis*, Hall.	(rr)
6. *Microdon (Cypricardella) tenuistriatus*, Hall.	(rr)
7. *Microdon (Cypricardella) bellistriatus*, Hall.	(rr)

It is somewhat difficult to determine sharply the line between the Hamilton and Sherburne on this hill. Shales or thin sandstones containing but a few fossils continue for forty feet up the small run southwest of the main creek. A few of the Hamilton species in this locality seem to occur somewhat above the horizon of the top of the Hamilton, in shales which, farther west, are in the lower part of the Sherburne.

XX H[4]. Sixty-five feet above the outlet of Turtle lake, greenish shales and sandstones begin and continue for fifty feet to the top of the hill. These rocks contain a few fossils; thirteen specimens of *Liorhynchus mesacostalis*, Hall, and two of *Spirifer mucronatus* (Con.), Bill., were collected beside specimens having fucoidal markings. These fifty or more feet of shales and sandstones are regarded as belonging in the Sherburne formation, but it appears that the unfossiliferous fine blue shales of the Unadilla valley have changed into these more arenaceous shales in which *Liorhynchus* is not uncommon. In the brook to the west of Turtle lake and near the divide, are smooth rocks which may belong in the Hamilton, while the loose ones on the ground are very similar to the Sherburne. The elevation of this locality is about the same as the horizon considered as the top of the Hamilton south of Turtle lake, but on account of the heavy deposit of drift over the region of the divide, it is difficult to determine accurately the underlying geologic formation.

XX H[2]. Ledges near the upper part of the glen, one-half mile northwest of Garrattsville and 120 feet higher than the village hotel. The rocks consist of shales and thin sandstones and contain plenty of Hamilton fossils. Typical Hamilton rocks with the characteristic fauna of the formation.

1. *Tropidoleptus carinatus* (Con.), Hall. (c)
2. *Spirifer mucronatus* (Con.), Bill. (r)
3. *Spirifer Tullius*, Hall. (c)
4. *Cryptonella (Eunella) Lincklæni*, Hall. (a)
5. *Stropheodonta perplana* (Con.), Hall. (rr)
6. *Palæoneilo fecunda*, Hall. (rr)
7. *Palæoneilo constricta* (Con.), Hall. (rr)
8. *Schizodus appressus* (Con.), Hall. (rr)
9. *Leda diversa*, Hall. (rr)
10. *Grammysia cuneata*, Hall. (rr)
11. *Grammysia arcuata* (Con.), Hall. (rr)

XX H[1]. In this same brook at the foot of the glen and only fifteen feet above the hotel, are argillaceous, blue, soft Hamilton shales, containing an abundant Hamilton fauna. The dip is heavy to the southwest, judging from the exposure in the brook. The following species were collected in a short time:

1. *Tropidoleptus carinatus* (Con.), Hall. (a)
2. *Spirifer mucronatus* (Con.), Bill. (c)
3. *Spirifer Tullius*, Hall. (rr)
4. *Grammysia alveata* (Con.), Hall (?). (rr)
5. *Nuculites triqueter*, Con. (c)
6. *Lunulicardium fragile*, Hall (?). (rr)

   Rather heavy concentric undulations like *Paracyclas*; too imperfectly preserved for positive identification.

7. *Chonetes lepida*, Hall (?). (rr)

   Specimens do not show the stronger striae near the center, although one is apparently the ventral valve.

8. *Pleurotomaria capillaria*, Con. (?). (rr)
9. *Pholadella radiata* (Con.), Hall. (rr)
10. *Phacops rana* (Green), Hall. (rr)
11. *Aviculopecten*, sp. (rr)

A section partly along this brook from Garrattsville northwest to Turtle lake is as follows:

325′		
	50′	H^4. *Sherburne.*
275′		
	25′	Covered. *Hamilton.*
250′		
	40′	
210′		H^3. Outlet of Turtle lake.
	90′	Partly covered.
120′		H^2.
	105′	Glen. *Hamilton.*
15′		H^1.
	15′	Covered.
0′		Garrattsville hotel level.

The hill on the western side of Butternut creek below Garrattsville is steep, but pretty well covered with drift, so that exposures of rocks are somewhat infrequent. About one and one-half miles below Garrattsville, Hamilton shales show by the roadside, while in the field, 150 feet higher, are rather thin arenaceous shales which run into sandstones and contain but few fossils, apparently in the upper part of the Hamilton. Seventy-five feet higher, or 225 feet above the road, are thin sandstones apparently in the Sherburne formation. Along the valley, three and one-quarter miles below Garrattsville and a short distance above Stetsonville, are rocks belonging in the Hamilton formation. On the road west, one hundred feet above the valley, are smooth, arenaceous, thin sandstones of the Sherburne formation. This agrees with the exposures of Sherburne found to the northwest in Pittsfield township about Ketchum, where the valleys and lower hills are composed of the Sherburne, with the Ithaca forming the summits of the higher hills.

The Hamilton probably follows the creek valley for a mile or more below Stetsonville, before reaching its upper limit. A dip of seventy feet per mile to the south would just about bring down what was called the top of the Hamilton on the hill south of Turtle lake to the level of the highway at Stetsonville. On the hillside, one mile below Stetsonville, and three miles northeast of Morris, are even-bedded, thin sandstones and arenaceous shales, in which no fossils were found belonging to the Sherburne formation.

One hundred feet higher, or 210 feet above the highway are shaly, arenaceous rocks (XX G¹) that contain abundant specimens of *Atrypa reticularis* (Linné), Dal., and a few other fossils. This ledge is probably in the lower part of the Ithaca formation. Below are more even-layered shales, with an occasional fossil similar to those in the more arenaceous portions of the Sherburne. The fauna of G¹ is:

1. *Atrypa reticularis* (Linné), Dal. (a)

   Rather small and gibbous specimens.

2. *Chonetes*, sp. (rr)
3. *Echinocaris* cf. *punctata*, (Hall), Whitfield. (rr)

   Part of the impression of the cephalothorax whose surface markings resemble those of this species.

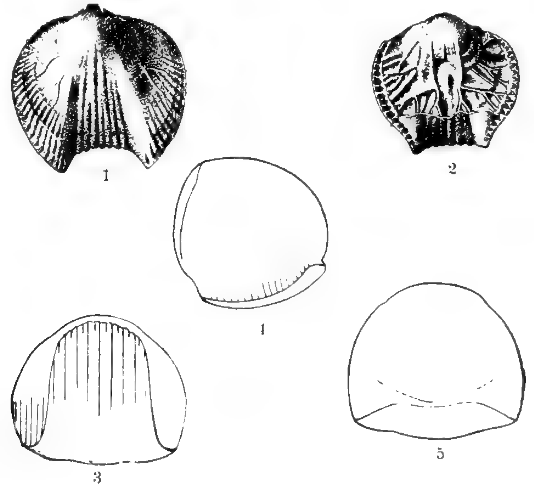
XXI B¹. East of the Butternut Creek, and directly east of Noblesville, near the foot of the hill, are quite smooth, greenish sandstones, in the midst of which are blocky shales in which *Rhynchonella venustula*, Hall, is common. A few other species are associated with the *Rhynchonella*, but they occur sparingly. Below this horizon are bluish shales which were shown in an excavation for a well, while higher on the hillside, along a small run, are thin, arenaceous shales, evidently the Sherburne formation, in which fossils were not found. The fauna of B¹ is:

1. *Spirifer mucronatus* (Con.), Bill. (rr)
2. *Atrypa reticularis* (Linné.), Dal. (r)

   The rather small form.

3. *Tropidoleptus carinatus* (Con.), Hall. (rr)
4. *Rhynchonella* (*Hypothyris*) *venustula*, Hall. (c)

While engaged in the field work necessary for determining the top of the Hamilton formation in the Butternut valley, the line of separation between the Hamilton and Sherburne formations was indicated as approximately the same horizon as that at which *Rhynchonella venustula* was found. Later, the specimens were carefully compared with the figures of this species and authentic specimens from the State Museum, and it was found that in form, number of plications in fold and sinus, and in vascular markings the specimens from Noblesville agree closely with typical specimens of *Rhynchonella venustula.*



RHYNCHONELLA (HYPOTHYRIS) VENUSTULA, Hall.
Noblesville, N. Y.

1. Partially exfoliated pedicle-valve, showing seven plications in the sinus.
2. Internal cast of pedicle-valve, showing vascular markings.
3-5. Front, lateral and cardinal views, showing the strongly gibbous form of the specimens.

The distribution of *Rhynchonella venustula*, Hall, which is either identical with or very closely related to the European species *R. cuboides*, Sowerby, has previously been confined to a belt of country in central New York, extending from Madison county on the east to Yates county on the west, and in its range Professor Hall reported the species "in the Tully limestone, at Tully and Tinker's falls in Onondaga county; at Ovid in Seneca county; at Benton and Penn Yan in Yates county, New York."[1] The final volume of the Palaeontology of New York (Brachiopoda II) does not indicate either a greater distribution or range for the New York species, although it notes its close relationship to the *R. cuboides* of Europe.[2] The species has also been considered by Professor H. S. Williams in a paper on "The Cuboides Zone and its Fauna," but no mention is made of its occurrence at additional localities.[3] Professor S. G. Williams in his paper on "The Tully limestone, its Distribution and its known Fossils," reported the species from South Lebanon in the southern part of Madison county,[4] which, as far as the writer is aware, was its farthest known eastern distribution previous to its discovery in Otsego county.

[1] Geological Survey, New York, Palaeontology, Vol. IV., Part I., 1867, p. 348.
[2] *Ibid.*, Vol. VIII., Part II., 1894, p. 200.
[3] Bulletin Geological Society of America, Vol. I., pp. 481-500.
[4] Sixth Annual Report State Geologist [New York] 1888, pp. 18, 27.

The discovery of *R. venustula* at Noblesville extends its distribution thirty miles farther to the southeast than heretofore reported; and on account of the very limited known range of the species this discovery is regarded as very strong evidence in support of the horizon considered in this report as the top of the Hamilton formation. The species was also noted at this position in the geological series at a few other places in Otsego county, and so it seems to the writer that this question as to where the line of division between the Hamilton and overlying formation is to be drawn in that county, should be finally settled by this evidence. This seems a perfectly tenable position, especially since the closely related species, *R. venustula*, of New York, and *R. cuboides*, of Europe, are regarded as occurring at very nearly the same geologic horizon. In the words of Professor H. S. Williams: "The correlation thus established is one not merely of homotaxy, but within relatively short limits, of contemporaneity; and that the Tully limestone may be said to have been deposited during the period of deposition of the *Cuboides Schichten*, of England, Belgium, France, Germany, Russia and the East."[1]

Along the road and a small stream to the southeast of Noblesville, are occasional exposures of smooth, unfossiliferous shales and thin sandstones belonging in the Sherburne formation.

XXI B². At the summit of the hill, 360 feet by the barometer above the ledge with *Rhynchonella venustula*, are quite fossiliferous, arenaceous shales and thin sandstones affording the following species:

1. *Spirifer mesastrialis*, Hall. (c)
2. *Spirifer mucronatus* (Con.), Bill. (rr)
3. *Rhynchonella (Camarotœchia) eximia*, Hall (?).
   Rather small specimens with sharp plications.

The specimens of *Spirifer mesastrialis* are typical and common, indicating these rocks to be in the Ithaca formation. It is probable that the base of the Ithaca beds is a hundred feet lower than the summit of the hill, and that the high land between Noblesville and Gilbert's lake belongs in this formation.

XXI C¹. At the three corners on the road following the township line between New Lisbon and Laurens, one-third of a mile west of Gilbert's lake, are rather coarse shales that are very fossiliferous, especially thin layers which are largely composed of *Spirifer mesastrialis*, Hall. A very brief time was spent in collecting, and only two other species were noted, viz.: *Atrypa reticularis*, (Linné), Dal., and *Tropidoleptus carinatus* (Con.), Hall. This locality is, according to one barometric reading, seventy feet lower than

[1] Bulletin Geological Society of America, Vol. I., p. 498.

XXI B² at the summit of the hill southeast of Noblesville, and 510 feet above the hotel in Laurens, four miles to the southeast in the valley of Otego creek.

To the north of Noblesville are occasional exposures of rather coarse, arenaceous shales in which Hamilton fossils are not uncommon. *Atrypa reticularis* (Linné), Dal., is one of the most common species. The shales with this species are exposed near the three corners, one and one-half miles northeast of Noblesville (XXIV D⁷), and still better shown in the ledges along the hillside in the northern part of school district No. 8. In the coarse arenaceous shales of XXIV D⁷ there was little opportunity for collecting, and only the three following species were noted:

1. *Atrypa reticularis* (Linné), Dal. (c)
2. *Productella*, sp. (r)

   A large species similar to the one found at XXIV D⁴, N. E. of Gilbert's lake.
3. *Phacops rana* (Green), Hall.

Hamilton ledges with characteristic fossils are well shown on the steep hillside above the corners, about one and one-quarter miles south of Garrattsville. To the northeast of the locality just mentioned and east of Garrattsville is a steep hill, the top of which may be capped by rocks belonging to the Sherburne formation. By the highway on the eastern side of the hill and about north of New Lisbon Centre are coarse, arenaceous Hamilton shales, which show glacial striae running S. 50° W.

Near the top of the hill to the northeast a loose piece of stone was found in the field in which *Rhynchonella (Hypothyris) venustula*, Hall, is common. In the same block was an internal impression of *Spirifer mucronatus* (Con.), Bill., and a *Chonetes*, sp. This block probably came from the same horizon as the one east of Noblesville in which the *Rhynchonellas* were found in place, and this indicates the extension of that horizon to the northeastward on the high hill in the northern part of New Lisbon. The top of the hill is so thoroughly covered by drift that exposures of the bed rock are rare; but the larger part of the loose pieces are apparently from the Hamilton formation mixed with unfossiliferous pieces, possibly from the Sherburne beds.

XXI A¹. To the northeast of Garrattsville a road climbs the steep hill east of Butternut creek, the summit of which is two miles from the village, giving a section of nearly 500 feet of Hamilton rocks. About one and one-half miles N. E. of Garrattsville and 335 feet above the level of Butternut creek are conspicuous ledges of bluish and iron-stained blocky shales that contain plenty of characteristic Hamilton fossils. One hundred and twenty feet higher, on the road near the top of the hill are bluish shales (XXI A²), containing numerous fossils belonging in the Hamilton formation. In a few minutes, specimens of the following species were found:

1. *Spirifer mucronatus* (Con.), Bill. (c)
2. *Cyrtina Hamiltonensis*, Hall. (rr)
3. *Ambocœlia umbonata* (Con.), Hall. (rr)

About thirty-five feet higher on the road running southwest, shales and thin sandstones outcrop which contain Hamilton fossils. This seems to show that the summit of the high hill two miles northeast of Garrattsville is in the Hamilton formation.

The section may be tabulated as follows:

SECTION OF HIGH HILL NORTHEAST OF GARRATTSVILLE.

490′		Shales at top of hill, *Hamilton.*
	35′	
455′		A². Bluish shales with *Spirifer mucronatus.*
	120′	
335′		A¹. Blocky shales.
	335′	
0′		Level of Butternut creek, *Hamilton.*

XXIV D⁶. Exposures of rather coarse, bluish shales at the lower end of the gorge one mile northeast of Noblesville and in the first brook north of that village. In these shales specimens of *Liorhynchus* are common, which are probably *L. mesacostalis*, Hall, although there is a decided tendency in the striae to remain on the sides of the shells as is the case with *L. multicosta*, Hall. It is probable that these shales are in the Sherburne formation, although they may perhaps represent the extreme upper part of the Hamilton. Twenty feet higher is an excellent outcrop of bluish, argillaceous shales in which no fossils were found.

XXIV D⁵. At the head of the gorge, two miles northeast of Noblesville, are bluish and olive argillaceous shales, with an occasional thick stratum of sandstone; these, according to the barometer, are 195 feet higher than D⁶. In some of these shales specimens of *Productella* are abundant, and the fauna would indicate the lower part of the Ithaca formation. Judging from several observations in the southern part of New Lisbon, the dip is very heavy to the southwest. The fauna of D⁵ is:

1. *Productella*, sp. (a)

Apparently between *P. speciosa*, Hall, and *P. lachrymosa* (Con.), Hall. One of the specimens is truncated at the beak.

2. *Atrypa reticularis* (Linné), Dal. (rr)
3. *Palæoneilo constricta* (Con.), Hall. (rr)

Almost identical with the small one figured on plate 48, figure 16 (Palaeontology of New York, Vol. V, Part I), from Ithaca, N. Y.

4. *Coral*, sp. (rr)
5. *Actinopteria eta*, Hall (?). (rr)

XXIV D^4. Ledges of coarse, arenaceous shales on the hillside west of Pool creek, three and one-third miles east of Noblesville and about three-quarters of a mile northeast of Gilbert's lake. The shales merge into thin sandstones which, on the weathered surfaces, are brownish from iron stain. The ledges show a heavy dip to the southwest. According to the barometer, this locality is 125 feet higher than D^5, and 320 feet above D^6. In these shales specimens of *Atrypa* and *Productella* are common, the complete fauna being:

1. *Atrypa reticularis* (Linné), Dal. (c)
2. *Productella*, sp. (c)

The specimens are large, with wrinkles and folds on the ears.

3. *Chonetes setigera*, Hall. (rr)
4. *Grammysia subarcuata*, Hall (?). (rr)

From a hasty examination of this region I was not able to positively determine the formation, and it is quite possible that on the accompanying geologic map the top of the Hamilton is represented somewhat too far to the south in the valley of Pool creek.

XXIV $D^{3\frac{1}{2}}$. On the divide between Pool creek and Fall brook, one and one-half miles east of D^4, are thin bluish and olive shales in which no fossils were found. This locality is in the southeastern part of New Lisbon, school district No. 16, and is, according to the barometer, 470 feet above the level of Otego creek at Mt. Vision, two and one-half miles to the southeast.

XXIV D^3. On the eastern side of the hill, by the roadside, about 110 feet below $D^{3\frac{1}{2}}$, are rather argillaceous shales in which Hamilton fossils are common, especially typical specimens of *Spirifer mucronatus* (Con.), Bill. These shales are clearly in the Hamilton formation, the top of which is then fully 360 feet above the level of Otego creek at this place. The fossils are:

1. *Spirifer mucronatus* (Con.), Bill. (a)
2. *Ambocœlia umbonata* (Con.), Hall. (c)

3. *Stropheodonta perplana* (Con.), Hall. (rr)
4. *Atrypa reticularis* (Linné), Dal. (rr)
5. *Palæoneilo emarginata* (Con.), Hall. (rr)

XXIV D[2]. Somewhat below the above locality the rocks of the hillside are well exposed along the gorge of Fall brook, which has rocky banks with several cascades in the course of its steep descent. All the rocks along the gorge are clearly Hamilton in age. In the upper part of the gorge above the upper bridge are bluish, arenaceous shales. Those near the top are thinner, and the layers more even, approaching thin sandstones in texture. The upper shales of the brook are about 230 feet above the level of the Otego creek, at Mt. Vision, one and three-quarter miles to the southeast. Fossils are common, and careful collecting would yield a fairly large number of species. The following were obtained in a short time:

1. *Spirifer granulosus* (Con.), Hall. (r)
2. *Terebratula (Eunella) Lincklaeni*, Hall, (rr)
3. *Ambocœlia umbonata* (Con.), Hall. (r)
4. *Spirifer Tullius*, Hall. (c)

   One of the noticeable features in the palaeontology of Otsego county is the large number of specimens of the above species in the upper Hamilton.

5. *Spirifer fimbriatus* (Con.), Bill. (rr)
6. *Tropidoleptus carinatus* (Con.), Hall. (rr)
7. *Stropheodonta perplana* (Con.), Hall (?). (rr)
8. *Chonetes setigera*, Hall. (rr)
9. *Nucula bellistriata* (Con.), Hall. (r)
10. *Palæoneilo perplana*, Hall. (rr)
11. *Grammysia (Sphenomya) cuneata*, Hall. (c)
12. *Phacops rana* (Green), Hall. (rr)

Under the upper bridge of Fall brook is a stratum containing numerous specimens of *Spirifer granulosus* (Con.), Hall.

XXIV D[1]. At the foot of the gorge, only sixty-five feet above the Otego creek, are bluish, rather coarse, arenaceous shales which contain plenty of fossils, especially *Tropidoleptus carinatus* (Con.), Hall. The list is as follows:

1. *Tropidoleptus carinatus* (Con.), Hall. (a)
2. *Spirifer mucronatus* (Con.), Bill. (r)
3. *Spirifer granulosus* (Con.), Hall. (rr)
4. *Microdon (Cypricardella) tenuistriatus*, Hall. (rr)

The following diagram will give an idea of the Fall brook section, extending from one and one-half to two and one-half miles northwest of Mt. Vision:

470′		D^{3+}. On divide, blue shales of *Sherburne.*
	110′	
360′		D^3. On road, *Spirifer mucronatus, Hamilton.*
	130′	
230′		D^2. Near top of rocks in Fall brook.
	100′	
130′		Abundant specimens of *Spirifer granulosus.*
	65′	
65′		D^1. Foot of Fall brook gorge. *Hamilton.*
	65′	Covered.
0′		Level of Otego creek at Mt. Vision.

Laurens.

The township of Laurens lies directly south of New Lisbon, except the northeastern corner, which is south of Hartwick, the township adjoining New Lisbon on the east. Otego creek flows through the eastern part of the township, bordered by a very steep hill on the eastern side, broken only by small brooks, the largest being Keyes brook in the northeastern corner of the township. The ridge on the western side of Otego creek is not nearly as steep as the one on the eastern side, and it is broken by a number of brooks and creeks of fair size, with corresponding valleys.

XXIV C^1. Slightly northeast of the village of Mt. Vision, in the northeastern corner of the township, is a steep hill, which rises 375 feet above the Otego creek, known as Mt. Vision. The hill lies between the valleys of Otego creek and Keyes brook, the latter being at its greatest distance only a little more than one and one-half miles east of Otego creek. The hill has, of course, been formed by the erosion of the streams on its eastern and western sides, with its steeper flank toward the larger stream and tapering to a point opposite the junction of the two streams. On the hillside, one hundred feet above the creek, are prominent ledges of coarse, arenaceous shales. They are quite coarse-grained, with every lithologic appearance of the coarser Hamilton, while the abundant Hamilton fauna refers them unquestionably to that formation. The list is:

1. *Spirifer Tullius*, Hall. (c)
2. *Spirifer mucronatus* (Con.), Bill. (c)
3. *Spirifer granulosus* (Con.), Hall (?). (rr)
4. *Tropidoleptus carinatus* (Con.), Hall. (c)
5. *Chonetes coronata* (Con.), Hall. (rr)
6. *Ambocœlia umbonata* (Con.), Hall. (rr)
7. *Stropheodonta demissa* (Con.), Hall. (rr)
8. *Microdon* (*Cypricardella*) *tenuistriatus*, Hall (?). (rr)
   Probably young specimens of this species, though they resemble somewhat figures 19 and 20, plate 73 of *M. bellistriatus*, Con.
9. *Tellinopsis subemarginata* (Con.), Hall. (rr)
10. *Modiomorpha mytiloides* (Con.), Hall. (rr)
11. *Glyptodesma erectum* (Con.), Hall. (rr)
12. *Pterinea flabella* (Con.), Hall. (rr)
13. *Liopteria DeKayi*, Hall. (rr)
14. (?) *Psilophyton princeps*, Dn. (rr)
   Fragment.

Near the top of the hill, about 207 feet above the base of C[1], is an irregular, concretionary stratum, similar to those which are not unfrequently found in the upper Hamilton and higher formations of eastern New York.

XXIV C[2]. At the top of the steep escarpment, near the brow of the hill, some 350 feet above the creek level, are thin sandstones and shales, certain layers of which contain many specimens of *Spirifer mucronatus* (Con.), Bill. The following species were collected:

1. *Spirifer mucronatus* (Con.), Bill. (a)
2. *Cyrtina Hamiltonensis*, Hall. (rr)
3. *Orthothetes Chemungensis* (Con.), Hall. (rr)
4. *Ambocœlia umbonata* (Con.), Hall. (rr)
5. (?) *Aviculopecten princeps* (Con.), Hall. (rr)

The rocks and fauna of this outcrop are similar to those of XXIV D[3], on the western side of Otego creek, about 360 feet above its level. It seems clear that the Hamilton formation extends to the top of the ledges on Mt. Vision and forms nearly, if not quite all of the hill.

SECTION OF MT. VISION.

375′		Top of Mt. Vision.
350′		C². *Hamilton* ledges at brow of hill.
	43′	
307′		Concretionary stratum.
	207′	
100′		C¹. *Hamilton.*
	100′	
0′		Level of Otego creek at Mt. Vision.

XXIV B¹. About three-quarters of a mile south of Mt. Vision, on the eastern side of Otego creek, is a rocky hillside on the Field farm, known locally as the "Owl Patch." A short distance farther south, the point of the hill strikes the highway about seventy-five feet above the creek level, and thin, argillaceous, quite fossiliferous shales of bluish or olive color with thin strata of sandstone are quite well exposed by the roadside. The following species were obtained:

1. *Spirifer mucronatus* (Con.), Bill. (c)
2. *Atrypa reticularis* (Linné), Dal. (rr)
3. *Goniophora Hamiltonensis* (Hall), Miller. (rr)
4. *Nuculites oblongatus*, Con. (rr)
5. *Platyceras*, sp.

XXIV B². Seventy-five feet higher on the hillside, in the "Owl Patch," are conspicuous ledges of coarse, arenaceous shales, in lithologic character and fauna similar to those of the lower ledges (XXIV C¹) of Mt. Vision. This outcrop belongs in the Hamilton formation, and the fossils are abundant and typical, as will be seen below:

1. *Spirifer mucronatus* (Con.), Bill. (c)
2. *Tropidoleptus carinatus* (Con.), Hall. (r)
3. *Spirifer Tullius*, Hall. (c)
4. *Tellinopsis subemarginata* (Con.), Hall. (rr)
5. *Microdon (Cypricardella) tenuistriatus*, Hall. (a)

   These specimens are smaller than the figures of this species and perhaps are the forms of *M. bellistriatus*, Con., which have fine striae, but they agree with the description of the young forms of *M. tenuistriatus*, Hall.

6. *Nucula corbuliformis*, Hall. (rr)
7. *Grammysia arcuata* (Con.), Hall. (rr)

8. *Palæoneilo constricta* (Con.), Hall. (rr)
9. *Liopteria DeKayi*, Hall (?) (c)

All imperfectly preserved.

*XXIV B*³. Ledges are rather conspicuous on the hillside towards its top, and 170 feet above B² is a prominent ledge of even-bedded, thin sandstones forming the upper terrace of the hillside. These sandstones are fine-grained, greyish to slightly olive in color, weathering to a brownish grey. Portions of them are literally filled with specimens of all sizes of *Rhynchonella venustula*, Hall, although scarcely any other fossils occur; a broken specimen *Paracyclas lirata* (Con.), Hall (?), being the only one noted. In the loose fragments among the talus, apparently from this ledge, were pieces of rock containing abundant specimens of *Spirifer mucronatus* (Con.), Bill., and a single broken specimen of *Palæoneilo emarginata* (Con.), Hall (?). The hill is rounded above this ledge and does not extend much higher, and the rocks are covered by soil; but the presence of the abundant specimens of *Rhynchonella venustula* indicates that the Hamilton formation extends nearly to its summit. This ledge is 320 feet above the level of Otego creek, and when the hill is compared with Mt. Vision, rather more than three-quarters of a mile to the north, the highest rocks of which are 350 feet above the creek level, or the top of the hill approximately 375 feet above the creek, it will be seen that all of that hill must belong in the Hamilton formation, since a dip of seventy-five feet per mile, probably less than the true dip, would carry the Hamilton rocks over the summit of Mt. Vision.

This *Rhynchonella venustula* ledge is seven miles southeast of the locality already described near Noblesville, carrying the distribution of the species so much farther eastward, as well as fixing precisely in the Otego valley a point for the separation of the Hamilton and Sherburne formations.

SECTION OF THE "OWL PATCH," THREE-QUARTERS OF A MILE SOUTH OF MT. VISION.

320′		B³. Thin sandstones with abundant specimens of *Rhynchonella venustula*. Top of *Hamilton*.
	170′	
150′		B². Coarse, arenaceous shales, abundant Hamilton fossils.
	75′	
75′		B¹. *Hamilton* shales on highway.
	75′	
0′		Otego creek level.

XXIV A[1]. Shales and thin blue sandstones by the side of the highway along Lake brook, one-half mile northwest of Laurens. This locality is about three miles southwest of the "Owl Patch" (XXIV B[2 & 3]), and 110 feet above the main street of Laurens. In some layers there are plenty of fossils, especially *Spirifer mucronatus* (Con.), Bill. The complete list is as follows:

1.	*Spirifer mucronatus* (Con.), Bill.	(a)
2.	*Tropidoleptus carinatus* (Con.), Hall.	(rr)
3.	*Atrypa reticularis* (Linné), Dal.	
4.	*Conularia undulata*, Con.	(rr)
5.	*Athyris Cora*, Hall (?).	(rr)

XXIV A[2]. Coarse, arenaceous shales on hill, one and four-tenths miles northwest of Laurens and 260 feet above the main street. They form a prominent outcrop in the field on the eastern side of the east and west cross-road, and contain numerous specimens of *Atrypa reticularis* and *Spirophyton*. The list is:

1.	*Atrypa reticularis* (Linné), Dal.	(a)
2.	*Cyrtina Hamiltonensis*, Hall.	(rr)
3.	*Productella*, sp.	(c)
4.	*Actinopteria decussata*, Hall (?).	(rr)
5.	*Spirophyton*, sp.	(rr)

These shales of XXIV A[1] and A[2], resemble those of the Hamilton group more than they do those of the Ithaca formation.

Hartwick.

Hartwick township lies east of New Lisbon and Burlington, and north of Laurens and Milford townships, its southern half extending eastward to the Susquehanna river. The topography of the southern half exhibits steep hills bordering narrow valleys, the most important of which is the Susquehanna.

XXIV C[3]. In the southern part of the township, two and one-half miles northeast of the village of Mt. Vision, is a high hill, known as Bowie hill, the summit of which is approximately 750 feet higher than the valley of Otego creek at Mt. Vision. Above the top of Mt. Vision which, as already stated, is in the Hamilton, the rocks are mostly covered by drift. At the school-house No. 15, on the road directly south of Bowie hill, are bluish, argillaceous shales, very similar to the Sherburne formation, in which only a single specimen of *Chonetes setigera*, Hall, was found.

XXIV C[4]. Near the summit of Bowie hill, some 715 feet above Otego creek, about one-half mile southwest of Arnold lake, is an outcrop of rather coarse-grained, bluish to dark grey sandstone, containing numerous specimens of *Spirifer mesastrialis*, Hall. There are shaly partings with iron concretions, and these shales are more fossiliferous than the massive sandstones, for they contain numerous specimens of *Spirifer mucronatus* (Con.), Bill.; *Tropidoleptus carinatus* (Con.), Hall; *Chonetes setigera*, Hall; *Rhynchonella Stevensi*, Hall, and *Liorhynchus mesacostalis*, Hall. Loose pieces of bluish, arenaceous shales scattered over the top of the hill contain specimens of *Liorhynchus mesacostalis*, Hall, and fucoidal markings. The rocks in place near the summit of Bowie hill clearly belong in the lower part of the Ithaca formation. The complete fauna is:

1. *Spirifer mesastrialis*, Hall. (c)
2. *Spirifer mucronatus* (Con.), Bill. (a)
3. *Tropidoleptus carinatus* (Con.), Hall. (a)
4. *Liorhynchus mesacostalis*, Hall. (c)
5. *Cyrtina Hamiltonensis*, Hall. (r)
6. *Chonetes setigera*, Hall. (r)
7. *Rhynchonella* (*Camarotœchia*) *Stevensi*, Hall. (a)
   Some of the smaller specimens more closely resemble *R. eximia*, Hall; but it is probable that the two forms blend into one species.
8. *Atrypa reticularis* (Linné), Dal. (rr)
9. *Actinopteria Boydi* (Con.), Hall. (c)
10. *Grammysia bisulcata* (Con.), Hall (?). (rr)

SECTION OF MT. VISION AND BOWIE HILL.

715′		C[4]. *Ithaca. Spirifer mesastrialis.*
	115′	Covered.
600′		C[3]. *Sherburne* (?).
	250′	Covered.
350′		C[2]. *Hamilton.*
	250′	
100′		C[1]. *Hamilton.*
	100′	Covered.
0′		Otego creek level at Mt. Vision.

XXIV C[5]. Along the outlet of Arnold lake, about 135 feet lower than the top of Bowie hill, are quite fossiliferous bluish sandstones and shales. Lower, along the highway to the southwest, are bluish thin shales with layers of thin concretionary sandstones which contain specimens of *Liorhynchus mesacostalis*, Hall, and *Spirifer mucronatus* (Con.), Bill. This fauna resembles very closely the first of the Ithaca fauna as it appears at the top of the Sherburne formation, to which horizon these rocks are referred. The following species were obtained from the bluish shaly sandstones at the outlet of the lake and have been referred to the Ithaca fauna:

1. *Liorhynchus mesacostalis*, Hall. (c)
2. *Spirifer mucronatus*, (Con.), Bill. (c)
3. *Spirifer mesastrialis*, Hall. (c)
4. *Grammysia elliptica*, Hall. (rr)
5. (?) *Terebratula* (*Eunella*) *Lincklaeni*, Hall. (c)

The imperfect form in which these specimens are preserved renders their identification difficult. Possibly they are narrow specimens of *Cryptonella Eudora*, Hall.

Arnold lake is well surrounded by hills with steep banks, and the ice of the glacial period probably excavated its basin.

C[6]. On the divide to the east of Arnold lake, from C[5] and somewhat higher, are thin olive shales and sandstones in which no fossils were found, except fucoid markings. The lithologic characters of the rocks and the absence of fossils make this outcrop agree closely with those in the Sherburne formation. To the east is a very steep hill, dropping 300 feet into the valley of Hinman Hollow brook; but, unfortunately, its flank is mostly covered by drift.

XXV A[1]. On the small divide between Hinman Hollow brook and a small branch from the western side not over a mile to the northeast of Arnold lake, and 290 feet below the divide at C[6], are ledges of coarse, bluish, arenaceous shales containing Hamilton fossils in abundance. The outcrop is on the north side of the road and is an excellent locality for collecting. There can be no doubt in reference to the Hamilton age of these rocks. The fauna is:

1. *Athyris spiriferoides* (Eaton), Hall. (a)
2. *Cyrtina Hamiltonensis*, Hall. (c)
3. *Spirifer granulosus* (Con.), Hall. (c)
4. *Spirifer mucronatus* (Con.), Bill. (c)
5. *Spirifer fimbriatus* (Con.), Bill. (c)
6. *Chonetes scitula*, Hall. (a)

7. *Chonetes setigera*, Hall. (r)
8. *Ambocœlia umbonata* (Con.), Hall. (c)
9. *Tropidoleptus carinatus* (Con.), Hall. (c)
10. *Terebratula* (*Eunella*) *Lincklaeni*, Hall. (c)
11. *Productella truncata*, Hall (?). (rr)
12. *Atrypa reticularis* (Linné), Dal. (rr)
13. *Orthothetes Chemungensis* (Con.), Hall and Clarke, var. *arctostriata*, Hall. (c)
14. *Microdon* (*Cypricardella*) *tenuistriatus*, Hall. (c)
15. *Chonetes coronata* (Con.), Hall. (c)
16. *Leda diversa*, Hall. (r)
17. *Palæoneilo muta*, Hall. (r)
18. *Nucula corbuliformis*, Hall. (rr)
19. *Modiomorpha concentrica* (Con.), Hall. (rr)
20. *Grammysia arcuata* (Con.), Hall. (rr)
21. (?) *Phthonia cylindrica*, Hall. (rr)
22. *Pterinopecten Vertumnus*, Hall (?). (rr)
23. *Coleolus tenuicinctus*, Hall. (rr)
24. *Bellerophon*, sp. (r)

    Compressed specimens that have concentric and longitudinal striae of about equal strength.

25. *Cypricardinia indenta* (Con.), Hall. (rr)
26. *Spirifer Tullius*, Hall. (rr)
27. *Orthis Vanuxemi*, Hall. (rr)
28. *Palæoneilo constricta* (Con.), Hall. (r)
29. *Phthonia sectifrons* (Con.), Hall. (rr)
30. *Schizodus appressus* (Con.), Hall. (rr)
31. *Glyptodesma erectum* (Con.), Hall. (rr)
32. *Microdon* (*Cypricardella*) *bellistriatus*, Con. (?). (rr)
33. *Nucula bellistriata* (Con.), Hall. (r)
34. *Liopteria DeKayi*, Hall. (r)

    Small and young specimens, like figure 10, plate 88 (Palaeontology of New York, Vol. V, Part I).

35. *Pleurotomaria capillaria*, Hall. (rr)
36. *Trilobite* (fragment). (rr)
37. *Tæniopora exigua*, Nicholson. (c)

*XXV A*³. Nearly one mile directly east of A¹ on the high hill between Hinman Hollow brook and the Susquehanna river, is another small glacial lake, known as Gowey or Little Pond. On the hill north of the pond and 145 feet higher, or over 500 feet above the Susquehanna river at Clintonville, one and one-half miles to the southeast, are thin sandstones and bluish shales that are unfossiliferous. They belong in the Sherburne formation which caps the high hill between the Hinman Hollow brook and the Susquehanna river.

XXV A². On the divide to the east of Gowey pond, just at the beginning of the descent into the Susquehanna river valley, argillaceous shales with thin layers of blue sandstone show on the highway and in the field. This outcrop is a little more than one mile southwest of Hartwick Seminary, at an altitude of 400 feet above the Susquehanna river, and is typical Hamilton, both in its lithologic appearance and its fauna. The following species were collected:

1.	*Athyris spiriferoides* (Eaton), Hall.	(c)
2.	*Tropidoleptus carinatus* (Con.), Hall.	(c)
3.	*Chonetes coronata* (Con.), Hall.	(c)
4.	*Spirifer mucronatus* (Con.), Bill.	(r)
5.	*Spirifer Tullius*, Hall.	(rr)
6.	*Ambocœlia umbonata* (Con.), Hall.	(rr)
7.	*Chonetes scitula*, Hall.	(rr)
8.	*Orthis Vanuxemi*, Hall.	(rr)
9.	(?) *Crania*, sp.	(rr)
10.	*Modiomorpha concentrica* (Con.), Hall.	(rr)
11.	*Chonetes lepida*, Hall.	(r)
12.	*Cypricardinia indenta* (Con.), Hall.	(rr)
13.	*Nucula bellistriata* (Con.), Hall.	(c)
14.	*Leda diversa*, Hall.	(rr)
15.	*Schizodus appressus* (Con.), Hall.	(rr)

SECTION OF HILL NORTH AND EAST OF GOWEY POND.

510′		A³. *Sherburne.*
	110′	
400′		A². *Hamilton.*
	400′	Mostly covered.
0′		Level of Susquehanna river at Clintonville.

PLATE III

NARROW GORGE, ONE MILE NORTH OF MILFORD; SHOWING THIN SHALES OF THE UPPER HAMILTON.

In all this region between the Unadilla and Susquehanna rivers, the hills are so mantled with the drift that it is frequently puzzling to determine precisely where to draw the line of separation between different formations. The streams in general afford the most satisfactory sections, although outcropping ledges on the sides of the steep hills sometimes furnish valuable assistance.

Milford.

The township of Milford lies south of Hartwick and east of Laurens and Oneonta. The Susquehanna river flows through the eastern part of the township, to the east of which is a high and steep hill, while on the western side the hill rises much more gradually and is broken by a number of small valleys.

XXV B[1]. In the northern part of the township is the village of Milford, and nearly one mile north of the village is a gorge along a small brook. At the old mill the channel of the brook is narrow, with rock walls which afford an excellent idea of the nature of the rather thin shales of the upper Hamilton. The blue shales with which some thin sandstones alternate, contain abundant specimens of *Spirifer mucronatus* (Con.), Bill., and the complete list is:

1. *Spirifer mucronatus* (Con.), Bill. (a)
2. *Chonetes lepida*, Hall. (rr)
3. *Tropidoleptus carinatus* (Con.), Hall. (rr)
4. *Palæoneilo fecunda*, Hall. (rr)

XXV B[2]. At the upper end of the short gorge, just below the highway bridge, are bluish argillaceous shales in which Hamilton fossils are abundant. The locality is about thirty feet above B[1] and perhaps 130 feet above the hotel in Milford. This is a good locality for collecting, and the following species were obtained in a short time:

1. *Spirifer mucronatus* (Con.), Bill. (aa)
2. *Chonetes setigera*, Hall. (aa)
3. *Chonetes lepida*, Hall. (c)
4. *Tropidoleptus carinatus* (Con.), Hall. (c)
5. *Chonetes scitula*, Hall. (rr)
6. *Orbiculoidea*, sp. (rr)
7. *Nuculites triqueter*, Con. (rr)
8. *Schizodus appressus* (Con.), Hall. (c)
9. *Palæoneilo constricta* (Con.), Hall. (rr)

10. *Microdon (Cypricardella) tenuistriatus* (?), Hall.
11. *Goniophora Hamiltonensis* (Hall), Miller. (rr)
12. *Nucula lirata* (Con.), Hall. (rr)
13. *Grammysia arcuata* (Con.), Hall. (rr)
14. *Cimitaria recurva* (Con.), Hall. (rr)
15. *Palæoneilo maxima* (Con.), Hall. (rr)
16. *Modiomorpha mytiloides* (Con.), Hall. (rr)
17. *Dalmanites (Cryphæus) Boothi* (Green), Hall. (rr)

XXV C[1]. This station is located at the point where the "Gulf road" crosses the brook at the falls, one mile northwest of Milford, and about two hundred and ten feet higher than the hotel. The rocks forming the falls are coarse, arenaceous Hamilton shales, containing numerous specimens of *Spirifer granulosus* (Con.), Hall and Clarke, together with other fossils usually found in the coarser Hamilton shales. Along the highway just above the falls are finer shales, in which only the smaller forms of fossils occur. The fauna is:

1. *Spirifer granulosus* (Con.), Hall and Clarke. (a)
2. *Tropidoleptus carinatus* (Con.), Hall. (c)
3. *Chonetes coronata* (Con.), Hall. (r)
4. *Cyrtina Hamiltonensis*, Hall. (r)
5. *Spirifer fimbriatus* (Con.), Bill. (rr)
6. *Platyceras conicum*, Hall (?). (rr)
7. *Crinoid* segments. (c)
8. *Spirifer mucronatus* (Con.), Bill. (rr)
9. *Macrodon Hamiltoniæ*, Hall. (rr)
10. *Modiomorpha concentrica* (Con.), Hall. (rr)
11. *Microdon (Cypricardella) tenuistriatus*, Hall (?). (rr)
12. *Nucula corbuliformis*, Hall. (rr)
13. *Mytilarca (Plethomytilus) oviformis* (Con.), Hall. (r)
14. *Aviculopecten princeps* (Con.), Hall (?). (rr)
15. *Pleurotomaria capillaria*, Con. (rr)
16. *Coleolus tenuicinctum*, Hall. (rr)

XXV D[1]. Exposures along a small brook one and one-quarter miles southwest of Milford, to the north of the Edson's Corners road, and 195 feet above the Susquehanna river at Portlandville. Moderately coarse shales contain numerous Hamilton fossils, and the rocks are unhesitatingly referred to the Hamilton formation. The fauna is:

1. *Tropidoleptus carinatus* (Con.), Hall. (r)
2. *Chonetes coronata* (Con.), Hall. (rr)

PLATE IV

SHERBURNE SHALES ON HILL ONE MILE SOUTHWEST OF MILFORD

3. *Chonetes setigera*, Hall. (r)
4. *Nucula corbuliformis*, Hall. (rr)
5. *Nucula bellistriata* (Con.), Hall. (r)
6. *Nuculites triqueter*, Con. (rr)
7. *Leda diversa*, Hall. (rr)
8. *Ambocœlia umbonata* (Con.), Hall. (rr)
9. *Pleurotomaria capillaria*, Con. (rr)

XXV D[2]. In the field to the north of the brook and 225 feet higher, or 420 feet above the river, is a ledge of arenaceous shales and thin sandstones. The shales are partly thin and even-bedded, similar to the Sherburne, and unfossiliferous, with the exception of a layer possibly one inch thick. The thin layer in which the fossils occur is largely composed of specimens of *Spirifer*. A few of these are quite large, with the form and conspicuous fine striae of *Spirifer mesastrialis*, Hall; but the majority of them approach in form, nearer to *Spirifer Tullius*, Hall. These were the only fossils found at this exposure, and, as far as observed, were confined to the one-inch layer. I am inclined to regard them as representing the first of the Ithaca fauna appearing in rocks that are synchronous with the upper part of the Sherburne formation in the Chenango valley.

On the river road, one mile south of the point at which the Edson's Corners road joins it, are bluish shales that contain some Hamilton fossils. At this locality these shales are some sixty feet above the Susquehanna river level. The top of the Hamilton is considered to pass beneath the river level in the vicinity of Portlandville.

XXII E[2]. Short gorge in small brook just northwest of Milford Centre, about one and one-quarter miles southwest of Portlandville, or five miles southwest of Milford. In the glen, forty-five feet of shales and thin bluish sandstones are well exposed, and afford a good illustration of the unfossiliferous Sherburne rocks of the Susquehanna valley. In some of the blue, arenaceous, thin sandstones are fucoidal markings very similar in shape and general appearance to those figured by Vanuxem and Hall as *Fucoides graphica*, Van., from the Portage of central and western New York.

XXII E[3]. In the brook at the upper bridge and ten feet above the top of the gorge, are bluish, quite fossiliferous, rather arenaceous shales that contain the lower Ithaca fauna, Spirifers occurring in several layers. The locality is approximately 200 feet above the Susquehanna river level at Portlandville, which would indicate a thickness of at least 200 feet for the Sherburne formation in the Susquehanna valley. The fauna is:

1.	*Spirifer mucronatus* (Con.), Bill. Long mucronate specimens.	(a)
2.	*Chonetes setigera*, Hall. Typical specimens.	(aa)
3.	*Palæoneilo emarginata* (Con.), Hall.	(rr)
4.	*Grammysia elliptica*, Hall (?).	(rr)
5.	*Liorhynchus mesacostalis*, Hall.	(rr)
6.	Segments of small *Crinoid* stems.	(a)

SECTION OF THE MILFORD CENTRE GLEN.

200′		E^3. *Ithaca.*
	10′	
190′		
	45′	E^2. *Sherburne* of glen.
145′		
	145′	Covered.
0′		Susquehanna river level at Portlandville.

XXII E^1. On the river road, about two miles south of Milford Centre, or one-half mile north of Colliersville, are bluish shales by the side of the highway. This exposure is eighty feet higher than the Delaware and Hudson railroad at South Milford. Most of the rock consists of thin, blue, arenaceous shales, like those of the Sherburne formation, although a few fossils, small specimens of *Spirifer mucronatus* (Con.), Bill., and two imperfectly preserved specimens of *Chonetes scitula*, Hall, were found. On the hill to the northeast of South Milford, in the edge of Maryland township, are exposures of the Sherburne sandstones some 140 feet higher than the South Milford railroad station.

XXV E^1. Crossing the Susquehanna river at Portlandville, the line of division between the Hamilton and Sherburne was followed northeasterly along the western slope of the steep Crumhorn mountain. About one and one-half miles southeast of Milford, and below the corner of the road for Crumhorn lake, are ledges of rather coarse, arenaceous Hamilton shales on the side of the hill, perhaps 150 feet higher than the river. These shales contain a characteristic Hamilton fauna, as may be seen from the following list:

PLATE V

THE WHITE QUARRY WEST OF ONEONTA ITHACA GROUP.

1. *Spirifer granulosus* (Con.), Hall. (c)
2. *Spirifer mucronatus* (Con.), Bill. (c)
3. *Spirifer Tullius*, Hall. (rr)
4. *Chonetes coronata* (Con.), Hall. (c)
5. *Tropidoleptus carinatus* (Con.), Hall. (a)
6. *Stropheodonta demissa* (Con.), Hall (?). (rr)
7. *Orthothetes Chemungensis* (Con.), Hall and Clarke. (rr)
8. *Cyrtina Hamiltonensis*, Hall. (rr)
9. *Terebratula (Eunella) Lincklaeni*, Hall. (rr)

About opposite Milford village, the Cherry Valley creek enters the Susquehanna river from the east. The top of the Hamilton follows the western side of Crumhorn mountain, on the eastern side of Cherry Valley creek, to the northeast into Westford township. In the brook southeast of Westville village, 420 feet above it and five and one-quarter miles northeast of Milford village, are bluish shales containing plenty of Hamilton fossils and belonging to the Hamilton formation. The fauna is:

1. *Spirifer Tullius*, Hall. (r)
2. *Spirifer mucronatus* (Con.), Bill. (rr)
3. *Chonetes coronata* (Con.), Hall. (rr)
4. *Chonetes scitula*, Hall. (rr)
5. *Chonetes setigera*, Hall. (rr)
6. *Ambocœlia umbonata* (Con.), Hall. (rr)
7. *Crania Hamiltoniæ*, Hall (?). (rr)
8. *Nucula bellistriata* (Con.), Hall. (rr)
9. *Grammysia (Sphenomya) cuneata*, Hall. (rr)

In the upper part of the "Gulf," about one and one-half miles east of Westville, 560 feet above the village, are even shales and thin sandstones that are apparently unfossiliferous and belong in the Sherburne formation. Loose specimens contain *Tropidoleptus carinatus* (Con.), Hall. The top of the hill is some 900 feet above Westville village.

XXV G[1]. The top of the Hamilton follows around the side of the steep hill to the northeast of Westville, and is crossed by the hill road winding down the steep northeastern side toward Westford village, about two and one-half miles from Westville. The upper part of the hill is composed of the arenaceous shales and thin sandstones of the Sherburne formation; but on the road, 525 feet above the valley of Elk creek, two miles below Westford, are bluish argillaceous shales which break into rather small pieces and contain specimens of the smaller Hamilton fossils. The following species were collected:

1. *Chonetes scitula*, Hall. (rr)
2. *Spirifer mucronatus* (Con.), Bill. (rr)
3. *Tropidoleptus carinatus* (Con.), Hall. (rr)
4. *Orthis Vanuxemi*, Hall. (r)
5. *Nuculites triqueter*, Con. (rr)

Maryland.

This township lies to the east of Milford and south of Westford townships. Topographically it consists of very steep high hills separated by narrow valleys, giving the township a very rugged surface. Along its western side is Crumhorn mountain, a steep and high hill, while Schenevus creek flows from the northeast to the southwest diagonally across the township, and south of it is another steep hill.

XXII C[2]. A ledge of thin argillaceous shales is excellently exposed by the side of the street in the northeastern part of the village of Schenevus, to the east of Smoky Hollow brook. The road-cut reveals twenty feet of the shales, the base of which is perhaps 120 feet above the level of Schenevus creek. The shales have rather sharp edges, are of very dark blue to blackish color, and in lithologic characters resemble quite closely the thin shales of the Ludlowville and Moscow divisions of western New York, or the so-called "Genesee shales" (which are of upper Hamilton age) in northeastern Pennsylvania.[1]

These shales contain an abundance of characteristic Hamilton fossils and furnish one of the best localities for collecting noted in the eastern part of Otsego county. The following species were obtained:

1. *Spirifer granulosus* (Con.), Hall. (r)
2. *Spirifer mucronatus* (Con.), Bill. (c)
3. *Spirifer Tullius*, Hall. (c)
4. *Spirifer fimbriatus* (Con.), Hall. (rr)
5. *Athyris spiriferoides* (Eaton), Hall. (c)
6. *Chonetes coronata* (Con.), Hall. (c)
7. *Ambocœlia umbonata* (Con.), Hall. (c)
8. *Tropidoleptus carinatus* (Con.), Hall. (a)
9. *Cyrtina Hamiltonensis*, Hall. (rr)

[1] See Bulletin No. 120, United States Geological Survey; The Devonian system of eastern Pennsylvania and New York, pp. 36, 71, etc., for a discussion of the correlation of the fossiliferous shales in northeastern Pennsylvania.

10. *Cryptonella (Eunella) Lincklaeni*, Hall. (rr)
11. *Orbiculoidea Doria*, Hall (?). (r)

Dorsal valves very convex with high apex. Rather large for this species.

12. *Crania (Craniella) Hamiltoniæ*, Hall. (rr)
13. *Nucula bellistriata* (Con.), Hall. (a)
14. *Nucula corbuliformis*, Hall. (r)
15. *Nuculites triqueter*, Con. (c)
16. *Nuculites oblongatus*, Con. (c)
17. *Nucula lirata* (Con.), Hall. (rr)
18. *Palæoneilo muta*, Hall. (rr)
19. *Palæoneilo constricta* (Con.), Hall. (c)
20. *Leda diversa*, Hall. (c)
21. *Leda rostellata* (Con.), Hall. (rr)
22. *Microdon (Cypricardella) bellistriatus* (Con.), Hall. (aa)
23. *Modiomorpha subalata* (Con.), Hall. (c)
24. *Grammysia bisulcata* (Con.), Hall. (r)
25. *Tellinopsis subemarginata* (Con.), Hall. (rr)
26. *Phthonia sectifrons* (Con.), Hall. (rr)
27. *Prothyris lanceolata*, Hall. (rr)
28. *Modiella pygmæa* (Con.), Hall. (rr)
29. *Macrodon Hamiltoniæ*, Hall. (c)
30. *Orthonota* (?) *parvula*, Hall. (rr)
31. *Modiomorpha mytiloides* (Con.), Hall. (rr)
32. *Goniophora Hamiltonensis*, Hall. (rr)
33. *Orthonota carinata*, Con. (rr)
34. *Orthonota undulata*, Con. (rr)
35. *Schizodus appressus* (Con.), Hall. (r)
36. *Lingula densa*, Hall (?).
37. *Hyolithes aclis*, Hall. (rr)
38. *Coleolus tenuicinctum*, Hall. (c)
39. *Liopteria DeKayi*, Hall. (rr)
40. *Pleurotomaria capillaria*, Con. (rr)
41. Cf. *Murchisonia micula* (Hall), Miller. (rr)

Imperfect internal impressions, only five volutions seen, but evidence of carina on centre of body whorl.

42. (?) *Psilophyton princeps*, Du. (rr)
43. *Orthothetes Chemungensis* (Con.), Hall, var. *arctostriata*, H. (rr)

44. *Palæoneilo emarginata* (Con.), Hall. (rr)
45. *Chonetes scitula*, Hall. (rr)
46. *Chonetes setigera*, Hall. (rr)

XXII C[1]. On the Schenevus creek road, one and one-half miles below C[2], or about one-half mile east of Chaseville, is another outcrop of dark blue and blackish finely arenaceous shales of the Hamilton formation, containing an abundant fauna. The ledge is from twenty to twenty-five feet high, about ninety feet lower than C[2], and thirty feet above the creek level. This ledge shows a dip of more than 10° S. 57° W., which means a dip in that direction of over one hundred feet per mile. The fauna is as follows:

1. *Spirifer granulosus* (Con.), Hall. (c)
2. *Spirifer mucronatus* (Con.), Bill. (r)
3. *Spirifer fimbriatus* (Con.), Bill. (rr)
4. *Chonetes carinata* (Con.), Hall. (c)
5. *Spirifer Tullius*, Hall. (r)
6. *Tropidoleptus carinatus* (Con.), Hall. (rr)
7. *Athyris spiriferoides* (Eaton), Hall. (c)
8. *Tellinopsis subemarginata* (Con.), Hall. (rr)
9. *Orthis Vanuxemi*, Hall (?). (rr)
10. *Chonetes lepida*, Hall. (r)
11. *Cryptonella* (*Eunella*) *Lincklaeni*, Hall (?). (rr)
12. *Palæoneilo maxima* (Con.), Hall. (rr)
13. *Palæoneilo constricta* (Con.), Hall. (r)
14. *Ambocœlia umbonata* (Con.), Hall. (rr)
15. *Nucula bellistriata* (Con.), Hall. (c)
16. *Leda diversa*, Hall. (c)
17. *Nuculites triqueter*, Con. (rr)
18. *Nuculites oblongatus*, Con. (rr)
19. *Palæoneilo muta*, Hall. (rr)
20. *Microdon* (*Cypricardella*) *bellistriata*, Con. (rr)
21. *Schizodus appressus* (Con.), Hall. (rr)
22. *Pleurotomaria capillaria*, Con. (rr)
23. *Lingula* (*Dignomia*) *alveata*, Hall (?). (rr)

XXII I[1]. South of the Schenevus creek, opposite Schenevus village, is a steep hill, on the side of which, along the highway and a small brook, are frequent exposures. The lower part of the hill is composed of bluish-black irregular shales that contain Hamilton fossils, and belong to that formation.

PLATE VI

THE HAMILTON SHALES AT SCHENEVUS

These shales extend up the hillside 185 feet higher than the level of the railroad. Near the foot of the hill they are quite fossiliferous, the following species having been obtained:

1. *Spirifer Tullius*, Hall.
2. *Microdon (Cypricardella) bellistriata* (Con.), Hall.
3. *Modiella pygmæa* (Con.), Hall.
4. *Tropidoleptus carinatus* (Con.), Hall.
5. *Nuculites oblongatus*, Con., var.
6. *Phacops rana* (Green), Hall.
7. *Orthoceras cælamen*, Hall.
8. *Rhodea pinnata*, Dn.
9. *Spirifer mucronatus* (Con.), Bill.
10. *Grammysia subarcuata*, Hall.
11. *Chonetes coronata*, Con.
12. *Palæoneilo emarginata* (Con.), Hall (?).
13. *Nucula corbuliformis*, Hall (?).

At nearly the top of the Hamilton shales, by the side of the highway, the following species were collected:

1. *Vitulina pustulosa*, Hall. (c)
2. *Tropidoleptus carinatus* (Con.), Hall. (c)
3. *Spirifer Tullius*, Hall. (r)
4. *Chonetes coronata* (Con.), Hall. (rr)
5. *Microdon (Cypricardella) tenuistriatus*, Hall. (rr)

XXII I². Above the Hamilton are 175 feet of thin sandstones alternating with greenish argillaceous shales. These rocks belong in the Sherburne formation. No fossils were found.

XXII I³. Just above the even shales of I² is an irregular layer that contains clay pebbles of various forms and some fossils, the species mentioned below having been obtained:

1. *Spirifer Tullius*, Hall. (r)
2. *Tropidoleptus carinatus* (Con.), Hall.
3. *Leda diversa*, Hall. (r)
4. *Microdon (Cypricardella) tenuistriatus*, Hall. (rr)
5. *Palæoneilo constricta* (Con.), Hall (?). (rr)
6. *Modiomorpha* cf. *subalata* (Con.), Hall, var. *Chemungensis*, Hall. (rr)

   A larger and longer specimen than any of the figures of the above species.

A little higher on the highway is quite a prominent concretionary sandstone, like the strata noted at other localities in the Ithaca formation. This fauna and irregular lithologic structure occur at what may be considered the base of the Ithaca formation in this section. About sixty feet above its base by the roadside is an old stone quarry, which has been worked to some extent for building stone. The shaly partings are quite fossiliferous, and several good specimens of *Spirifer mesastrialis* were found. The fauna and stratigraphic position of this zone are considered to indicate that it clearly belongs in the Ithaca formation as it is developed in the eastern part of Otsego county. The species mentioned below were collected here:

1. *Spirifer mesastrialis*, Hall.	(c)
2. *Paracyclas lirata* (Con.), Hall.	(rr)
3. *Tellinopsis subemarginata* (Con.), Hall.	(rr)
4. *Nucula bellistriata* (Con.), Hall	(r)
5. *Actinopteria Boydi*, Con.	(c)
6. *Actinopteria zeta*, Hall (?).	(r)
7. *Pleurotomaria capillaria*, Con.	(c)
8. *Palæoneilo emarginata* (Con.), Hall.	(rr)
9. *Chonetes setigera*, Hall.	(rr)
10. *Spirifer mucronatus* (Con.), Bill (?).	(r)
11. *Pterinopecten suborbicularis*, Hall (?).	(rr)
12. *Phacops rana* (Green), Hall.	(r)
13. *Grammysia subarcuata*, Hall.	(rr)

Somewhat above the quarry a stratum of thin sandstone was seen (I^{3+}) which contains some fossils; the following were obtained

1. *Tropidoleptus carinatus* (Con.), Hall.	(r)
2. *Spirifer mesastrialis*, Hall.	(rr)
3. *Spirifer mucronatus* (Con.), Bill.	(rr)
4. *Goniophora Hamiltonensis*, Hall.	(rr)

XXII I^4. At 260 feet above the quarry, or 680 feet above the railroad level on the top of the hill by the schoolhouse, is the base of a greenish, coarse-grained sandstone, which marks the base of the Oneonta sandstone. This massive stone remains very near the surface, and large blocks of it lie on the ground so that the country for one mile to the south has a very rocky appearance.

The above section for the hill south of Schenevus gives a thickness of 320 feet for the Ithaca formation and 175 feet for the Sherburne, or 495 feet for the two; and at the bottom more than 185 feet of the upper Hamilton.

PLATE VII

GENERAL VIEW OF THE SILVERNAILE QUARRY NORTH OF CHARLOTTEVILLE, SHOWING UPPER HAMILTON FLAGSTONES.

SECTION OF HILL SOUTH OF SCHENEVUS.

XXII I.

735′		Top of hill approximately 2,000 feet A. T.
	55′	I[4]. *Oneonta.*
680′		
	260′	*Ithaca.*
420′		I[3]. Quarry.
	60′	
360′		I[3]. Layer with pebbles and fossils.
	175′	I[2]. *Sherburne.*
185′		Approximate top of *Hamilton.*
	185′	I[1]. *Hamilton.*
0′		Railroad level at Schenevus 1,272 feet A. T.

XXII H[1]. To the north of Chaseville is a small brook, with steep hills on both sides, that on the north rising over 900 feet above the level of Schenevus creek at Chaseville. Near the top of the rock exposures in the glen and about 215 feet above the creek level at Chaseville, are blue, argillaceous shales containing Hamilton fossils. This outcrop belongs in the Hamilton formation, and the following species were obtained:

1. *Tropidoleptus carinatus* (Con.), Hall. (c)
2. *Spirifer mucronatus* (Con.), Bill. (rr)
3. *Chonetes setigera*, Hall. (r)
4. *Orbiculoidea Doria*, Hall (?). (rr)
5. *Palæoneilo maxima* (Con.), Hall. (rr)
6. *Nuculites oblongatus*, Con. (rr)
7. *Nucula bellistriata* (Con.), Hall. (rr)
8. *Phthonia sectifrons* (Con.), Hall (?). (rr)
9. *Palæoneilo constricta* (Con.), Hall. (rr)
10. *Coleolus tenuicinctum*, Hall. (rr)
11. *Bellerophon*, sp. (r)

XXII H². On the road along the western side of the brook, 210 feet above H¹, are thin, unfossiliferous sandstones and arenaceous shales resembling the Sherburne formation in lithologic characters and probably belonging to it. A little higher, a concretionary stratum crosses the road; while at 582 feet above the creek level, or 157 feet higher than the lowest exposures of H², sandstones similar to those of the Sherburne are exposed on the road.

XXII H³. On the road almost at the summit of the divide, two miles north of Chaseville and twenty-three miles northwest of Schenevus, are argillaceous shales and shaly sandstones at an elevation of over 850 feet above Schenevus creek. *Spirifer mesastrialis*, Hall, occurs abundantly in certain layers of these shales, and they are unhesitatingly referred to the Ithaca formation. The outcrop is a small one, but afforded the following species:

1. *Spirifer mesastrialis*, Hall.	(a)
2. *Rhynchonella eximia*, Hall.	(c)
3. *Goniophora*, sp.	(rr)
4. *Pleurotomaria* cf. *rotalia*, Hall.	(c)

XXII H⁴. On the hillside north of the road and fifty feet higher than H³, are plenty of arenaceous shales and thin sandstones containing an abundance of the species which occur in the Ithaca formation of Otsego county. The rocks closely resemble those that are found on the hill west of Oneonta above the White quarry, and contain a similar fauna. The species are:

1. *Spirifer mucronatus* (Con.), Bill.	(a)
2. *Spirifer mesastrialis*, Hall.	(c)
3. *Tropidoleptus carinatus* (Con.), Hall.	(rr)
4. *Chonetes setigera*, Hall.	(rr)
5. *Rhynchonella eximia*, Hall, or *R. Stevensi*, Hall.	(c)
6. *Nucula corbuliformis*, Hall.	(a)
7. *Paracyclas lirata* (Con.), Hall.	(rr)
8. *Palæoneilo maxima* (Con.), Hall.	(rr)
9. *Nuculites cuneiformis*, Con.	(rr)
10. *Tentaculites* cf. *attenuatus*, Hall.	(r)

XXII H⁵. On the top of this high hill, some 930 feet above the level of Schenevus creek at Chaseville, and scarcely twenty-five feet above H⁴, is a ledge of irregularly bedded, coarse-grained, greenish-grey sandstones resembling in all respects the greenish-grey sandstones of the Oneonta formation in the vicinity of Oneonta, and this stratum is regarded as forming the base of that formation, and has been so indicated on the accompanying geologic map.

Dump heap of the Silvernaill quarry

The Chaseville section may be tabulated as follows:

SECTION OF XXII H.

930′		*Oneonta* sandstone on top of hill.
		H^5.
907′		H^4. *Ithaca* in field.
	50′	
857′		H^3. *Ithaca* in road.
	275′	
582′		Covered.
	139′	*Sherburne.*
443′		Concretionary stratum.
	18′	
425′		H^2. *Sherburne.*
	210′	Covered.
215′		H^1. *Hamilton* shales.
	215′	
0′		Schenevus creek level at Chaseville.

The above section shows that north of Chaseville, the thickness of the Sherburne and Ithaca formations is between 505 and 715 feet.

XXII B^1. On the south side of Schenevus creek, three-quarters of a mile to the southwest of Chaseville, is a brook which affords a good section of over 500 feet. In the lower part, and but a short distance above the highway, are thin, argillaceous shales, containing only a few fossils, among them *Tropidoleptus carinatus* (Con.), Hall. A little higher, the shales are coarser, blocky, and contain quite a number of Hamilton species. The lithologic characters of the lower shales are nearer those of the Sherburne formation, and the upper shales bear those of the Hamilton. The fauna is:

1. *Tropidoleptus carinatus* (Con.), Hall. (c)
2. *Spirifer mucronatus* (Con.), Bill. (rr)
3. *Lingula densa*, Hall (?). (rr)
4. *Palæoneilo constricta* (Con.), Hall. (rr)
5. *Palæoneilo muta*, Hall. (rr)
6. *Grammysia alveata* (Con.), Hall (?). (rr)

7. *Leptodesma Rogersi*, Hall. (r)
8. *Liopteria DeKayi*, Hall. (rr)
9. *Bellerophon acutilira*, Hall (?). (rr)

The striae are coarser than those in the species represented in the figures.

XXII B². The shales are more arenaceous than those of B¹, alternating with thin sandstones. The rocks are of bluish color, and fossils are rare, only three species being found:

1. *Tropidoleptus carinatus* (Con.), Hall. (c)
2. *Spirifer mucronatus* (Con.), Bill. (r)
3. *Spirifer Tullius*, Hall. (c)

XXII B³. Above the first fall is a rather thin, somewhat coarse-grained sandstone, in which fossils are rare. In thin layers several specimens of *Liorhynchus* were found, though poorly preserved. As a rule, however, the rocks are quite destitute of fossils. The fauna of B³ is:

1. *Liorhynchus mesacostalis*, Hall. (r)
2. *Crania*, sp. (c)

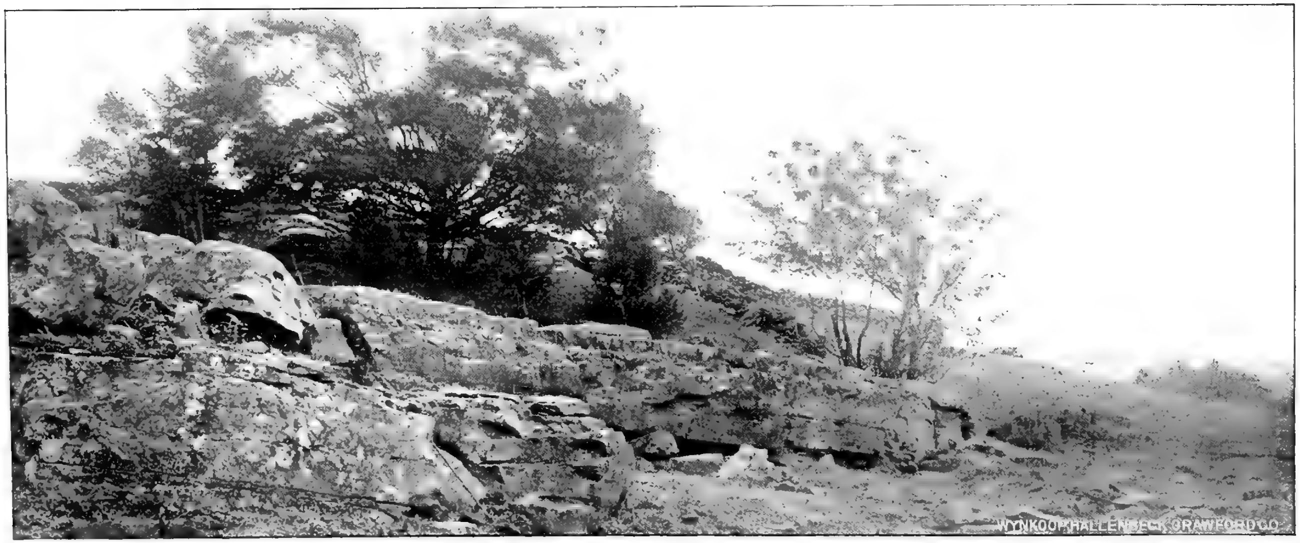
Poorly preserved, possibly *C. Leoni*, Hall.

3. (?) *Cryptonella Eudora*, Hall. (rr)

XXII B⁴. Thin, blue-grey sandstones and arenaceous shales, which contain numerous specimens of *Spirifer mesastrialis*, Hall; *Spirifer mucronatus* (Con.), Bill.; *Tropidoleptus carinatus* (Con.), Hall, and other fossils. These sandstones are near the top of the hill, nearly 500 feet above the level of the creek and are clearly in the Ithaca formation. The fauna is:

1. *Spirifer mesastrialis*, Hall. (a)
2. *Spirifer mucronatus* (Con.), Bill. (c)
3. *Tropidoleptus carinatus* (Con.), Hall. (c)
4. *Chonetes scitula*, Hall. (a)
5. *Rhynchonella (Camarotœchia) eximia*, Hall. (rr)
6. *Rhynchonella (Camarotœchia) Stevensi*, Hall. (r)
7. *Liorhynchus mesacostalis*, Hall. (rr)
8. *Nucula bellistriata* (Con.), Hall. (rr)
9. *Palæoneilo constricta* (Con.), Hall. (rr)
10. *Leptodesma Rogersi*, Hall (?). (r)
11. *Actinopteria*, sp. (rr)

PLATE IX



BASE OF THE ONEONTA SANDSTONE SOUTH OF JEFFERSON

SECTION OF XXII B.

600′		Near the summit of the hill.
	110′	*Ithaca.*
490′		B⁴. Sandstones with *Spirifer mesastrialis.*
	140′	
350′		Coarse-grained sandstones.
	120′	
230′		B³. Sandstones with *Liorhynchus.*
	45′	
185′		B². Small *Spiriferi.*
	55′	
130′		B¹. Shales with *Hamilton* fossils.
	130′	
0′		Level of Schenevus creek.

XXII B⁵. On the road leading over the steep hill south of the village of Maryland are, toward the summit of the hill, exposures of the Ithaca formation. One at an elevation of 470 feet above the creek level at Maryland, contains numerous species of the Ithaca fauna, as will be seen from the list:

1. *Spirifer mucronatus* (Con.), Bill. (c)
   Part of the specimens have decided mucronate extensions of the shell and are typical.
2. *Spirifer mesastrialis*, Hall. (rr)
3. *Tropidoleptus carinatus* (Con.), Hall. (c)
4. *Rhynchonella* (*Camarotœchia*) *Stevensi*, Hall. (rr)
5. *Rhynchonella* (*Camarotœchia*) *eximia*, Hall. (r)
6. *Chonetes scitula*, Hall. (c)
7. Fragments of Gastropods. (?) *Pleurotomaria*, sp. (rr)
8. *Palæoneilo*, sp. (rr)
9. *Coleolus aciculum*, Hall (?). (rr)
10. *Orthoceras*, sp. (rr)
11. *Homalonotus DeKayi* (Green), Emm. (rr)

XXII B⁶. Fifty feet higher, or 620 feet above the creek, near the summit of the hill, are massive ledges of greenish-grey coarse-grained sand stone, which form the base of the Oneonta sandstone. Judging from outcrops to the north of the village of Maryland, the Hamilton formation runs along the creek valley at this locality, so that the thickness of the Sherburne and Ithaca formations in the hill to the south of Maryland is less than 600 feet.

XXII A. In the vicinity of Maryland village, two brooks enter Schenevus creek from the north; Whitney brook, which flows through the eastern part of the village, and Morehouse brook, about three-fifths of a mile farther west. Their general direction is to the southwest, each side being flanked by very steep hills. The hill forming the divide between them is especially steep and narrow, and is known in that region as Little Crumhorn mountain. Along Whitney brook, after reaching an altitude of seventy feet above Schenevus creek, are frequent ledges and cliffs of rocks until the upper part of its course is reached. From these outcrops the following section along this brook was constructed, the divisions being characterized as follows:

The first outcrop is seventy feet above Schenevus creek level, where a stratum of blue sandstone (A^2), two and one-half feet thick, crosses the brook. No fossils were found, but it has the usual lithologic characters of the rather heavy layers of Hamilton sandstone.

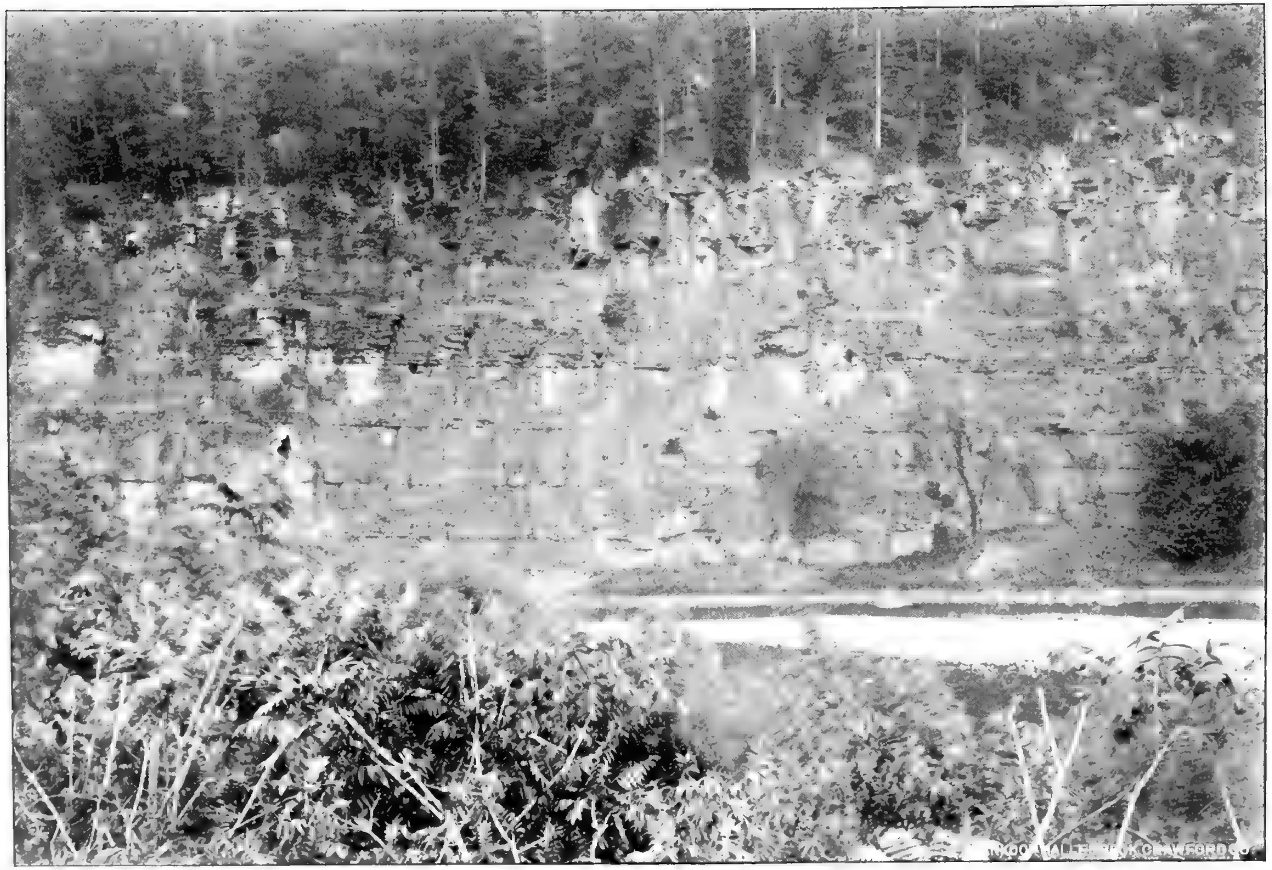
XXII A^3. For thirty feet above the first sandstone stratum there are numerous outcrops of shaly sandstones, shales and bluish sandstones along the bed and banks of the brook about one-quarter of a mile northeast of Maryland village. Some of the beds are of typical Hamilton character, containing a great abundance of Hamilton species, while others are thin, rather even sandstones, with a greenish rather than bluish tint, resembling considerably some of the Ithaca layers of Tompkins and Cortland counties. Some of the layers containing abundant Hamilton fossils are of a very dark color, almost black. The fauna is as follows:

1. *Spirifer granulosus* (Con.), Hall.	(a)
2. *Spirifer Tullius*, Hall.	(r)
3. *Cyrtina Hamiltonensis*, Hall.	(r)
4. *Tropidoleptus carinatus* (Con.), Hall.	(c)
5. *Modiomorpha concentrica* (Con.), Hall.	(rr)
6. *Phthonia sectifrons* (Con.), Hall (?).	(rr)
7. *Athyris spiriferoides* (Eaton), Hall.	(rr)
8. *Palæoneilo muta*, Hall.	(rr)
9. *Grammysia bisulcata* (Con.), Hall.	(rr)

Loose on the highway to the west of the brook and higher than A^3, the following species were collected:

1. *Nucula bellistriata* (Con.), Hall.	(r)
2. *Palæoneilo constricta* (Con.), Hall.	(rr)

PLATE X



Foot of Wauhalla mountain, on the Schoharie creek, north of Breakabeen: showing upper Hamilton beds.

3. *Tropidoleptus carinatus* (Con.), Hall. (r)
4. *Athyris spiriferoides* (Eaton), Hall (?). (rr)

XXII A^4. At an elevation of one hundred feet, the bluish shales containing an abundant Hamilton fauna are succeeded by greenish to bluish unfossiliferous shales and thin sandstones. This zone is about seventy-five feet thick and forms the bottom of the brook for some distance.

XXII A^5. At the top of these greenish rocks, and 175 feet above the level of Schenevus creek, are blackish to bluish, sharp argillaceous shales, some forty-five feet of which occur along the banks of the creek. They contain plenty of fossils, the following list of species having been obtained in a comparatively short time:

1. *Spirifer granulosus* (Con.), Hall. (c)
2. *Spirifer mucronatus* (Con.), Bill. (rr)
3. *Spirifer Tullius*, Hall. (rr)
4. *Atrypa reticularis* (Linné), Dal. (r)
5. *Liorhynchus multicosta*, Hall. (rr)
6. *Tropidoleptus carinatus* (Con.), Hall. (c)
7. *Chonetes mucronata*, Hall. (rr)
8. *Athyris* cf. *Cora*, Hall. (rr)
   One poorly preserved specimen, resembling this species more closely than *A. spiriferoides* (Eaton), Hall.
9. *Nucula bellistriata* (Con.), Hall. (c)
10. *Nucula corbuliformis*, Hall. (rr)
11. *Palæoneilo constricta* (Con.), Hall. (rr)
12. *Nuculites triqueter*, Con. (r)
13. *Nuculites oblongatus*, Con. (rr)
14. *Modiomorpha concentrica* (Con.), Hall. (rr)
15. *Schizodus appressus* (Con.), Hall. (rr)
16. *Modiomorpha mytiloides* (Con.), Hall. (rr)
17. *Microdon* (*Cypricardella*) *tenuistriatus*, Hall (?). (rr)
18. *Cyclonema Hamiltoniæ*, Hall. (rr)
19. *Orthoceras crotalum*, Hall. (rr)

When this section was studied, the author was not positive whether the top of zone A^3 should be considered the top of the Hamilton formation and the abundant fossils of A^5 a recurrent Hamilton fauna in the Sherburne formation, or whether the forty-five feet of zone A^5 should be referred to the Hamilton. However, after examining the fauna of A^5 and comparing the section with the others of that vicinity it seems better to consider the top of

A^5 as the upper limit of the Hamilton. In the section to the north of Chaseville, which is one and one-half miles east of Whitney brook, the Hamilton formation and fauna were found up to 215 feet above Schenevus creek. The next 210 feet are covered, but it is probable that the Hamilton formation extends considerably higher, since on the south side of Schenevus creek opposite Schenevus and Maryland the combined thickness of the Sherburne and Ithaca formations is about 500 feet, while it is 715 feet from the top of the last Hamilton exposure in the brook north of Chaseville to the bottom of the Oneonta sandstone.

XXII A^6. About twenty-five feet above the top of A^5, is the foot of a cascade at a distance of about one and one-quarter miles from the village. The rocks are bluish argillaceous, and even arenaceous shales that weather to a slightly olive tint. They contain but few fossils, though they show plenty of fucoidal and mud markings. In this latter character and their lithologic appearance they clearly resemble the Sherburne shales. Only fragments of these fossils were found:

1. *Spirifer* cf. *mucronatus* (Con.), Bill. (rr)
2. *Liopteria DeKayi*, Hall. (rr)

XXII A^7. The lithologic characters of the shales between the two falls are quite similar to those below the falls, and they contain a few fossils. In a thin layer about ten feet above the top of the lower falls are a considerable number of specimens of *Lingula*. The complete list is:

1. *Lingula punctata*, Hall (?). (c)

   The specimens are not quite as broad as the figures of this species, except figure 6f, plate 1 (Palaeontology of New York, Vol. IV), but the shell shows fine punctæ.

2. *Tropidoleptus carinatus* (Con.), Hall. (rr)
3. *Spirifer*, sp. (rr)

   Two small and imperfect specimens.

4. *Nuculites triqueter*, Con. (rr)
5. *Bellerophon*, sp. (rr)

   Fragments that have markings somewhat like those of *B. Leda*, Hall.

6. (?) *Rhodea pinnata*, Dn. (rr)

   Stem like the above plant, except that the branching is alternate instead of opposite as in that species.

XXII A^8. Near the top of the second falls, 290 feet above the Schenevus creek, are bluish, slightly irregular shales, which contain a number of

PLATE XI

View in the Westkill at North Blenheim, Schoharie valley.

fossils. The fossiliferous layer is only about six inches in thickness, and contains the following species:

1. *Spirifer mucronatus* (Con.), Bill. (r)
2. *Spirifer mesastrialis*, Hall (?). (rr)
3. *Spirifer fimbriatus* (Con.), Bill. (rr)
4. *Chonetes setigera*, Hall. (rr)
5. *Chonetes lepida*, Hall. (rr)
6. *Stropheodonta* (*Leptostrophia*) cf. *perplana* (Con.), Hall. (r)
7. *Lingula*, sp. (rr)
8. *Goniophora Hamiltonensis*, Hall. (rr)
9. *Palæoneilo constricta* (Con.), Hall. (rr)

XXII A[9]. Above the second falls the rocks are much more generally covered by soil than below. In the occasional exposures of shales and sandstones for the next 130 feet an occasional specimen of *Tropidoleptus carinatus* (Con.), Hall, and one or two other species were noticed. At 420 feet above Schenevus creek is a stratum of irregular sandstone, with partly concretionary structure, similar to those which occur not infrequently in the upper portion of the Middle and Upper Devonian in eastern central New York. The structure of this stratum may be similar to that noted by Clarke in Chenango and Ontario counties,[1] except that this is not stained red, inasmuch as it is considerably below the lowest of the red rocks. Shales of bluish and olive color occur both above and below the sandstone stratum. The shales and sandstone contain a few fossils, *Cyrtina Hamiltonensis*, Hall, being abundant in a thin layer. The other species collected are:

2. *Spirifer mucronatus* (Con.), Bill. (rr)
3. *Tropidoleptus carinatus* (Con.), Hall. (r)
4. *Liorhynchus*, sp. (r)

Small and imperfectly preserved specimens.

Fifteen feet above the concretionary stratum is a layer containing *Liorhynchus*. For the next 195 feet to the east and west highway, the rocks are mostly covered; which is also true for the additional 185 feet when the top of the divide between the Whitney and Morehouse brooks is reached. This divide is approximately 815 feet above the level of Schenevus, or over 2,000 feet above sea level In this section the Ithaca formation is scarcely exposed, the upper part of the brook and the hill slope being deeply covered by drift. *Spirifer mesastrialis*, Hall, was found loose in the brook below the east and west highway. The Sherburne formation contains a number of thin layers in

[1] Thirteenth Annual Report State Geologist [New York], p. 538. Bulletin No. 16, United States Geological Survey, p. 38.

which fossils are not uncommon, in fact, they are more plentiful at this locality than is the case in Chenango county and the western part of Otsego. The Hamilton in the lower part of the valley contains plenty of Hamilton fossils, though they are very rare in a zone in the upper part of the formation.

XXII A. SECTION OF WHITNEY BROOK NORTH OF MARYLAND.

815′		Approximately 2,013 feet A. T.	
		Top of Little Crumhorn mountain, between Whitney and Morehouse brooks.	
	185′	A^{12}. Covered.	
630′		E. & W. highway.	
	195′	A^{11}. Mostly covered.	
435′		*Liorhynchus* A^{10}.	
	15′		
420′		Concretionary layer A^{9}.	
	130′	A^{8}. Largely covered.	
290′		Top of upper cascade.	
	45′	A^{7}.	
245′		Foot of lower cascade.	
	25′	A^{6}. *Sherburne* formation.	
220′		Top of layer with abundant Hamilton fossils.	
	45′	A^{5}.	
175′			
	75′	A^{4}. Greenish shales and thin sandstones.	*Hamilton.*
100′		Abundant Hamilton fossils.	
	30′	A^{3}.	
70′		A^{2}. Blue sandstone, two and one-half feet thick at base of rocks.	
	50′		
27′		Railroad level, 1,218 feet A. T. A^{1}.	
	20′		
0′		Level of Schenevus creek.	

PLATE XII

MINEKILL FALLS, SCHOHARIE VALLEY; ITHACA BEDS.

XXII D[1]. In the Morehouse brook at the lower end of its gorge, between 125 and 150 feet above the level of Schenevus creek, are arenaceous blocky shales containing an abundant Hamilton fauna. Higher in the gorge are thin, even, sandy shales that closely resemble the Sherburne shales. The lower part of the glen is clearly Hamilton, as may be seen from its fauna:

1. *Spirifer mucronatus* (Con.), Bill. (a)
2. *Spirifer granulosus* (Con.), Hall and Clarke. (c)
3. *Tropidoleptus carinatus* (Con.), Hall. (c)
4. *Orthothetes Chemungensis* (Con.), H. and C., var. *arctostriata*. (rr)
5. *Atrypa reticularis* (Linné), Dal. (rr)
6. *Athyris spiriferoides* (Eaton), Hall. (rr)
7. *Palæoneilo muta*, Hall. (rr)
8. *Modiomorpha mytiloides* (Con.), Hall. (rr)
9. *Ambocœlia umbonata* (Con.), Hall. (rr)
10. *Terebratula (Eunella) Lincklaeni*, Hall. (rr)

CONCLUSION.

On the geologic map accompanying this report, the boundaries of the Hamilton formation, and the Sherburne and Ithaca formations taken together are given for Chenango, Otsego, Schoharie, Albany and Greene counties. In the preceding portion of this report detailed sections with lists of fossils are given for Chenango and Otsego counties. It was intended to give a similar account of the investigation in Schoharie, Albany and Greene counties, but the pressure of other duties renders it necessary to defer their description until a later date, when a summary of the more important facts brought out by this investigation will appear. However, in order that the reader may apprehend the more important changes advocated in the present report, it is thought best to state them briefly.

On comparison it will be noticed that the line marking the upper boundary of the Hamilton formation on the geologic map is from five to fifteen miles farther south than the similar line on the geologic map, recently published by the Geological Survey of the State of New York.[1]

As stated in the introductory part of this paper, wherever the Tully limestone is found, it affords a sharp line of separation between the Hamilton and Chemung series; but in eastern and eastern central New York the Tully limestone as well as the overlying black Genesee slate has disappeared and there is a more gradual passage from the Hamilton to the Chemung series. The author began work in De Ruyter, Madison county, where both the Tully limestone and Genesee slates occur, and followed those formations into the Chenango valley, where they disappear. In Onondaga, Cortland, Madison and Chenango counties, above the Tully limestone and Genesee slate, are the thin bluish sandstones and smooth shales of the lower Portage of central and western New York. Vanuxem proposed the name "Sherburne flagstone"[2] for this formation, which has been adopted in this report, and it is shown to have a thickness of 250 feet in the Chenango valley. In this valley and the westward the Sherburne formation contains comparatively few fossils, though to the east, after the disappearance of the Tully limestone and Genesee slates, the number of species, particularly of Hamilton forms, increases, as has been shown in the latter part of this report in describing the exposures in the eastern part of Otsego county. However, when the sections are carefully studied by one familiar with the Hamilton and Chemung series,

[1] Preliminary Geologic Map of New York, exhibiting the structure of the State so far as known. Prepared under the direction of James Hall, State Geologist, by W. J. McGee. Published by authority of the Legislature of the State of New York. Printed by the United States Geological Survey, 1894 (distributed April, 1896).

[2] Fourth Annual Report, Third Geological District (Assembly Document No. 50, 1840), p. 381.

PLATE XIII

Manorkill falls, Schoharie valley, above Gilboa. Oneonta sandstone.

almost invariably the change from the Hamilton to the Sherburne formation may be readily determined even in the eastern part of the area under consideration. On the geologic map prepared for this report, the Tully limestone, and its horizon where it could be recognized, was regarded as defining the upper limit of the Hamilton formation. On the geologic map of New York, the upper line of the Hamilton is represented as crossing the northwestern townships of Chenango county, Lincklaen, Otselic and Smyrna, several miles to the south of the outcrops of the Tully limestone, which enters the county near the northwestern corner of Smyrna township and was followed along the southern side of Pleasant brook to Smyrna village. After the disappearance of the Tully limestone the transition from the Hamilton to the Sherburne formation was generally readily recognized, and this horizon as traced across the eastern part of Chenango, Otsego, Schoharie, Albany and Greene counties, is represented on the accompanying map as marking the upper limit of the Hamilton formation. The above division of these rocks is confirmed palaeontologically by the discovery of the characteristic Tully species, *Rhynchonella venustula*, Hall, at this horizon in the central part of Otsego county.

Above the Sherburne formation is one, containing numerous fossils, that may be followed westward from the Chenango valley across Chenango, Cortland and Tompkins counties to Ithaca, where it long ago received the name "Ithaca group."[1] The Ithaca formation has a thickness of fully 500 feet in the Chenango valley, and from there it may be traced eastward into Greene county, which is apparently near the limit of its eastern extent. The upper limit of the Ithaca formation is determined by the appearance of the coarse, greenish-grey and red sandstones and shales of the overlying Oneonta formation. On the present map, the Sherburne and Ithaca formations are represented together, the line already defined as representing the top of the Hamilton indicating the base, and the line separating the Ithaca and Oneonta defining the top. On the geologic map of New York, from the Chenango valley eastward, the base of the Oneonta sandstone was regarded as forming the top of the Hamilton formation, the Ithaca and Sherburne formations being mapped as a part of the Hamilton formation. Consequently, with some modifications, the line representing the top of the Hamilton on the State map will be found to correspond to the line on the accompanying map representing the top of the Ithaca formation. From what has just been said it will be understood that on the State map from the Chenango valley eastward there is no line corresponding to what the author regards as the line of division

[1] Third Annual Report, Fourth Geological District, New York (Assembly Document No. 275, 1839), p. 318.

between the Hamilton and Chemung series or, to express it more precisely, between the Hamilton and Sherburne formations.

In the region under consideration, the field work directly preliminary to the preparation of the geologic map of New York was conducted by Mr. N. H. Darton, of the United States Geological Survey. Mr. Darton evidently regarded all of the fossiliferous rocks underlying the Oneonta formation as belonging to the Hamilton, and did not consider what became of the Tully limestone, Genesee slate, Sherburne and Ithaca formations which, at Ithaca, fifty miles west of Norwich in the Chenango valley, have a thickness of nearly 850 feet.

Mr. Darton first published an account of this work in March, 1893, in which he stated that "The stratigraphic components of the Oneonta formation are somewhat variable in its smaller subdivisions, but certain members preserve general characteristics throughout. The basal beds are grey flags which merge into the Hamilton."[1] The same correlation was shown in his figure 2 B through Oneonta and Franklin,[2] where the Oneonta is represented as resting directly on the Hamilton. Again it is stated that "the Hamilton is exposed" at the Lyon brook bridge[3] in the Chenango valley, a locality which has been described in this report as representing the top of the Ithaca formation capped by the basal part of the Oneonta.

At an earlier date the writer published a paper[4] in which was traced the development of the classification of the Upper Devonian system in central and eastern New York. The error of correlating the fossiliferous beds below the Oneonta sandstone in the Chenango and Susquehanna valleys with the upper Hamilton was fully explained, both the stratigraphic and palaeontologic evidence being given.

[1] American Journal of Science, Third series, Vol. XLV., p. 206.

[2] *Ibid.*, p. 205.

[3] *Loc. cit.*, p. 207.

[4] The Upper Hamilton and Portage stages of central and eastern New York. American Journal of Science, Third series, Vol. XLVI., Sep. 1893, pp. 212–231.

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

(GEOLOGICAL MAP.)

THE STRATIGRAPHIC POSITION OF THE PORTAGE SANDSTONES IN THE NAPLES VALLEY AND THE ADJOINING REGION.

JAMES HALL,
State Geologist.

D. DANA LUTHER,
Assistant.

1895.

James Hall, *State Geologist.*

Sir:—I herewith submit a brief account of the geology of the Naples valley, designed to show in some detail the nature of the Portage section in that meridian, and the stratigraphic relations of the upper beds, originally termed the Portage sandstones.

Respectfully yours,

D. DANA LUTHER.

Naples, N. Y., *March* 28, 1896.

PLATE I

THIRD FALL, GRIMES GULLY, NAPLES,

The Stratigraphic Position of the Portage Sandstones in the Naples Valley and the Adjoining Region.

By D. Dana Luther.

The deep wells that have penetrated the great beds of rock salt lying at varying depths below the surface of a large section of country in western and central New York, have demonstrated that the northern limit of these beds is approximately the line of outcrop of the Corniferous limestone, the top of which is but little more than 500 feet above the salt horizon.

South from this line, owing to the dip of the strata and the generally increased elevation of the surface, deeper drilling is required, as the strata that compose the Marcellus, Hamilton, Genesee, Portage and Chemung groups are successively added to those that intervene between the surface and the salt.

In the Warsaw or Oatka valley, in Wyoming county, the sandstones at the top of the Portage group are a little more than 2,000 feet above the salt. This distance increases slightly toward the east, and more rapidly toward the south.

Nearly all of the deep north and south valleys that are so numerous in this section of country, have been excavated in the soft shales of the Hamilton, Genesee and Portage groups, and end at the south in the harder and heavier bedded Upper Portage and Chemung sandstones. Although the salt beds are known to increase in thickness toward the south, those reached by the wells in these valleys have been found abundantly sufficient for all purposes, and but two plants, the Duncan Salt Co.'s, at Silver Springs, and that at Castile, have been put into operation where the stratigraphic horizon of the mouths of the salt wells is above the top of the Portage sandstones, and in those wells the thickness of Chemung rock included in the sections is not great.

As these "Portage sandstones," so designated on account of their great development and abundant exposure at the upper Portage falls, on the Genesee river, and described by Professor Hall in the Report on the Geology of the Fourth District, 1843, can be easily identified by any careful observer, and are fairly persistent in character from Tompkins county to the shores of lake Erie, their line of outcrop may, for the reasons previously mentioned, be considered as marking the southern limit of that part of the salt-producing area of central and western New York, that is profitably accessible for commercial purposes.

In order to show the position of the Portage sandstones in the strata and their relations to the geologic divisions above and below them, the rock section in a typical valley of the "finger lake region" lying in the extreme southern part of Ontario county, and in the central part of the New York salt fields, the valley of Naples, is here given.

The valley of Canandaigua lake extends about five miles beyond the head of that lake in a southwesterly direction, to the southern boundary line of the town of Naples, Ontario county. It has an average width of about one mile. The sides are steep and high. Hatch hill on the east side rises to the height of 1,041 feet above the lake level, and Pine hill at the south, and High point, one mile west of the valley, are each about two hundred feet higher.

The floor of the valley for three and one-half miles from the lake is a low alluvial plain, but at the south end there is an immense deposit of morainic till, and the delta terrace at the mouth of Grimes gully, nearly 200 feet high, projects half way across the valley. The village of Naples is situated at the foot of this terrace.

On the steep hillsides the soil, which is composed largely of the disintegrated shales, is thin, and loose fragments removed but slightly from their original position in the harder sandy layers, abound everywhere. The dugways ascending the hills diagonally, frequently afford long exposures of the bed rock, but the best opportunities for examination of the rock strata are presented in the ravines or gullies, of which there is a large number debouching into the main valley. The largest of these is the Parrish gully, on the east side, about two miles south of the lake. An alluvial cone at the mouth is about fifty feet higher than the lake. Above the cone the bottom and sides of the ravine present an interesting and accessible rock section somewhat less than 600 feet high, that includes all of the strata of the Portage group except some shale beds at the base.

The Tannery gully, also on the east side, but near the south end of the valley, exposes a continuous section 500 to 600 feet thick, beginning in the middle Portage or Gardeau flags, and extending upward into the Chemung sandstones.

On the west side, the Grimes gully exposes about 400 feet of the upper Portage and lower Chemung rocks. The Portage sandstones are particularly well displayed in this ravine and present abundant opportunity for the most critical examination.

The three ravines above specified are veritable canyons with vertical rock walls, 100 to 200 feet high, and many beautiful cascades. Besides these there are many others but little less extensive, in which there may be found good exposures of every horizon of the Portage group, and which have at their mouths alluvial cones composed of the debris brought down by the streams flowing through them.

The more important named in order from the lake southward, are the Snyder, Hartman, Biehl, Yaw, Pottle, Dunton, Lincoln and Hoecker gullies on the west side, in which the lower and middle Portage beds are exposed, and the Caulkins, Tyler and Reservoir or Olney gullies in the upper Portage and lower Chemung. Although no single exposure gives a continuous section from undoubted Genesee to undoubted Chemung rocks, the outcrops are so numerous that, as the strata persistently maintain their individual character, which can usually be easily recognized by the careful observer, it is not difficult to join the sections with comparative accuracy.

This report and the diagram accompanying it are the result of examinations and measurements made at all of the best exposures in the valley.

The contact with the Genesee slate at the base of the Portage group, is not distinctly marked, and any dividing line established between these two divisions must necessarily be, in this locality, a somewhat arbitrary one.

At the head of Canandaigua lake, near the Woodville hotel, there is an exposure that embraces fifty to sixty feet of typical upper Genesee slate, soft, dark blue-grey, in which *Lunulicardium fragile* and other characteristic fossils are abundant.

By the side of the road leading southward toward the village of Naples, the upper layers of the same bed are exposed for a quarter of a mile, to the mouth of the Snyder gully. In this ravine the dark slaty shales are overlaid by about fifteen feet of soft, clayey, olive shales that contain a few fossils common to the Portage group, but *L. fragile* is still the most abundant form. These beds were termed by Clarke, "transition shales," and may properly be so considered, as there is no recurrence of the Genesee slates, and *L. fragile* is very rarely seen above them. Next above occur fifteen feet of dark slaty and lighter sandy shales, in which are intercalated a few thin flags, in which the proportion of dark shale increases toward the top, where the lighter layers disappear and a bed of densely black, bituminous fissile shale about fifteen feet thick is found, overlaid by fifteen feet of black and grey shale of the same character as those below the bituminous layer. Plant remains are common here, and fish scales and plates are sometimes found. Other fossils appear to be very rare in these beds.

These forty-five feet constitute what has been termed the Lower Black Band of the Portage group, and the contact line between the Portage and Genesee groups is, in this report, assumed to be at the top of the transition shales before mentioned, and at the base of this black band. Directly above there are seventy-six feet of bluish or olive, sandy shales and very soft and thinly laminated sandstones with occasional flags. Both shales and sandstones are almost entirely devoid of traces of life except for the object known as *Fucoides graphica*, and some undeterminable plant remains. Six feet of blue sandstones overlie these barren shales, above which the recurring olive shales are softer and argillaceous.

This latter bed of shale is seventy feet thick, the lower part nearly barren of fossils, but the upper layers contain in some abundance *Cardiomorpha suborbicularis* and *Cardiola retrostriata*, while several species of goniatites and other characteristic forms are common. The composition of the strata changes very frequently in the succeeding 150 feet, and embraces thick and thin blue and grey sandstones and blue, olive, grey and black shales in thin beds. Concretions and concretionary layers also occur, with one highly concretionary layer of impure limestone about four inches thick. Fossils are fairly abundant in these beds at nearly every horizon, and many new and interesting forms have been found in them during the last few years. Near their top is a bed of black shales twenty feet, nine inches thick, known as the Second Black Band. Its summit is 287 feet above the base of the group.

This second black band is overlaid by forty-one feet of olive and bluish grey, soft shales, through which are distributed a few thin flags. The shales contain many fossils, and in some of the sandy layers casts of *Goniatites Pattersoni* are not infrequent.

The section thus far described is that exposed in the Snyder, Hartman and Parrish gullies and the escarpment at the foot of Hatch hill. The measurements for the remainder of the Portage strata were made in the Grimes gully. The lowest rock exposed in this ravine is 375 feet above the base of the Portage strata and is composed of flags or very thin, blue sandstones separated by layers of shale, usually light-blue or olive, sometimes dark, and occasionally black and bituminous.

Fossils, except plant remains, are exceedingly rare. A very large and exceptionally fine specimen of *Lepidodendron Chemungense*, fifteen feet in length, now in the State Museum at Albany, was taken from one of these thin

PLATE II

Portage sandstones at top of third fall, Grimes gully, Naples.

sandstones about ten feet above the bottom of the exposure, and a slab from a layer of densely black slate immediately overlying the layer of sandstone, had on one surface the impression of a number of fish scales and plates.

The general character of the material and of the stratification of the succeeding 135 feet of the section in this ravine is quite uniform, though the proportion of sandstones varies at different horizons, with a gradual increase toward the top. Fossils are rarely seen. Impressions or casts of *Goniatites Pattersoni* occur occasionally on the lower surface of the sandstones, and large forms of *Spathiocaris Emersoni* are sometimes found.

Near the knife factory, in this ravine, a sandy layer four inches thick, and forty feet above the *Lepidodendron* layer before mentioned, has on its upper surface a very interesting bed of plant remains of lignitic character, in which are hundreds of specimens, some of them several feet long. The majority are not in a condition to be identified, but many fragments of *Lepidodendron* occur. The only traces of animal life so far observed in this bed are two specimens of a large *Orbiculoidea*, species undetermined, and one large *Conularia*. One hundred and two feet above the plant bed, a band of sandstones two feet thick, forms the crest of a cascade sixty-seven feet high, known as the "Second Falls." The "First Falls" are near the knife factory and are produced by the waters of a lateral ravine flowing over the side of the main gully. They are about sixty feet high. Above the sandy layers at the top of the second falls the shales and thin sandstones come in again and continue a little more than sixty feet, to near the top of the "Third Falls."

In the face of the precipice at the third falls, and exposed in the walls of the canyon, a thin layer of soft blue sandy shale has been found to contain *Cardiola retrostriata*, *Pleurotomaria capillaria*, *Palæoneilo muta*, *Goniatites Pattersoni* and *Bactrites*, also a finely striated *Cardiola*, species undetermined; a distinctively Portage fauna. Twenty-four feet higher, and nine feet below the top of the fall, occurs a layer of bluish sandstone, four inches thick, that splits easily near the middle and discloses impressions and casts of a considerable number of fossils. The most abundant form here is apparently *Liorhynchus quadricostatus*. Many of these are an inch in breadth. Smaller specimens bear some resemblance to *L. limitaris*. A small form of *Atrypa reticularis* is also abundant. An *Orbiculoidea*, species undetermined, is common; *Productella speciosa* and *Ambocœlia umbonata* var. *gregaria* occur sparingly.

This fossiliferous layer has been traced for several rods along the vertical sides of the ravine, but the most diligent search has failed to discover this fauna or any other fossils in this horizon elsewhere in the Naples valley.

In the large ravine, six miles east of Grimes valley, near the Big Elm, in the town of Italy, Yates county, loose fragments of a layer of the same character were found from approximately the same horizon.

According to the measurements made, this layer is 599 feet higher in the strata than the base of the Portage group, as previously assumed. The fauna contained in it is the lowest of a distinctively brachiopodous character that has been discovered in this vicinity, and no recurrence of a fauna of Portage characteristics has been observed above it. The sandstone layer at the brink of the falls is one foot and four inches thick, compact and of a light blue color. Above it there are exposed in this ravine forty feet of sandstones of the same character, except that a few of the layers are schistose. They are from a few inches to two feet and six inches thick, and are separated by thin layers of very hard blue shales. These are the Portage sandstones. A solitary specimen of a large *Atrypa reticularis* is the only fossil yet observed at this horizon. Above the sandstones, ten feet of soft, dark bituminous shales complete the Grimes gully section.

On the opposite side of the valley on the steep slope of Hatch hill, the sandstones form a well defined and prominent terrace that shows the southern dip of the strata very plainly.

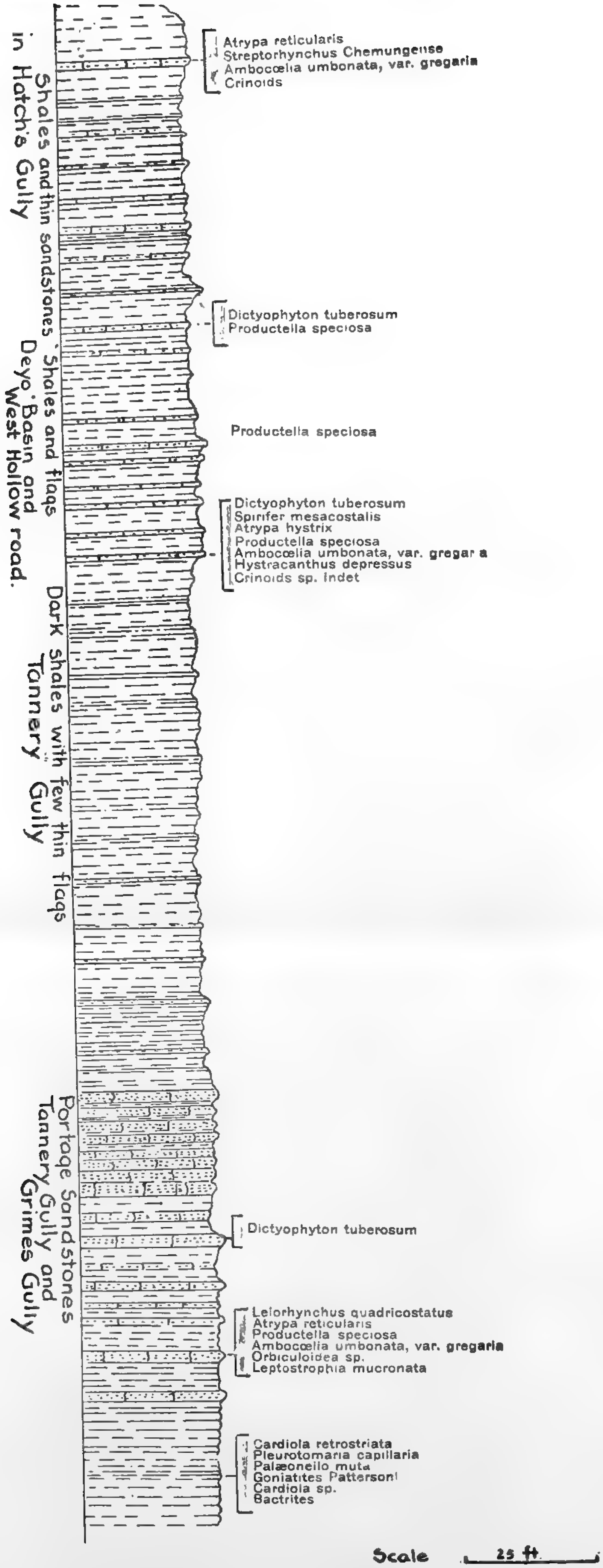
In Caulkins' gully and the quarry on the south bank, the sandstones are very compact and thicker, and the proportion of shale much less.

In the Tannery gully and Kaltenbach's quarry, the section differs but slightly from that in the Grimes gully, though some of the sandstones are more inclined to a schistose condition. Their character is the same at the exposure near the water works' Reservoir.

In the ravines at the head of Italy hollow, eastward in Yates county, the sandstones are well exposed, generally in thinner beds, and with an increasing tendency to be schistose.

For nearly fifty feet above the sandstones, the section in the Naples valley is composed principally of dark and black shales, in which the most diligent search has failed to discover any fossils, and the few interstratified sandstones are likewise barren.

Above this, the sandstones again predominate and are somewhat lighter colored. The lowest fossiliferous layer observed above that at the third falls in the Grimes gully, is on the road leading easterly across Deyo Basin, two miles south of the village of Naples, a little south of the schoolhouse on the road from Naples to Ingleside. This layer is exposed by the roadside near the foot of the hill, five or six rods from the Ingleside road. It is an isolated



The Upper Portage and Lower Chemung Rock section at the south end of the Naples valley.

exposure and its stratigraphic position can not be ascertained with precision. It is, however, not far from one hundred feet above the top of the third falls sandstones. The layer is a compact sandstone, five inches thick, and contains the following fossils:

Dictyophyton tuberosum.
Hystracanthus.
Spirifer mesacostalis.
Atrypa hystrix.
Productella speciosa.
Ambocœlia umbonata var. *gregaria.*
Crinoid stems and heads, sp. und.

This is clearly a Chemung fauna. About twenty feet higher in this exposure a sandy layer contains *Productella speciosa* quite abundantly, and forty-two feet above the lower fossiliferous layer there occurs a bed of plant remains, in which *D. tuberosum* and two or three other species of fossil sponges are common. Other Chemung fossils are also found here.

On the road leading from Naples village to West Hollow, near the residence of Charles S. Sutton, one of the thin sandstones of this horizon exposed at the roadside contains *Orthis Tioga, Liorhynchus mesacostalis, Productella spinulicosta, Ambocœlia umbonata, Atrypa reticularis* and sections of crinoid columns.

In a layer in the west branch of the Tannery gully, opposite M. Hatch's house, *Atrypa reticularis, Orthothetes Chemungensis, Ambocœlia umbonata,* and a mass of crinoid plates and segments occur. This horizon is a little higher than the others mentioned.

Above these fossiliferous layers, others occur at frequent intervals, in which the number of individuals and of species, which nearly or quite all belong to the ordinary lower Chemung fauna, is much increased, sometimes producing more or less persistent calcareous layers. The sandstones also become coarser and lighter colored.

From the foregoing it will be seen that the heavy sandstones at the top of, and above the third falls in Grimes gully are the "Portage sandstones," and are the upper and most southerly division of the Portage group. They are here about fifty feet thick, including the interstratified shales, and from 599 to 650 feet above the bottom of the lower black band.

Toward the east from Naples, the line of outcrop of these sandstones is easily followed around the head of Italy hollow, thence with a northerly bend over Italy hill, and then south above Keuka lake, crossing the valley about two miles southwest from Hammondsport, and bending again to the north on the east side of the lake. The deep valley of Seneca lake carries it far to the southward again, but the condition of the sandstones, which have become generally thinner and schistose, makes it more difficult to trace. It crosses the valley, however, somewhere in the vicinity of Millport.

The wells of the Watkins Salt Co., at Salt Point, two miles from the head of Seneca lake which, at the present date, are the most southerly ones operated for the production of salt, were begun in the lower part of the Portage group; and the mouths of the wells of the Ithaca Salt Co., at the head of Cayuga lake, are nearly in the horizon of the base of the Portage.

Westward from Naples, all parts of the group appear to increase in thickness, the shales are generally softer, and the sandstones more compact and heavier bedded. This is especially the case with the upper beds. They are frequently exposed in the ravines on the sides of the valleys of Honeoye and Canadice lakes, Springwater valley, and the valley south of Conesus lake.

In the Stony Brook glen, two miles south of Dansville, the sandstones appear at the top of the banks at the railroad bridge. In a soft shale a few feet below them, *Cardiola retrostriata*, *Goniatites Pattersoni*, and *Aulopora annectens* are common.

The high ridge west of the Dansville valley carries the line of their outcrop northward to about a mile south of Union Corners, where it bends to the south and follows the west side of the Nunda valley to the south end, where it is well exposed in Stone Quarry hill, three-quarters of a mile south of the village of Nunda. Quarries have been operated here for many years in the layers of compact sandstone, aggregating about forty feet, that are most accessible. Apparently the full thickness of the formation is not exposed. The fossil known as *Spirophyton cauda-galli* is common here. It does not occur in the Naples section, but is very abundant in the sandy layers of the Portage in the western part of the state, and is sometimes found in the middle portion of the group. *Fucoides verticalis* occurs here sparingly.

Underlying the heavy sandstones in the old quarry where the reservoir of the Nunda waterworks is now located, there are five feet of bluish, blocky shales in which are imbedded numerous small calcareous, and sometimes pyritiferous concretions. *Goniatites Pattersoni* and other Portage fossils occur in the shales, but are very rare. This peculiar deposit is found over a large area. It increases in thickness rapidly to the western border of Wyoming county where it is about seventy-five feet thick.

The exposure of the Portage sandstones in the walls of the deep gorge of the Genesee river, near the high bridge of the Erie railroad, is by far the most extensive and best known. The thickness of the individual layers and the aggregate thickness of the sandstones appear to be greater here than elsewhere. On the west side of the river, a short distance below the village of Portageville, a bed of sandstones, nearly all of which are compact, is separated by six feet of shales from a similar bed about thirty-five feet thick, beneath which the concretion bearing shales are exposed with a thickness of eight feet. The upper bed of sandstones was extensively quarried during the construction of the Genesee Valley canal for material for locks, culverts and the great aqueduct that crossed the river at this point.

Above Portageville the fall in the river is very slight, and the horizon of the upper sandstones is above the river bed for several miles to the south.

The Genesee Blue Stone Co. has a large quarry in these upper beds, about three miles south of Portageville, near the tracks of the Western New York and Pennsylvania railroad, the product of which is used in Rochester and New York city.

The next good exposure westward is in the gorge of Wolf creek, one-half mile below the village of Castile. A band of black shales is exposed near Hopkins & Son's mill, and the sandstones are below it. The top of the sandstones is here 150 to 200 feet lower than the crest of the ridge between the Genesee river and the Silver lake basin, and the line of outcrops is carried northward by the configuration of the land, and crosses the ridge about three miles north of Castile. It bends southward around the Silver lake basin, and again to the north over the high lands between the lake and the Oatka Creek valley.

The extensive quarries of the Warsaw Blue Stone Co., at Rock Glen, expose about thirty-five feet of these sandstones. As a stratum of the concretionary shale is exposed in the bottom of the quarry, it is probable that the layers utilized are those of the middle and lower beds.

From the records of the salt wells in the southern part of the Warsaw valley, it appears that the total thickness of the Portage rocks is here 800 to 850 feet, or about 200 feet greater than in the Naples section, thirty-five miles east.

The high plateau in the western part of Wyoming county, between the Oatka Creek valley and the valley of Tonawanda creek is covered by drift, and the bed rock is rarely exposed.

The large ravine near Varysburg presents a fine section of the shales of the middle Portage that reaches the lower part of the sandstones, thereby furnishing a datum from which the location of the sandstones on the plateau may be ascertained with a good degree of accuracy. At the south end of the Tonawanda Creek valley and in the vicinity of North Java and Java Center the sandstones are covered by drift.

In a deep ravine two and one-half miles north of Strykersville, cut through the lower soft shales, some heavy layers of sandstone aggregating fifteen to eighteen feet in thickness, occur at the top of a cascade known as Johnson's falls. They are very compact and present exactly the same appearance as the upper beds.

The upper stratum, about eight feet thick, is exposed at Java village, in the bed of the stream, where it crosses the main street. In the ravine above, there appear first about twenty-five feet of black fissile shale, then seventy-five feet of soft, blue shale, in which the small concretions abound; then sixty feet of typical upper Portage flags and hard shales to the bottom of the upper sandstone beds.

In the northern and western parts of the town of China, the rocks are covered by drift; but in the southwestern part, near the village of Arcade, in the Cattaraugus creek valley, the upper sandstones are exposed in a quarry that has been operated for many years. The rock section is about twenty feet thick. Some of the layers are very hard and compact, others are rather schistose. These beds are quite barren, but on the road leading eastward from the village, Chemung fossils are common at an horizon of fifty feet above that of the quarry.

Westward from Arcade, the upper limit of the Portage group is found in the high hills on the south side of the valley of Cattaraugus creek, with extensions towards the south in the numerous lateral valleys.

There are probably some thin outliers of Chemung rocks of small area on the north side of the valley in Erie county.

The upper Portage flags and sandstones are exposed along Walnut creek, in Arkwright, and in the bed of Canadaway creek, at and above Laona, where one compact layer, four feet thick, and another three feet thick that splits easily into flags, are quarried. The compact layer is also quarried near Brockton, and in the village of Westfield. It disappears beneath the waters of Lake Erie, about three and one-half miles southwest from Westfield.

The Portage sandstones, so well defined in Livingston and Wyoming counties, in their westward extent gradually lose their heavy bedded character, and in the vicinity of Lake Erie they are composed mainly of thin sandstones separated by thin layers of hard shales.

GEOLOGIC MAP

OF THE

TOWNSHIP OF NAPLES

ONTARIO COUNTY N.Y.

BY

D. D. LUTHER.

WYNKOOP HALLENBECK CRAWFORD CO. NEW YORK & ALBANY.

LEGEND

CHEMUNG

PORTAGE

GENESEE

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

(GEOLOGICAL MAP.)

THE ECONOMIC GEOLOGY OF ONONDAGA COUNTY, NEW YORK.

JAMES HALL,
State Geologist.

D. DANA LUTHER,
Assistant.

1895.

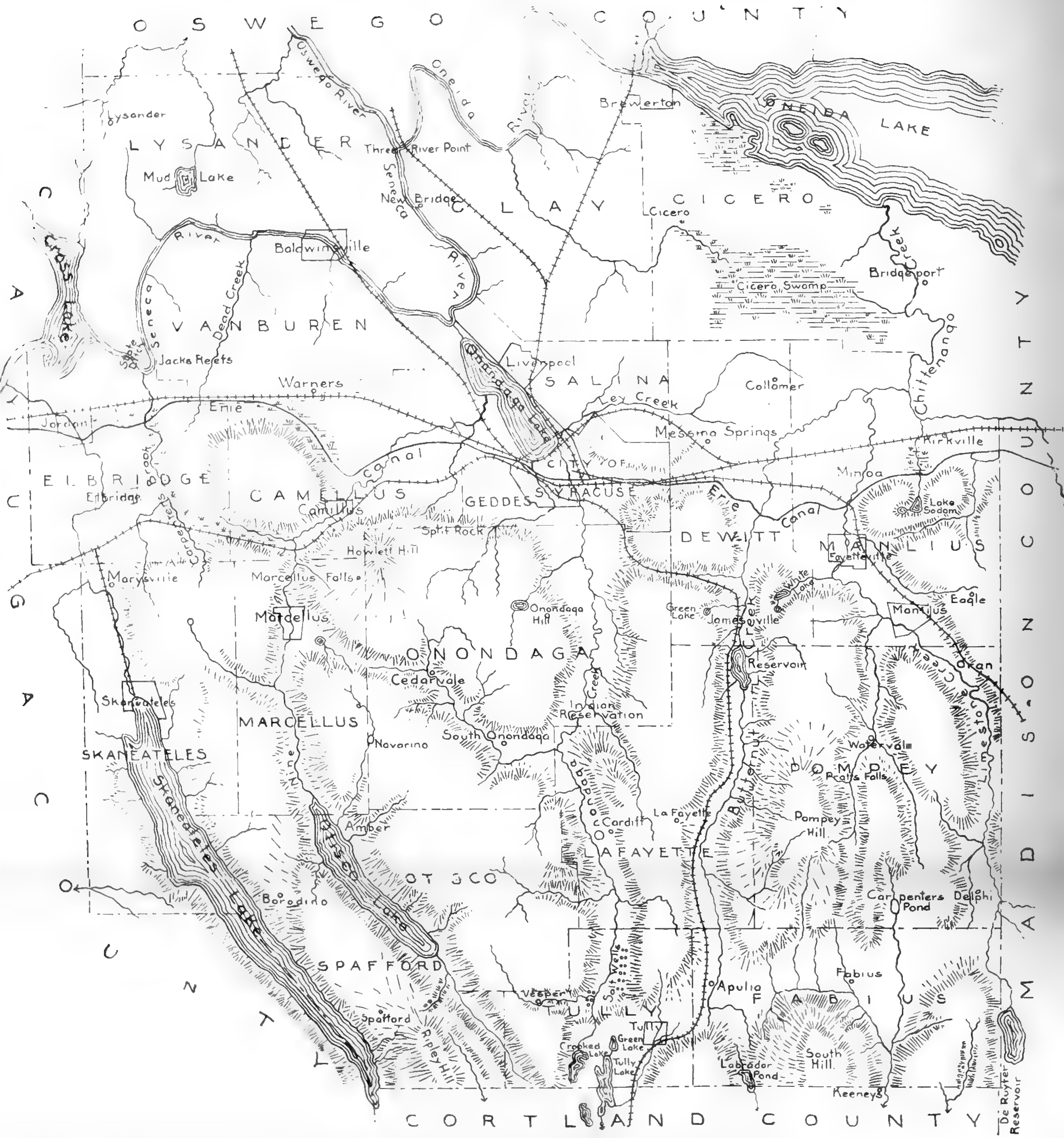
JAMES HALL, *State Geologist.*

SIR:—Herewith I submit my report on the Economic Geology of Onondaga county, New York.

Respectfully yours,

D. DANA LUTHER.

NAPLES, *March* 1, 1896.



MAP OF ONONDAGA COUNTY.

The Economic Geology of Onondaga County, New York.

By D. Dana Luther.

CONTENTS.

Location, Area and Topography.

The county of Onondaga is, in shape, a nearly rectangular parallelogram, lying between 42° 45′ and 43° 15′ north latitude, and 0° 29′ and 1° 6′ longitude east from Washington. It is bounded on the north by Oswego county, the Oneida river forming a part of the boundary line at the north and Oneida lake on the northeast; on the east by Madison county, Chittenango creek making a part of the county line; on the south by Cortland and Cayuga counties, from the latter of which it is separated in the southwest corner by Skaneateles lake, and on the west by Cayuga county. The greatest length of the county from north to south is thirty-three miles, the average length being twenty-nine miles and the average width twenty-eight miles. It has an area of 812 square miles, or 519,680 acres, of which 459,229 acres are land, the remaining 60,451 acres representing the combined area of the lakes.

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In the northeastern part, a section five or six miles wide, parallel to the shore of Oneida lake, is low and flat and, in the town of Cicero, embraces several large swamps. The northern parts of the towns of Manlius, Dewitt and Clay lie partly in this tract which, on the eastern borders of the county, extends as far south as the Erie canal, and includes the territory about the foot of Onondaga lake and its outlet. The average altitude is not greater than 390 feet A. T.

In the town of Lysander the land is gently undulating in the eastern part, but higher in the western part where the rounded drift hills sometimes rise 100 to 150 feet above the level of Cross lake and the Seneca river. The northern part of the town of Van Buren is rolling, the sides of the hills frequently showing the soft red and green shales of which they are composed.

The Erie canal crosses the county a little north of the center, at an elevation of 401 to 409 feet A. T. The territory lying north of the canal is generally flat or gently undulating. The soft Clinton, Niagara and Salina shales that here constitute the bed rock, offer little resistance to denuding or disintegrating forces, and are buried under drift or, when exposed, smoothly rounded over.

The southern part of Van Buren and the northern parts of Elbridge and Camillus are generally flat and low. The broad swampy intervales of Nine Mile creek, Carpenter's brook and other streams, extend through the higher and rougher southern parts of Camillus and Elbridge to the line of the Auburn branch of the New York Central railroad.

South of this lower and comparatively level part of the county, a succession of rugged ledges and vertical walls of limestone, constituting the Helderberg escarpment, stretches across the county, on a very irregular, but nearly east and west line. This escarpment is the upturned edge of the limestones of the Salina, Lower Helderberg and Corniferous groups, lying upon each other to the thickness of 400 to 500 feet. It causes an abrupt elevation of the surface to the height of 800 to 850 feet A. T. From the top of the escarpment to the south line of the county the average elevation gradually increases to 1,500 or 1,600 feet A. T., and the extreme height reaches 2,020 feet A. T., at the top of South mountain, in the town of Fabius, and 1,968 feet, at Ripley hill in Spafford. This high land in the southern tier of towns forms the summit ridge or watershed between the drainage areas of lake Ontario and the Susquehanna river.

The waters of Limestone creek, Butternut creek, Onondaga creek, Spafford creek and Skaneateles lake flow toward the north and reach the sea by way of Oswego river, lake Ontario and the St. Lawrence river, while Fabius creek, which has its rise in a small spring on the top of Pompey hill, together with Labrador brook, the outlet of the Tully lakes, and Cold creek in Spafford, flow south into the Tioughnioga river, and reach the ocean by way of the Susquehanna river and Chesapeake bay.

Five deep, narrow valleys extend from the south line of the county in a northerly direction and break through the Helderberg escarpment at different points. These principal valleys, named in order from the east, are: Limestone creek valley, Butternut creek valley, Onondaga valley, Otisco or Nine Mile creek valley, and the Skaneateles lake valley. They have many lateral branches, some of them quite extensive, and deep rocky ravines with high cascades are numerous.

Limestone creek valley is situated near the east line of the county. The DeRuyter storage reservoir for the Erie canal at the southeast corner of the county, is near the south end of the valley. From the reservoir, which is about 1,250 feet A. T., to Delphi the descent is rapid, and a deep gorge has been cut by the stream through an immense mass of glacial drift that chokes the valley at this point. From Delphi to near Manlius the descent is slight; the sides are sloping and there is an intervale half a mile wide. At Manlius, where the valley is cut through the limestone, it is narrower and rocky. Edward's falls, one and one-half miles south of the village, are ninety feet high, and below them is a narrow gorge with high banks. Just below the village of Manlius the valley of the west branch of Limestone creek is connected with the main one by a deep ravine, one-half mile long, ending at Brickyard falls, seventy feet high. Above the falls the valley, which is generally rough and irregular, extends towards the south for several miles. Pratt's falls, five miles south of Manlius, in this valley, are 137 feet high. Below the junction of the two streams the valley spreads out rapidly. The floor is somewhat uneven, and the bed rock is but thinly covered, cropping out in many places. The sides of the valley are rough and steep, with bare masses and cliffs of limestone, 200 to 300 feet high, on both sides as far as Fayetteville. North of Fayetteville the bordering hills are lower and do not extend beyond the Erie canal.

Butternut creek valley is connected at its head in the western part of Fabius with the valley of Limestone creek by a wide, high, east and west valley, and also with the Tully lake plateau by an extension which has a southwesterly course, with the drainage in the same direction. Near Apulia, where the bottom of the valley is highest, it is 1,225 feet A. T. It is narrow and rocky for most of the distance to Jamesville, the average descent being about fifty feet per mile. North of Jamesville, where it breaks through the limestone beds, it becomes a narrow gorge, with a cascade at Dunlop's mills, where the first saw mill in the county was built, in 1792, and the first grist mill, in 1793, by Asa Danforth. Half a mile north of Dunlop's mills the "Jamesville cut," a canyon fifty rods wide, 250 feet deep, and three miles long, diverges towards the west and connects Butternut creek valley with the Onondaga valley. The Delaware, Lackawanna and Western railroad runs through this cut and the entire length of the Butternut creek valley south of Jamesville.

The Onondaga valley is the north end of an ancient river bed that, at the close of the glacial epoch, had been filled with drift to so great a height in what is now the township of Tully, that a col was formed at an elevation of 1,200 feet A. T., the water on the south side following the old channel to the Susquehanna river, and on the north to Onondaga lake and the Seneca river. At the point where the southern boundary line of Onondaga county crosses, the valley is about three miles wide, the southern extension of Butternut creek valley coming into it just there from the east and nearly doubling the width. The sides are 300 to 500 feet high and very precipitous. The col, or separating ridge, lies on the north side of all the Tully lakes, except Crooked lake. Two and one-half miles north of the county line, the high upper section ends abruptly, and the floor of the valley sinks, in the distance of about half a mile, from 1,200 feet A. T. to 800 feet A. T. At the foot of this declivity a well sunk near the middle of the valley, which is here about a mile wide, penetrated 400 feet of clay, sand and fine gravel, and was abandoned without reaching bed rock, from which it appears that the morainic filling of the old channel is at least 800 feet thick. Many copious springs burst out on the steep slope of the gravel bed, forming small streams that unite with the Vesper brook which comes in from the west through a deep ravine, and over a cascade seventy feet high, and together make the Onondaga creek. The water of these springs is saturated with lime taken up from the drift, and large masses of travertine have been deposited in many places. An extensive deposit of red clay, the material of which is evidently derived principally from the red Salina shales, lies nearly across the extreme south end of this lower section of the valley. From this point to Syracuse, about seventeen miles, the valley is from one to two miles wide, the sides of the bordering hills sloping gently at the base, but becoming precipitous and in many places rocky in the middle portion, while the upper part is a succession of rounded eminences that rise

PLATE II

View of the south end of the valley of Onondaga creek, from the reservoir of the Solvay Process Company's salt wells in the town of Tully.

500 to 800 feet above the bottom of the valley. The intervale is an alluvial plain having an average descent toward the north of twelve feet to the mile. Unlike the other four valleys that have been excavated through the Helderberg escarpment in this county, the Onondaga valley becomes wider after it reaches the hard limestones in the vicinity of the Indian reservation, about midway between the head and Onondaga lake, spreading out into a plain one and one-half to two and one-half miles wide. The sides of the valley decrease somewhat in height, but are still 250 to 400 feet high, steep and rocky, abounding in cliffs and ledges, the location of many quarries. The ridge on the east side of the valley extends to Ley creek, a little north of the head of Onondaga lake, with a deep valley crossing it, two miles from the north end, through which the Erie canal and the New York Central railroad find passage to the eastward into the city of Syracuse. On the opposite side the hills recede toward the west, and do not reach quite so far north. The basin of Onondaga lake is located in the low section of the county, extending in a northwesterly direction from the line of the Helderberg escarpment. It is excavated to the depth of 450 to 500 feet in the Salina red shales, and is a continuation of the old channel, which is now the valley of Onondaga creek. The bottom of this channel at the head of the lake has been found to be fifty-two feet below the level of the sea. At the Solway Co.'s first well at Tully, the drill penetrated 400 feet of sand and clay without reaching the rock, and in two wells on the east side of the valley, forty-five feet of drift was found in one, and in the other, 590 feet therefrom toward the center of the valley, 322 feet. The latter well is about 2,000 feet from the center of the valley. Nowhere in the middle of the valley is bed rock exposed, nor has it been reached by drilling, and there is every probability that the great depth of the old channel below the bottom of the present valley, found at both the head and the foot of this lake, is continuous throughout its whole length.

The Otisco lake valley has its beginning in Cortland county, and extends in a northwesterly direction. From the foot of Otisco lake southward it is about half a mile wide, with steep sides, where the soft shales are frequently exposed. The hills adjacent to this part of the valley rise from 800 to 1,000 feet above the bottom of the valley. The valley is narrower north of the lake, and the outlet, known as Nine Mile creek, runs among drift hills and shale knolls to Marcellus village, where a narrow rocky canyon begins, which is cut through the Helderberg escarpment to the depth of 250 feet, about four miles to Marcellus station. From this point Nine Mile creek flows toward the northeast through a narrow valley having steep sides and a flat alluvial intervale that has a very slight descent. One-half mile south of Marcellus a wide, deep opening has been cut through the east side of the Nine Mile creek valley down to the top of the limestone. This is the head of the Cedarvale valley, which extends in a southeasterly direction and joins the Onondaga valley near South Onondaga.

The Skaneateles lake valley, near the western border of the county, has a general direction from the southeast to the northwest. Skaneateles lake, which is sixteen and one-half miles long and has an average width of about one mile, occupies the southern part of the valley. About the head of the lake the sides are precipitous and rocky to the height of 100 to 400 feet, then they slope gently upward to the height of 700 to 1,100 feet above the level of the lake, which has an elevation of 860 feet A. T. Toward the north end of the lake the width of the valley is greater, the hills are much lower, and the gentle slope of the sides is continued quite to the shores. The passage through the limestone escarpment is about one-half mile wide and three miles long. The rocks are abundantly exposed, but there are no high cliffs nor deep rock cuts. North of the New York Central railroad the valley winds among low hills of drift or shale in a northerly direction across the town of Elbridge to the Seneca river.

THE GEOLOGIC SUCCESSION.

The rocks exposed on the surface in this county are all of sedimentary origin, with the exception of a small amount of eruptive matter in a single locality. The geological formations to which they belong, named in order from the lowest, are:

Niagara Period	Clinton Group. Niagara Group.
Salina Period	Red Shales. Gypseous Shales.
Lower Helderberg Period	Hydraulic Limestone.
Oriskany Period	Oriskany Sandstone.
Upper Helderberg Period	Corniferous Limestone.
Hamilton Period	Marcellus Shales. Hamilton Shales. Tully Limestone.
Chemung Period	Genesee Slate. Portage Group.
Quaternary System	Glacial Drift. Champlain Deposits.

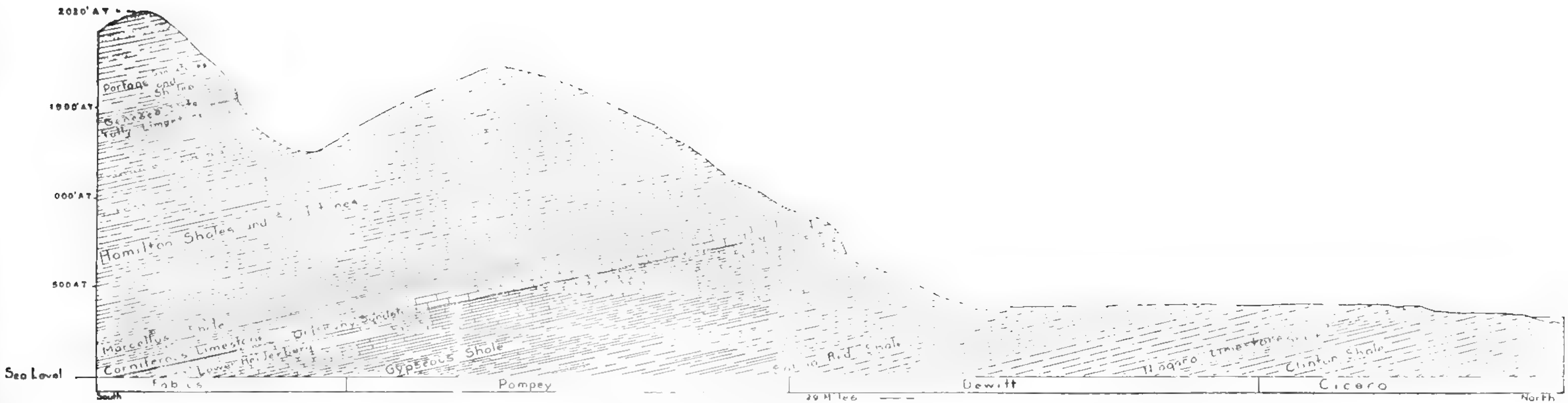


FIGURE 1. THE NORTH AND SOUTH ROCK SECTION THROUGH ONONDAGA COUNTY.

Clinton Shales.

The lowest sedimentary rock formation exposed in this county is the Clinton shales of the Niagara period. These are the bed rock underlying the north part of the towns of Cicero, Clay and Lysander. This territory has an average elevation of perhaps a little below 400 feet A. T. The surface is gently undulating and the soil is generally sandy or gravelly. The streams are all very sluggish and do not usually cut down to the rocks; hence exposures are very rare.

In the vicinity of the village of Brewerton, at the foot of Oneida lake, the covering of drift is quite thin, and the rock is frequently uncovered by the grading of the highways and in digging cellars. The rock is nearly all a soft olive green shale, quite light colored when first exposed but, owing to the iron it contains, it rapidly becomes a dark rusty brown. Some thin layers occur, composed largely of fine grains of iron. They oxidize rapidly on exposure and crumble into dust.

The Disciples church, in the village of Brewerton, stands on a knoll about ten feet high, composed of the Clinton shales, which are exposed near the sidewalk in front. Forty or fifty rods south from the station of the Ontario and Western railroad, the highway cuts through a similar knoll, exposing four or five feet of the shales, and other similar small exposures occur toward the east along the shores of Oneida lake, and toward the west near the Oneida river, though they are not sufficiently dispersed, nor of such a character as to permit the accurate measurement of the thickness of that part of the Clinton group included in the surface rocks of this county.

The exposures at Brewerton are fifteen to twenty feet above the Oneida river, and three miles from the line of the outcrop of Niagara limestone, and the elevation is very nearly the same, so that the thickness of the intervening beds of shale can only be determined by ascertaining the amount of dip, which can not be done by direct measurement on account of the lack of good exposures. It is impossible, for the same reason, to locate the contact line between the Clinton and the overlying Niagara shale.

Niagara Limestone.

The limestones of the Niagara period are exposed at several places along a line from the northwest corner of the county to Bridgeport, across a section of country which has an elevation of 375 feet at the east line of the county, and rarely rises above 400 feet A. T., except in the northwestern part of the town of Lysander. Their position is sometimes indicated by a low ridge, but this ridge is nowhere high enough to affect the drainage to any appreciable extent, except as it forms the northern rim of a shallow basin from eight to ten square miles in extent, known as the Cicero swamp.

Diedrich's quarry, from which Niagara limestone has, for many years, been taken for building purposes and for the manufacture of quicklime, is located in the western part of the village of Lysander, a few rods south of the crossing of the Main street and the little stream known as Ox creek, which runs through a shallow north and south valley, about thirty-five rods wide at this point. The rock is exposed or very thinly covered for the entire width of the depression and on both banks for a short distance. A small quarry formerly existed on the east bank, a few rods north of the street, and another a mile further north, near Baird's corners, from which a considerable amount of building stone was taken. A kiln for making quicklime was located there.

At Diedrich's quarry the stratum uncovered is about five feet thick and consists of a number of layers from two to six inches thick, of very hard, fine grained, dark grey bituminous magnesian limestone. Some of the layers are quite even in thickness, while others are mere lenticular concretionary masses and are very uneven. Thin scaly seams of black bituminous matter separate the layers. Small irregular cavities, lined with crystals of calcite are common. Fossils are very rare. The quarries mentioned have supplied the principal part of the cellar and foundation stone used in the village of Lysander and vicinity, and slabs of considerable size have been used for the covering of road culverts and like purposes. A fair quality of quicklime was formerly made here, and the ruins of the old kiln remain. The rock breaks easily across the bedding with a straight smooth face and makes a handsome wall. Under the chisel it has a slightly conchoidal or cuppy fracture. The thickness of the Niagara limestone at this locality is unknown. It was penetrated eleven feet in a well dug near the residence of O. O. Brown, forty rods northeast of Diedrich's quarry, and the bottom was not reached.

On lands owned by Otis Bigelow, Esq., two and one-half miles northwest from Baldwinsville, the limestone is covered by three to four feet of drift over several acres. Workings, known as Ham's quarry, were formerly operated at this place. The stone used in building Houghtaling & Bigelow's large flouring mill in Baldwinsville was quarried here, and it has been used extensively for cellar and foundation stone, bridge abutments, culverts, and similar work in the vicinity. It was also used in the construction of the Delaware, Lackawanna and Western railroad. The stratum of limestone is about four feet thick in several layers, some of which are quite even in thickness.

Apparently the upper parts of the limestone beds have been removed, and the layers remaining are those of the base of the strata, as dark bluish shales appear in the bottom of the quarry. The excavations extend over a considerable area, but are very shallow. They are now partially filled with water, and are overgrown with weeds and bushes, thus precluding satisfactory examination. The line of outcrop crosses the Seneca river, one mile north of Newbridge. No outcrop is now visible, but loose slabs are very abundant, and were used in the construction of the Oswego canal, which occupies a part of the old river bed.

On Peter Young's farm, one-half mile northeast from Cigarville (Clay corners), in the town of Clay, the limestone has been uncovered by the removal of one to two feet of soil, and about 500 cubic yards of material for culverts and bridge abutments were quarried from the stratum, two feet thick, of good stone found here, and used in the construction of the Syracuse Northern railroad. A smaller amount was hauled to Brewerton for cellar stone. One layer, eight inches thick, is compact and quite even; the rest is not so good. The quarry has not been worked recently. The ground here is nearly level, and the old pit is now partly filled with water, and no outcrop is visible.

In the town of Cicero, two and one-half miles east of the village of Cicero, the limestone lies very near the surface of an area more than one hundred acres in extent, and blocks of it, formerly scattered over the fields, now make a large part of the fencing for a number of farms. A quarry has been in operation for many years, on land owned by Mr. O. Whitney, and has supplied the principal part of the building stone used in this vicinity. About three feet of hard, compact limestone in fairly even layers, three to twelve inches thick, are here exposed. The color of the rock is very dark, dull grey, and where it has been long exposed in the farm fences, it is black. Some parts are very finely granular in character. Cavities of irregular shapes, lined with crystals of calcite are quite abundant. Quicklime was formerly made in a kiln situated about one-fourth of a mile east of Whitney's quarry.

At Bridgeport, the limestone is exposed in the bed of Chittenango creek, where it appears as a bar and creates a water power of considerable value. Although the Niagara limestone is but a few feet thick, the ease with which it can be quarried, and the position of its line of outcrop across the northern tier of towns, makes it of considerable economic value to that part of the county. No other building stone except, in some localities, a few erratic boulders, can be obtained without the expense of transportation for fifteen to twenty miles.

At present the output from the five quarries, which have been opened in it, is not large, but the amount is governed entirely by the demand for good building stone.

Salina Group.

The Salina group is composed of two thick deposits, which differ greatly both in appearance and character. The lower beds are known as the Red shales, and the upper as the Gypseous shales.

Red Shales. The Red shales include many layers of green shales, and clouded or mottled red and green beds are of frequent occurrence. The red color is, however, very pronounced, a strong brick red; the green is a light but generally distinct pea green. Some of the upper layers near the contact line are olive. Red is the predominating color in the lower beds, and green toward the top. The shale is very soft and clayey, crumbling into dust on exposure, if dry, or turning to clay, if wet. Some of the green and olive layers are fissile to a slight degree.

In the Onondaga Brick Co.'s quarry, near Warner's, there occurs a layer of coarse sandstone that resembles the Medina sandstone. Thin layers of drab magnesian limestone occur among the shales in all parts of the sub-group, but more abundantly toward the top. The Red shales constitute the bed rock in a belt averaging about seven miles wide, extending across the county parallel with the line of the Erie canal, which may be taken as its southern boundary. From this territory there are to be deducted outliers of the succeeding Gypseous shales in the hills in the northern part of Camillus, and the northeastern part of Syracuse.

In the town of Van Buren, and particularly in its northern part in the vicinity of Dead creek and the Seneca river, the hills are beautifully banded and clouded in green and red where the shales come to the surface, or are but thinly covered by clay produced by their disintegration. The range of hills north of the West Shore railroad, near Warner's station, is mainly composed of shales of the middle and upper parts of this sub-division. The Onondaga Vitrified Brick Co. takes the raw material for its very large output of brick and tile from one of these hills, where a section seventy-five feet thick is exposed. The Central City Brick Co. also has a quarry in nearly the same horizon, in a low hill one and one-half miles southeast from Kirkville, near the Erie canal, from which it manufactures brick extensively.

The state ditch across the peninsula in the southwestern part of the town of Lysander, formed by the loop of the Seneca river near Jack's Riffs, was excavated through a bed of quite hard olive and green shales and thin limestones, reaching the top of the Red shales. An exposure of banded green and red shales occurs on the east side of Onondaga lake, not far from the corporation line of Syracuse, and the redder shales may be seen farther north toward Liverpool. Neither salt nor gypsum is found in any considerable quantity in the Red shales. Their only economic value lies in the fact that they supply an inexhaustible quantity of good material for the manufacture of brick. For this purpose the shale is dried and screened to remove any fragments of limestone or sandstone, then pulverized, after which it is brought to the proper consistency by the addition of water and pressed into the form of bricks. The bricks are dried and baked in immense conical kilns till thoroughly hardened.

The Onondaga Vitrified Brick Co. manufacture 10,000,000 building bricks annually. The Central City Brick Co. produced, in 1895, at their new plant at Kirkville, 1,500,000 ornamental pressed brick and expect the annual output to be many times that number hereafter.

At the top of the Red shales, thin layers of drab limestones, some of them cellular, and all cracked and seamed and containing the hopper shaped forms which indicate the former presence of salt crystals, make up a large part of the rock strata, the remainder being composed of soft, clayey, olive, or harder, bluish and drab gypsiferous shales. Some of the olive layers show even more plainly than the limestone, that salt in seams and veins and crystals was once abundant in these rocks, and the disturbed condition of the strata makes the supposition not unreasonable that one or more layers of rock salt have been removed by dissolution. The great deposits of rock salt in the western and central New York salt fields are all in this horizon, as is the bed reached in the wells of the Solvay Process Co. at Tully, which is, beyond doubt, the source whence has been derived the enormous quantity of salt held in solution in the brines of the Onondaga lake basin, from which there has been manufactured without material diminution of the strength of the brine, ten million tons of salt, equal to a bed of rock salt ten feet thick, covering 310 acres.

Historical Epitome of the Salt Industry. The first salt manufactured from the Onondaga Salt springs was on the sixteenth day of August, 1653, by Father LeMoyne, a Jesuit missionary, who says: "We tasted the water of a spring, which the Indians were afraid to drink, saying it was inhabited by a demon who renders it foul. I found it to be a fountain of salt water, from which we made a little salt, as natural as from the sea." The Onondaga Indians continued to own and control the salt springs until 1788. During the intervening time they had learned to use it with their food and to manufacture it. Small quantities of it were transported to Quebec and sold by them, and samples were carried by traders to Albany.

On the twelfth day of September, 1788, by the treaty of Fort Schuyler, under which the Onondaga Indians ceded to the State of New York all their lands, it is declared that "the salt lake and the lands for one mile around the same, shall forever remain for the common benefit of the people of the State of New York and of the Onondagos and their posterity, for the purpose of making salt, and shall not be granted, nor in any wise disposed of for other purposes."

In the month of May in that year, Comfort Tyler, with the assistance of an Indian who guided him to, and pointed out the salt spring, made thirteen bushels of salt in nine hours, with a fifteen-gallon iron kettle. In the winter of 1789–90, Nathaniel Loomis made between 500 and 600 bushels, which he sold for one dollar per bushel. In 1791 or '92, Wm. Van Vleck and Jeremiah Gould "made salt in chaldron kettles set in arches." In 1793, the first "block," four caldron kettles set in one arch, was erected by Moses Dewitt and Wm. Van Vleck. In 1798, the Federal Company erected a plant, containing thirty-two kettles in blocks of four each.

By act of Legislature, in 1797, the state assumed direct control of the salt reservation, and on June 20th of that year, William Stevens was appointed Superintendent of the Onondaga Salt Springs. Since that date the annual reports of the Superintendent show the amount of salt made each year. In 1798, it was 59,928 bushels. In 1862, it was 9,053,874 bushels, the largest amount made in one year. In 1810, the water of Yellow brook was used to drive a water wheel to elevate the brine, and pumps, driven by horse power, came into use about the same time.

About 1821, the manufacture of coarse salt by solar evaporation was begun. In this process the brine is exposed to the sun's rays in large shallow wooden vats until crystallization takes place. At the present time about seventy-five per cent. of the salt produced at the Onondaga Springs salt reservation is made by solar evaporation. The first wells were dug at the edge of the marsh at Salina. One of them, the first of any note, was sunk by Superintendent Kirkpatrick, about 1806. It was twenty feet square and thirty feet deep. In 1820, Major Benajah Byington was authorized to bore for rock salt anywhere on the reservation. His explorations were made in the higher land east of Salina. They resulted in failure. In 1825, Simon Ford, engineer in charge of the salt works, drove a tube, twelve feet in diameter and made of staves thirty-two feet long, to a depth of thirty feet, and then removed the mud and earth from the inside, thus making a new well. In 1826, a well was sunk at Liverpool, that appears to have been in the shales. It was the only well that did not require to be curbed. In 1827, wells were sunk at Geddes, Salina, and one mile north of Salina. In 1830, iron tubes, twelve inches in diameter and three and one-half feet long, were clamped together and sunk, by boring, to a depth of sixty feet. In 1831, the Onondaga Salt Co. bored a well, 160 feet deep, to good brine. In 1839, a well was sunk at Salina by the state to the depth of 600 feet, in search of the bed of rock salt that was thought might be in the immediate vicinity and supply the saline qualities to the waters of the marsh, by contact with subterranean streams. No crystals of salt were found. It had been ascertained that the strength of the brine was greater as the depth from which it was taken through the tubular wells on the borders of the lake and marsh was increased. At sixty feet it was twenty-five per cent. stronger than in the old shallow wells. By the use of tubes constructed of iron or of hard maple wood banded and clamped with iron, wells were sunk in the mud and sand of the low lands about the head and east side of the lake, which reached the depth of 225 to 340 feet in the Syracuse wells, 150 to 310 feet at Salina, and 80 to 100 feet at Liverpool.

In 1851, a well was sunk in the middle of the valley, at the head of the lake, to the depth of 414 feet, through the following strata:

White and beach sand	34	feet.
Blue and light colored clay	148	"
Coarse sand	209	"
Clear gravel	6	"
Quicksand	11	"
Cemented gravel	2	"
Red clay	3	"
Hard red clay	1	"

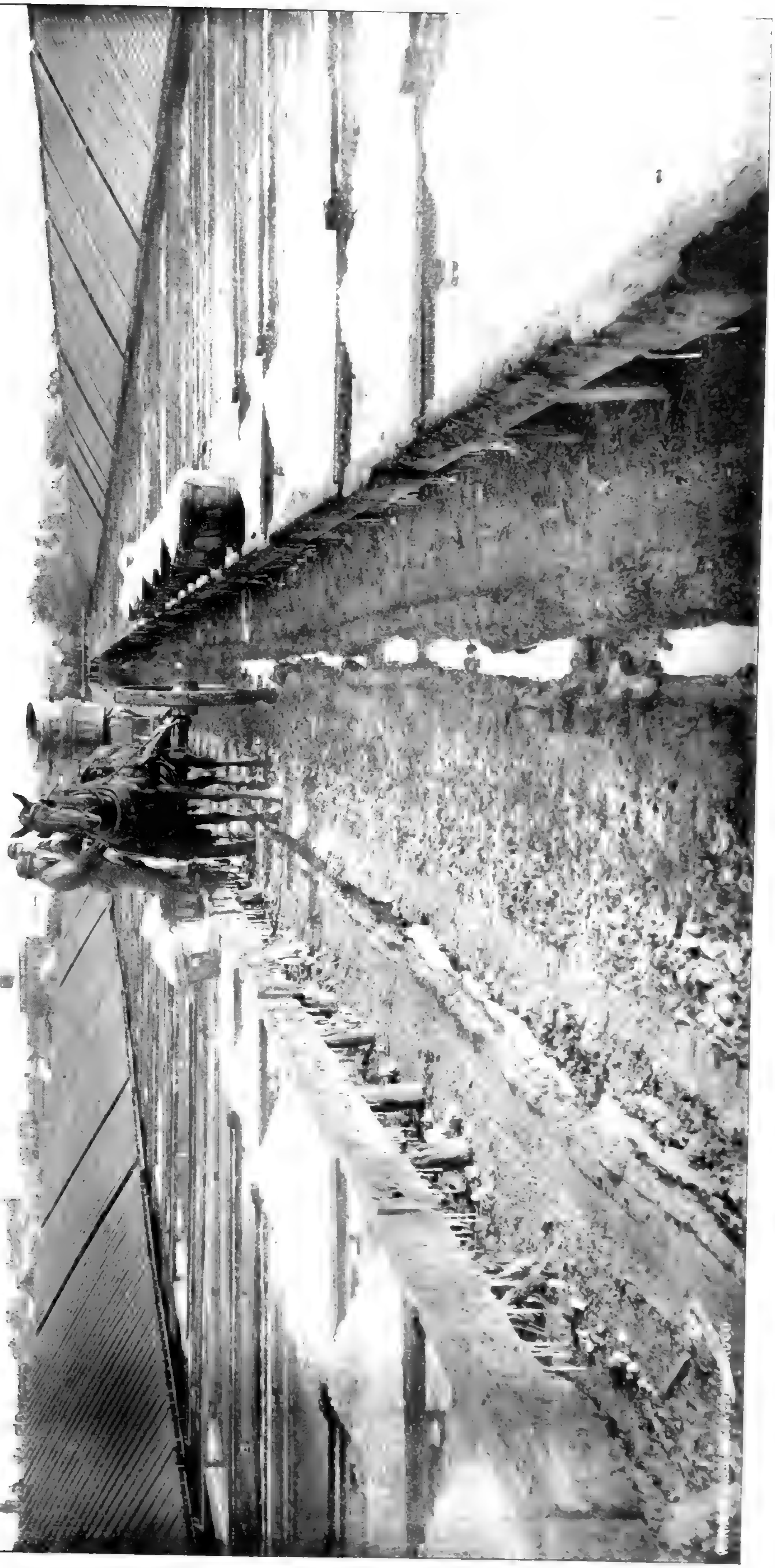
Except as to the thickness of the layers, this appears to represent the section in all of the producing wells, the best brine being found in the clear gravel, which is reached at varying depths in all of the wells. In 1888, fifty wells were in operation, and produced all of the brine from which salt was manufactured on the reservation. They were in five groups, as follows:

"Syracuse" group, fourteen wells; "De Wolf" group, six wells; "Gere" group, six wells; "Salina" or "Marsh" group, twelve wells, and the "Geddes" group, twelve wells, and produced brine of an average strength of seventy degrees salometer.

In 1878, the truth of the long maintained assertion of Professors Eaton, Hall, Vanuxem and other geologists, that beds of rock salt occur somewhere in the rocks of the Salina period, was proven by the discovery at Wyoming, Wyoming county, N. Y., in a deep well sunk for oil or gas, of a bed of rock salt, seventy feet thick, 497 feet below the top of the Corniferous limestone, and at the base of the Gypseous shales. The Onondaga Salt Co. had sunk a well 715 feet at Liverpool, in 1867, after which no deep wells were put down in Onondaga county, until 1881, when the Solvay Process Co. drilled 1,040 feet at Jamesville in the Butternut Creek valley, seven miles in a southeasterly direction from Onondaga lake, having reached the red shales at 587 feet, without finding salt. In 1882, the Solvay Co. put down a well at Cedarvale (formerly called Montfredy's mills), about eight miles southwest from the head of Onondaga lake. The mouth of this well was about 700 feet A. T., and not far from the horizon of the top of the Corniferous limestone. Red shales are reported to have been reached at 705 feet. Brine was found, but no rock salt. The total depth of this well was 1,157 feet. About this time a deep well was sunk at Danforth, two and one-half miles south of the lake, in the Onondaga valley. No record of this well is obtainable.

In 1884, Thomas Gale, Esq., had a well bored about three miles northwest of Syracuse, on the north side of Onondaga lake. The surface elevation at this well is 435 feet A. T. According to Dr. Englehardt's record, the Niagara limestone was reached at 527 feet. Brine was found at 485 feet, 532 feet, 1,395 feet and 1,500 feet, but no rock salt. In the same year the state well, situated on the south bank of the new channel of Onondaga creek, 1,000 feet east of the lake, and which had already been sunk to the depth of 430 feet, ending in red shale, was drilled to the depth of 1,969 feet. The mouth of the well is 369 feet A. T. Niagara limestone was at 578 feet. No salt was found, nor brine, except a small quantity in the upper shales. The sinking of these two wells settled the question as to the presence of rock salt beneath the reservation; but the search was resumed toward the south, in the Onondaga valley, by the Solvay Process Co.

In 1888, a well was begun in the town of Tully, eighteen miles south of Onondaga lake, in the middle of the south end of Onondaga creek, near a cross road at the foot of the drift hills. It was abandoned after penetrating



400 feet of gravel and quicksand, without reaching the bed rock. Another well was immediately started, 1,400 feet east of the latter, and on the side of the valley in the Hamilton shales. The Corniferous limestone was reached at 718 feet, and rock salt 498 feet lower, the distance between the top of the Corniferous limestone and the top of the rock salt being one foot more than in the Pioneer well at Wyoming. Drilling ceased after forty-five feet of salt had been penetrated. No red shales were found. The total depth of this well, which is known as the "Tully well," is 1,261 feet. The elevation of the mouth of the well is 901 feet A. T. The next well was put down one mile south of the village of Cardiff, three miles north of the Tully well. The top of the Corniferous limestone was reached at 244 feet; then 500 feet of limestone and 100 feet of red shale were drilled through without finding rock salt.

In 1889, ten wells were drilled by this company along the foot of the hill on the east side of the valley, north of the Tully well. Nine of these wells stopped at or near the bottom of a bed of salt, forty-one to forty-seven feet thick. One of them passed through this bed, forty-three feet, then through twenty-five feet of shale, reaching a second bed of rock salt, fifty-four feet thick. Below this bed, forty-one feet of "Magnesian shale" and ten feet of gypseous shale were penetrated.

In 1890, ten wells were sunk. The records kept by the drillers show that in one of them 318 feet, and in another 220 feet of rock salt were penetrated, but the number of beds and the thickness of intervening beds of shale, if any such were found, is not recorded.

In 1891, eight wells were drilled to the salt beds. In one of these, four beds were found, respectively forty-six, seventy-four, thirty-six and sixty feet thick, making a total of 214 feet of rock salt; these were separated by three beds of shale, forty, thirty and thirty feet thick.

In 1892, another well was sunk on the east side of the valley, making thirty wells in all. On account of its inconvenient location the "Tully well" has not been utilized. The twenty wells sunk in 1889 and 1890 were located in five groups, each group consisting of four wells, one at each corner of a rectangle, 400 feet long, from north to south, and 150 feet wide. The groups were 1,000 feet apart, and very nearly on a north and south line, making the distance between the wells at the north and south end of the series 6,000 feet.

Of the nine wells drilled in 1891 and 1892, five were added to the groups as then arranged, two were located further south and formed a new group, and two made a new group north of the others. The seven groups were designated A, B, C, D, E, F, G, beginning at the south. Very careful records of the strata, penetrated in drilling the wells, were kept by Mr. Hugh Graham, who superintended the work. The records of wells No. 1 and 4 of group "A," No. 1 of group "B," and No. 1 of group "C" are especially minute in detail. From them the diagram on page 263 has been compiled.

The land on which the wells are situated, has an upward slope from the bottom of the valley, becoming steeper very rapidly, and a few rods east of the wells the Hamilton shales crop out all along the hillside. The thickness of the drift passed through varies from eleven feet in two of the wells nearest the hill, to 256 feet and 322 feet in two of the most westerly, or nearest the middle of the valley.

In the fall of 1895, the Solvay Process Co. began the work of sinking ten wells on the opposite side of the valley, about three-fourths of a mile west of group "A." The wells are located in and about the mouth of the Vesper ravine. The record of the first well, completed on the west side, known as "No. 30," is as follows:

Surface elevation	833.2 feet A. T.
Top of Corniferous limestone at	675 "
Salt at	1,174 "

Measurement by Locke level shows the mouth of this well to be 497 feet below the base of the Tully limestone, as exposed near the road leading from Tully to Vesper, the outcrop being one-quarter of a mile south of the well. Allowing ten feet for dip of strata, would give 483 feet + 675 feet = 1,158 feet for the thickness of the Hamilton and Marcellus shales at this point. Salt was reached 499 feet below the top of the Corniferous limestone.

The record of well "No. 32" is:

Drift	12 feet.	
Corniferous limestone at	645 "	75 feet thick.
Oriskany sandstone at	720 "	15 " "
Salt at	1,150 "	90 " "
Depth of well	1,240 "	

Well "No. 33:

Corniferous limestone at	654 feet.
Rock salt at	1,164 "

The object sought by the Solvay Process Co. in drilling these forty wells, was a sufficient supply of salt to be used at the company's works at Geddes, in the manufacture of soda-ash. The salt is dissolved out of the bed and conveyed to the works by gravity, advantage having been taken of

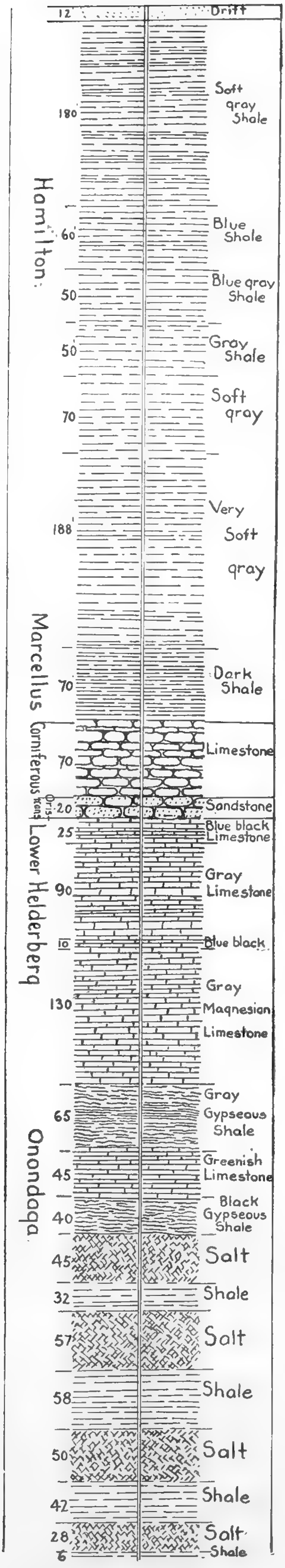


Figure 2. The rock section in the salt wells at Tully; from the surface to the top of the salt as in Well No. 1, Group B; from the top of the salt to bottom as in Well No. 4, Group A.

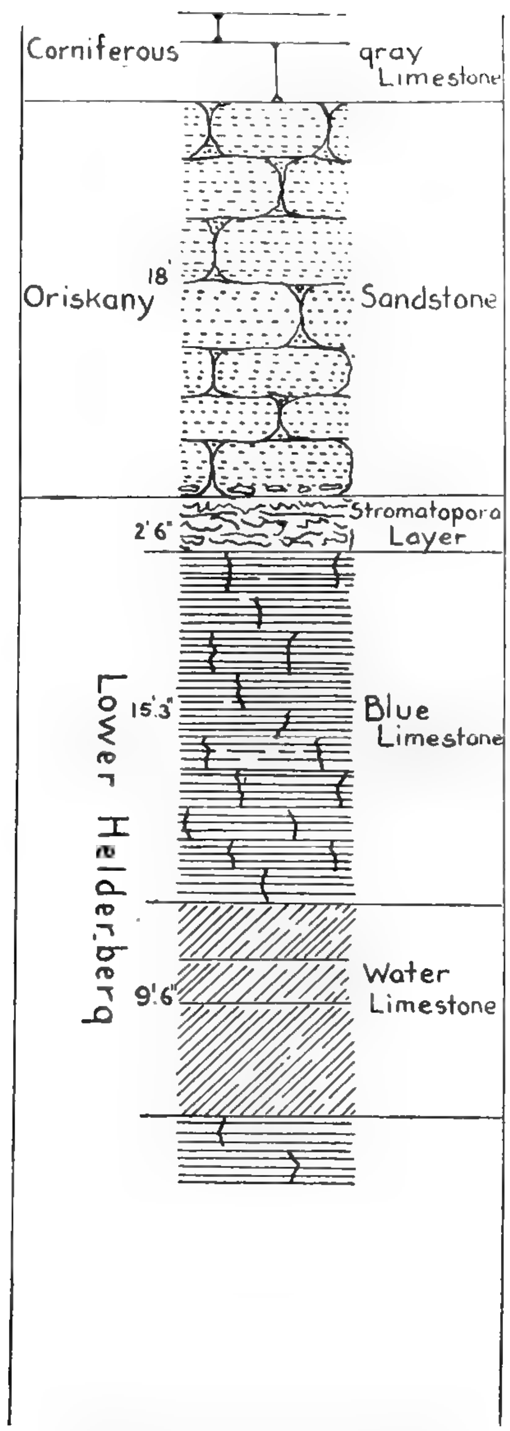


FIGURE 3.—THE ROCK-SECTION AT P. C. CORRIGAN'S QUARRIES AT SKANEATELES FALLS, ON THE SKANEATELES OUTLET.

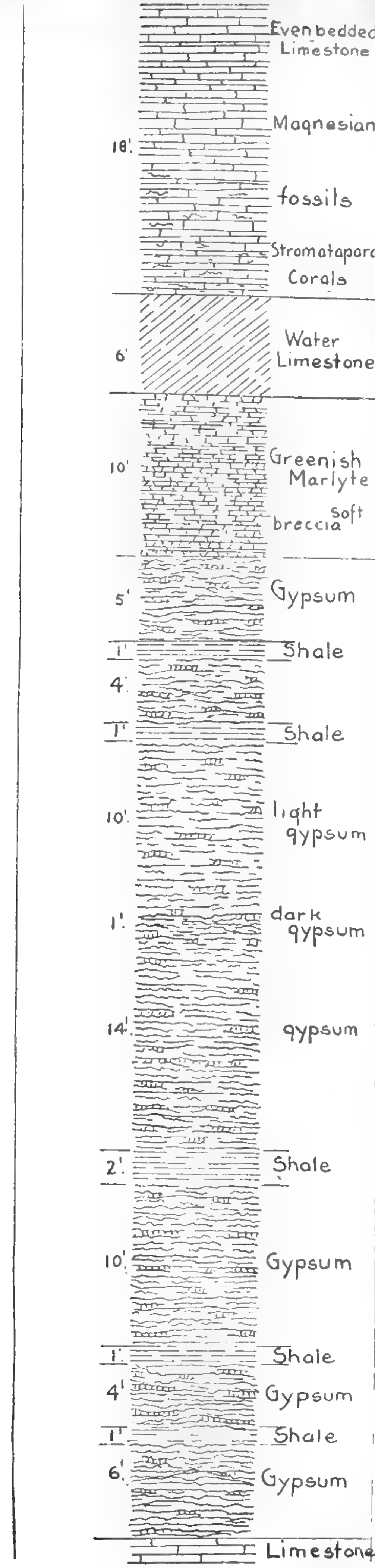


FIGURE 4. SECTION IN THE HEARD GYPSUM BEDS, ONE MILE SOUTH OF LYNDON, N. Y.

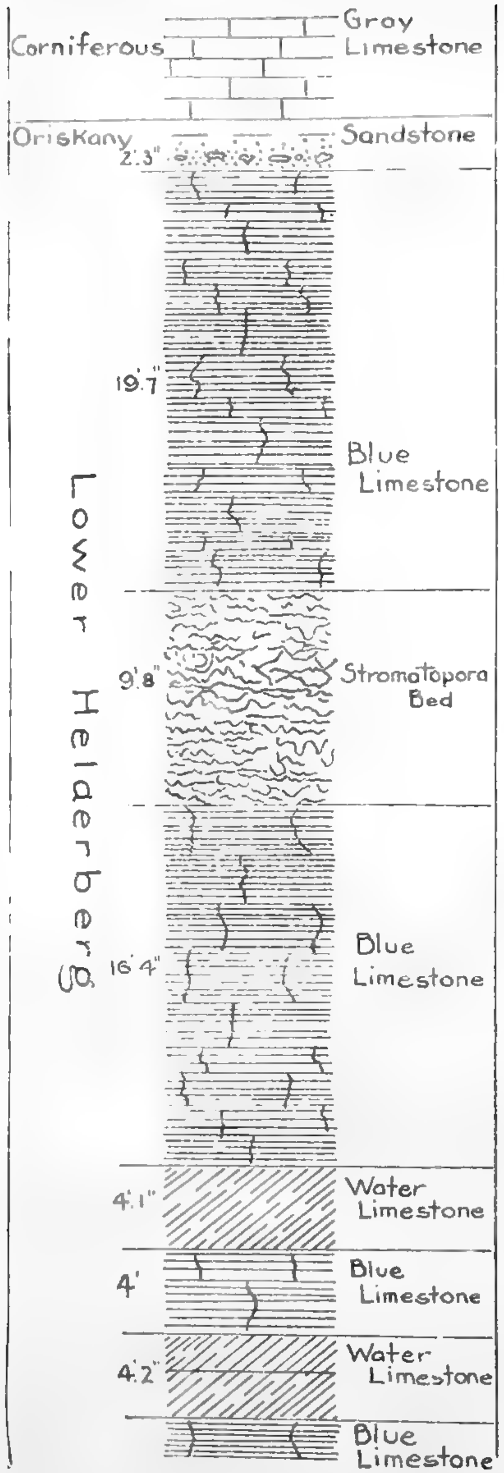


Figure 5. The rock section in A. E. Alvord's quarry, Manlius.

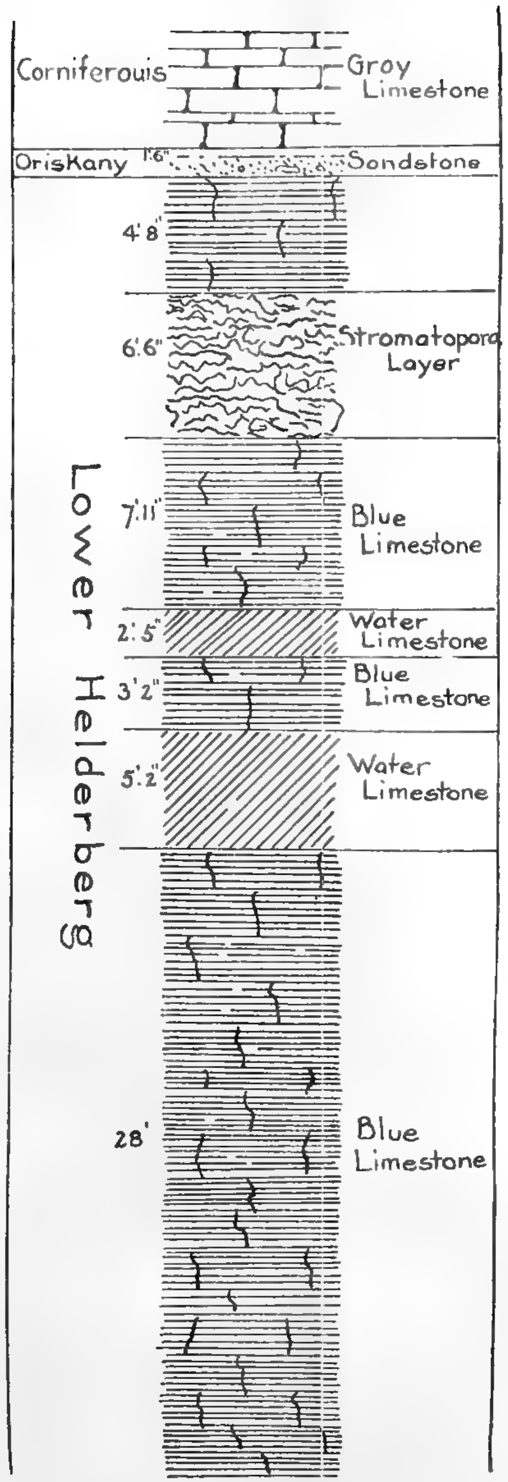


Figure 6. The rock section in the Britton and Clark quarry, near Brighton.

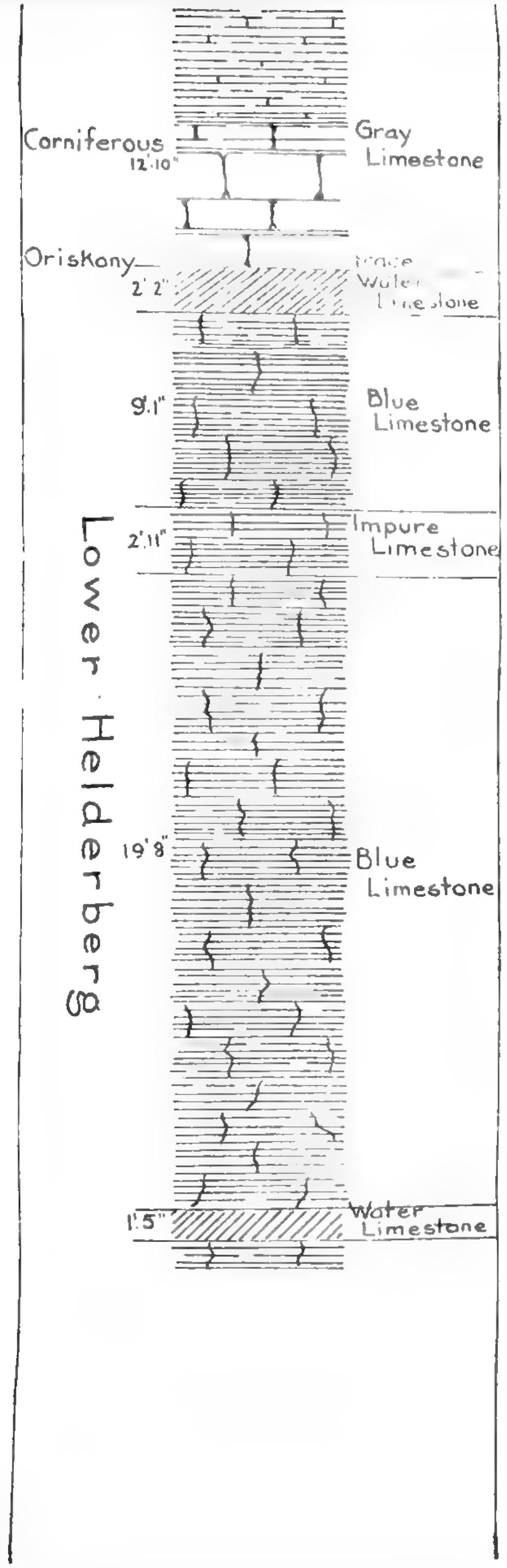


Figure 7. The rock section in the Solvay Process Company's quarry, at Split Rock.

the natural situation. The wells, having a surface elevation of from 720 feet to 909 feet A. T., are from 319 to 508 feet above the Erie canal, 401 feet A. T., which is, approximately, the elevation of the works.

About two miles southwest from the wells is Crooked lake, the only one of the Tully lakes that has a northern outlet; this has an elevation of 1,193 feet A. T., or 284 feet higher than the mouth of the highest well. A dam and gateway were built at the foot of the lake to regulate the discharge, and a conduit of twelve-inch cast iron water-pipe was laid, through which the water flows to the wells, where it reaches the salt bed through three-inch iron pipes, placed inside of the six-inch well casings and, dissolving as much salt as it can carry, becomes saturated brine. The pressure in the three-inch pipe forces the brine up through the space between the two pipes to the surface, where it overflows and is conducted to the twelve-inch cast-iron brine pipe, through which it flows by gravity to the reservoir at Solvay.

Mr. F. R. Hazard, Treasurer of the Solvay Process Co., has kindly furnished the following description of the Solvay process of manufacturing soda-ash or carbonate of soda:

"In considering the ammonia-soda process, it is convenient to start from two different raw materials, and to follow them through the several operations until they actually come together. For this purpose we consider salt and limestone.

"Starting first, then, with salt. This is found in the condition of rock salt at Tully, and is reached by boring wells in the familiar manner. Fresh water is introduced into the wells, where it dissolves the salt, and is forced to the surface in the form of a saturated brine. The brine is then forced from Tully to the works at Solvay, and enters the storage reservoir. From the reservoir it is drawn as required into the works. On entering the works, the brine first meets the waste gases from all of the operations, and is used to wash them free of the last traces of ammonia. The ammoniated brine is then allowed to settle a sufficient length of time for the deposition of the impurities thrown out of solution by this preliminary process.

"Turning now to the limestone. This is quarried from the ledges at the Split Rock quarries, and is broken to suitable sizes and transported in the overhead cable tramway system, and finally delivered at the top of the lime-kilns at the works. With the proper proportion of coke, the limestone is fed continuously into the top of the kilns. When burned, it produces ordinary quicklime, which is drawn from the bottom of the kilns. This is then placed in proper vessels, where it is slaked with water, and stirred up into a milk of lime. This milk of lime is sent to the distilling vessels in the works, where it meets the chloride of ammonia, produced in a later process. The reaction which here takes place, converts the calcium oxide of the milk of lime into calcium chloride, and sets free the ammonia which was held by the chlorine.

"In the burning of the limestone in the kilns, carbonic acid gas is produced. This is pumped by suitable pumping engines, and after being washed in water, is forced into the carbonating system, where it meets the brine which has been previously supplied with the proper amount of ammonia. The whole ammonia-soda process depends upon the reaction which now takes place. The carbonic acid gas first takes the ammonia and produces a carbonate of ammonia. In the presence of this substance, and the excess of carbonic acid gas, a double decomposition takes place. The carbonate of ammonia takes the chlorine from the salt, and the sodium from the salt takes the carbonic acid from the carbonate of ammonia. By these reactions, two new substances are produced, *i. e.* chloride of ammonia and bicarbonate of soda. The first of these is a liquid and the second a solid. By means of suitable filters, the liquid is separated from the solid, and the solid bicarbonate of soda is roasted in proper furnaces, driving off the excess of moisture, ammonia and carbonic acid gas, and reducing it to the form of mono-carbonate of soda, which is the ordinary soda-ash of commerce. After the necessary grinding and screening, the product of the furnaces is ready for packing

"The chloride of ammonia in the liquid form is now returned to the distilling columns, where it meets the milk of lime produced at the lime kilns, and gives up its chlorine to the lime, thereby releasing the ammonia, which in the form of gas is put back again into the process.

"The chemical reactions of the ammonia-soda process are extremely simple, and together form an almost complete cycle of operations. It only remains to separate the chlorine from the calcium in the waste product, to make the process absolutely perfect. Upon this point, many of the most able chemists of the world are at present engaged. Although the chemical reactions are without complications, the handling of the carbonic acid gas and the ammonia present many practical difficulties, which it has cost many years of patient study and experiment to overcome. The apparatus necessary for the proper carrying out of the process has become complicated out of all proportion to the apparent simplicity of the reactions. This, however, is to be accounted for by the fact that the reagents to be handled are largely in a gaseous state.

"The ammonia-soda process differs radically from the LeBlanc process, which was its predecessor, in that the old process works largely in the dry way, while the more recent process works entirely in the wet way to the point of the production of crude bicarbonate of soda. As this can only be decomposed by heat, it is necessary to use, for this purpose, a single furnace operation. Fifteen years ago, probably about four-fifths of all the soda produced in the world, was produced by the LeBlanc process. To-day it is safe to say that the ammonia-soda process produces fully three-fourths of the soda-ash produced in the entire world, and the remaining twenty-five per cent. alone is produced by the LeBlanc process."

The Solvay Process Co. was organized in 1881, for the purpose of engaging in the manufacture of soda-ash, and other soda salts by the ammonia process, under the American patents of Messrs. Solvay & Co., of Belgium, of which it has exclusive control. Works were erected near the Erie canal and New York Central railroad, a little west of the village of Geddes.

The following statement recently published is claimed to be authentic:

Capacity of works, 500 tons finished product daily. Present daily output, 350 tons finished product. Men employed, 3,000. Coal consumed, 1,000 tons per day. Limestone consumed, 1,200 tons per day. Brine consumed, 800,000 gals. per day. Water, 30,000,000 gals. per day. Land occupied, 2,000 acres.

The "Mineral Industry" for 1896 (Statistical Supplement of the Engineering and Mining Journal, Vol. IV, pp. 57, 58), gives in greater detail the present amount and valuation of this company's product, as follows:

"A few more or less unsuccessful efforts were made before 1884 to make soda in the United States, but the birth of the industry here must be said to have commenced practically in 1884 with the manufacture of 11,000 metric tons of soda-ash by the Solvay Process Company, at Syracuse, N. Y. This Company was organized in September, 1882, with a capital of $300,000, and commenced the erection of works with an estimated capacity of 30 tons of soda-ash a day, and in 1884 it commenced regular production. To-day its plant covers an investment of some $6,000,000, and has a capacity of 75,000 tons of soda-ash alone at Syracuse. The improvements introduced from the very beginning increased the output beyond the estimated capacity when the works were planned, as is shown in the accompanying table of materials used and products turned out each year. This valuable table contributed to the Mineral Industry by the courtesy of the company, is in itself almost a history of the alkali industry of the United States, for it covers probably nearly ninety per cent. of the entire output. In 1894 and 1895, when there were a number of other producers, the Solvay Process Company made about three-quarters of the entire output and is now building a large plant near Detroit, Mich.

"MATERIALS CONSUMED BY, AND PRODUCTS OF THE SOLVAY PROCESS WORKS, SYRACUSE, N. Y.

(IN METRIC TONS.)

	1884.		1885.		1886.		1887.		1888.		1889.	
	TONS.	PRICE.	TONS.	PRICE.	TONS.	PRICE.	TONS.	PRICE.	TONS.	PRICE.	TONS.	PRICE.
Materials used:												
Salt as brine	20,000	$1 25	28,000	$1 25	45,000	$1 25	58,000	$1 25	90,000	$1 12	99,000	$1 00
Limestone	21,000	1 25	29,000	1 25	47,000	1 25	60,000	1 25	100,000	1 25	124,350	1 00
Coal consumed	22,000	2 00	30,000	2 00	48,000	2 00	62,000	2 15	90,000	2 15	101,395	2 25
Coke	......	....	......	....	......	....	8,000	3 75	11,000	3 75	12,000	....
Ammonia as sulphate	440	69 00	520	70 00	615	68 00	680	66 00	920	66 00	990	66 00
Sulphuric acid	......	....	......	....	......	....	......	....	......	....	......	....
Bauxite	......	....	......	....	......	....	......	....	......	....	......	....
Products:												
Ammonia, sulphate	......	....	......	....	......	....	......	....	......	....	......	....
Tar produced	......	....	......	....	......	....	......	....	......	....	......	....
Soda-ash, 58%	11,000	40 00	15,000	35 00	24,000	32 00	34,700	28 50	50,700	26 25	54,500	26 35
Caustic	......	....	......	....	......	....	......	....	4,120	55 00	9,100	53 25
Bicarbonate	......	....	......	....	......	....	......	....	3,145	42 00	3,400	40 00
Crystals	......	....	......	....	......	....	......	....	......	....	......	....
Sulphate of soda	......	....	......	....	......	....	......	....	......	....	......	....
Crown filler ($Ca\ SO_4$)	......	....	......	....	......	....	......	....	......	....	......	....
Oxide of alumina hydrate	......	....	......	....	......	....	......	....	......	....	......	....

"MATERIALS CONSUMED BY, AND PRODUCTS OF THE SOLVAY PROCESS WORKS, SYRACUSE, N. Y.

(IN METRIC TONS.)"

	1890.		1891.		1892.		1893		1894.		1895.	
	Tons.	Price.	Tons.	Price.	Tons.	Price.	Tons.	Price.	Tons.	Price.	Tons.	Price.
Materials used:												
Salt as brine	115,000	$1 00	125,000	$1 00	150,000	$1 00	160,000	$1 00	197,000	$1 00	215,000	$1 00
Limestone	153,110	1 00	189,800	1 00	209,840	1 00	199,070	1 00	240,000	1 00	270,000	1 00
Coal consumed	122,690	2 25	142,910	2 25	173,180	2 25	162,485	2 25	170,000	2 25	200,000	2 25
Coke	14,680	3 50	17,340	3 50	18,785	3 50	17,220	3 50	20,000	3 50	25,000	3 50
Ammonia as sulphate	1,260	66 00	1,400	70 00	1,670	70 00	1,600	65 00	1,790	64 00	1,800	65 00
Sulphuric acid	......	.....	......	.....	......	.....	......	.....	700	.....	700	7 00
Bauxite	......	.....	......	.....	......	.....	545	.....	160	.....	......	.....
Products:												
Ammonia sulphate	......	.....	......	.....	75	65 00	130	65 00	135	65 00	135	65 00
Tar produced	......	.....	......	.....	276	8 00	420	8 00	415	8 00	420	8 00
Soda-ash, 58%	65,870	27 54	70,990	30 50	82,000	33 60	85,000	32 00	104,600	23 50	120,000	23 00
Caustic	11,120	60 00	14,960	69 00	23,800	69 00	22,700	66 00	30,000	53 00	36,000	41 00
Bicarbonate	4,090	40 00	6,520	39 00	8,400	39 00	8,940	37 00	9,900	36 00	9,900	36 00
Crystals	......	.....	......	.....	......	.....	......	.....	430	40 00	430	40 00
Sulphate of soda	......	.....	......	.....	......	.....	100	.....	330	11 00	350	11 00
Crown filler ($Ca\ SO_4$)	......	.....	......	.....	......	.....	......	.....	700	25 00	700	25 00
Oxide of alumina hydrate	......	.....	......	.....	......	.....	70	66 00	100	66 00	......	.....

Lardner Vanuxem, in his report on the Geology of the Third District of New York, 1842, describes the "shales and calcareous slates," in which, it now appears the salt beds occur, as the "second deposit" of the Onondaga salt group. He does not state the thickness of the strata included under that designation, nor can any be definitely given now, as it is exceedingly variable. Along the line of outcrop the thickness is not more than fifty feet, perhaps considerably less in some places, while at Tully, including the salt, it is more than 300 feet.

The layers of rock salt are also very unevenly bedded, as is shown by the Tully salt well records, and are probably largely heterogenous in character, as in the Livonia, Retsof, Lehigh and Greigsville salt mines in western New York. Mr. Graham states that the contact rock over the upper bed of salt in the Tully wells is limestone.

The following table is copied from the Solvay Process Co.'s record. Nearly all of the wells end at the bottom of the upper layer of salt:

PLATE IV

Caves in the Gypsum Beds, Wilcox quarry, Dewitt.

Group.	Well.	Salt below top of Corniferous.	Thickness.	Shale.	Salt.	Shale.	Salt.	Shale.	Salt.	Total salt.
A	1	498	45	...	..	..	..	..	..	45
	2	481	44	40	74	30	36	30	60	214
	4	404	45	32	57	58	50	42	28	180
B	1	495	..	..	..	..	..	..	..	318
	2	765	..	..	..	...	..	..	..	50
	3	528	..	..	..	..	..	..	..	228
	4	504	4	..	..	..	..	..	25	29
	5	520	54	..	..	..	..	..	..	54
	6	518	..	..	..	..	..	..	..	173
C	1	500	47	..	..	..	..	..	..	47
	2	497	45	..	..	..	..	..	..	45
	3	500	45	..	..	..	..	..	..	45
	4	507	44	..	..	..	..	..	..	44
D	1	544	43	25	54	..	..	..	..	97
	2	547	43	..	..	..	..	..	..	43
	3	548	48	..	..	..	..	..	..	48
	4	545	50	..	..	..	..	..	..	50
E	1	553	45	..	..	..	..	..	..	45
	2	550	44	..	..	..	..	..	..	44
	3	543	41	..	..	..	..	..	..	41
	4	556	39	..	..	..	..	..	..	39
	5	551	35	..	..	..	..	..	..	35
F	1	546	35	..	..	..	..	..	..	35
	2	537	47	..	..	..	..	..	..	47
	3	542	40	..	..	..	..	..	..	40
	4	539	41	..	..	..	..	..	..	41
	5	538	38	..	..	..	..	..	..	38
G	1	521	26	..	..	..	..	..	..	26
	3	530	38	..	..	..	..	..	..	38
West Side	30	430	90	..	..	..	..	..	..	90

The third division of the Onondaga group, designated by Vanuxem the "Gypseous deposit," is locally known under the name of the "Gypseous shales." It is the surface rock over a belt having an average width of two and one-half to three miles, parallel with the foot of the "Helderberg escarpment," with long extensions toward the south where the Limestone, Butternut, Onondaga, Marcellus and Skaneateles creeks have broken through and worn away the heavy limestones of the Corniferous and Lower Helderberg formations and uncovered the gypsum beds.

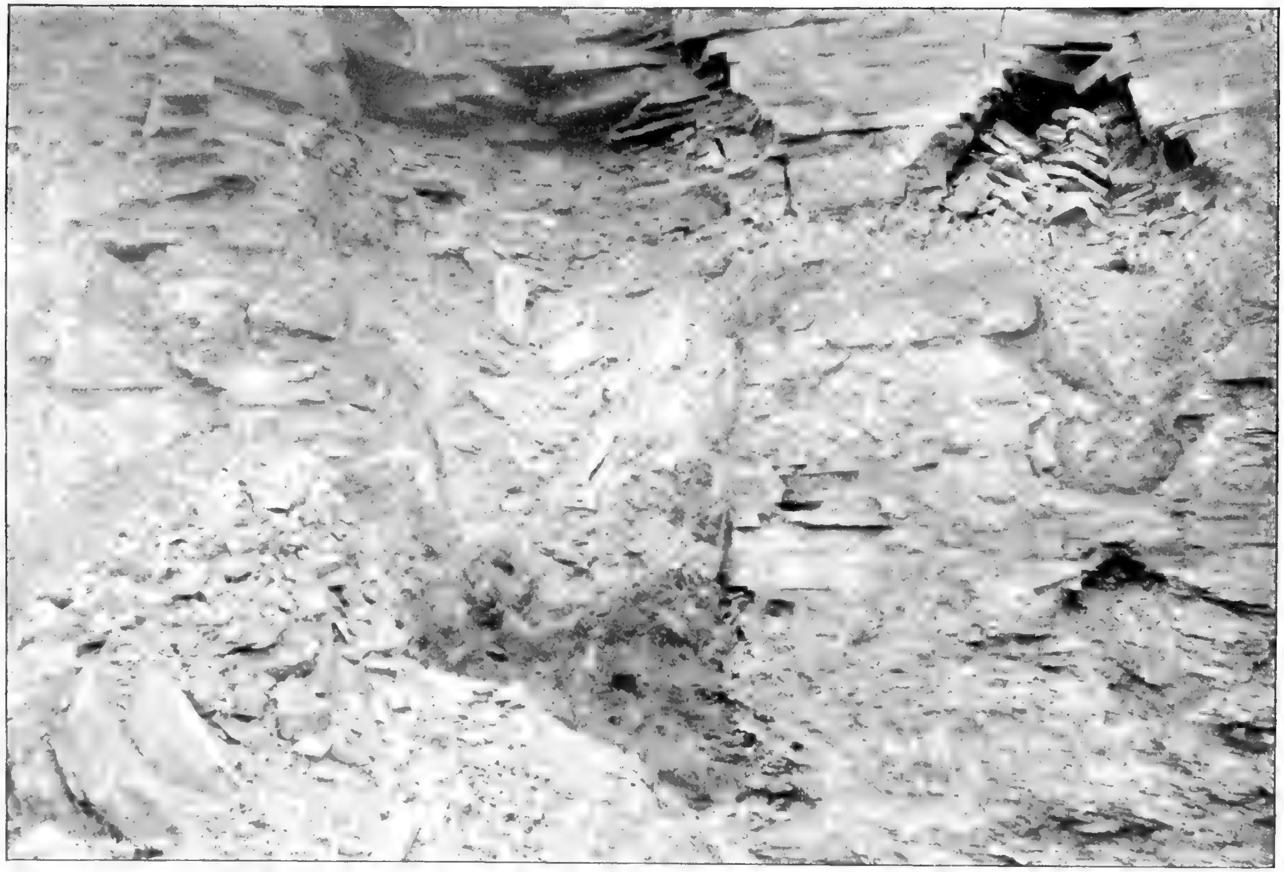
The contact line with the second deposit, that is, with the horizon of the salt beds along the north side of this belt, lies mostly in the low alluvial plains previously mentioned, and not far from the course of the Erie canal.

The contact line with the hydraulic limestones of the Lower Helderberg group in the south, is usually found at varying heights in the face of the Helderberg escarpment. The territory embraced between these lines is much of it broken and hilly, and the rocks are abundantly exposed throughout nearly its whole extent, though the exposures are not usually continuous for a very long distance.

The "Gypseous deposit" is composed in part of beds of fine grained magnesian or dolomitic limestones, generally in thin layers, sometimes so finely laminated as to become a slaty, calcareous shale. It also contains thick masses of gypsum and soft gypsiferous shale in two courses, separated by a bed of limestone forty or fifty feet thick. In the thicker and more compact layers of limestone, freshly broken blocks show the rock to be very dark, almost black, in the interior; but after exposure the color changes to an ashen grey or medium dark drab, sometimes showing a slight pink shade. It is very like hydraulic limestone in appearance, but the proportion of clayey admixture is so large as to injure or destroy its cohesive qualities. In the middle and lower beds it is frequently more or less porous or cellular. The cavities are sometimes an inch or more in diameter, very irregular and ragged in shape, and lined with a fine brown dust. When of this character, they are very unevenly distributed through the rock and most frequently are found on the surface of a layer, or opening into a joint.

In other layers, the cavities are found to be much more numerous, occupying in the aggregate nearly half the space of the rock, and having the form of circular cells, with the diameter ranging from one-fourth of an inch down to a needle point. Usually the cells in a particular layer of limestone have a considerable degree of uniformity in shape and size, but occasionally the con-

PLATE V



Caves in Gypsum beds, Severance quarry, Dewitt.

trary is the case. They are smaller in the lower beds. These cellular limestones are the "vermicular limestones" of the older reports.

In the shaft sunk to the rock salt beds at Livonia, N. Y., at the depth of 1,356 feet, thirteen feet above the salt bed, a stratum of this cellular magnesian limestone was reached, in which the cells were filled with salt. A large block was placed in a running brook, and in a few hours the salt had been dissolved out, leaving the rock in precisely the same condition that it presents when found in loose fragments or in the outcrops in this county. In the beds of limestone lying between the principal gypsum deposits, and more abundantly in that underlying the lower gypsum beds, hopper-shaped mud casts of what are supposed to have been salt crystals, are numerous. They are found in both the cellular and non-cellular layers.

The "needle cavities," or stylolites, are found in all the limestones, but more abundantly in the more compact layers at the top of the deposit. Gypsum occurs in layers, veins and nodules throughout the entire deposit, but most sparingly in the upper limestones, where it is either anhydrous or in the form of selenite. The two layers of gypseous shales, in which occur the gypsum beds that are quarried, appear, wherever this horizon is exposed, clear across the county, the upper bed forty to sixty-five feet thick, the lower twenty to thirty feet thick; the proportion of clayey matter being much greater at some localities than at others. The upper bed is better in quality, more convenient of access and much thicker. Most of the plaster quarries now operated are in it. It appears to have been deposited in quiet waters, the deposit consisting of gypsum and clayey matter, the sulphate of lime greatly predominating at some horizons, while in others the proportion was small, and a stratum of shale was formed. Where the bed has been exposed for a length of time, it looks like a bank of soft dark shale. The lines of deposition are very even except where water has penetrated to it through a crevice in rocks above and dissolved out the gypsum, leaving a cavern partly filled with the shaly residuum and fallen fragments of the overlying limestones. These caverns or "pockets" are quite common and sometimes extensive. Where the bed of overlying limestones is thin, it is broken through to the surface and "sinks" are formed, thereby increasing the inflowing stream of water and the rate of dissolution.

In the Heard quarry, a number of these partially filled cavities are exposed, extending from the bottom of the workings to the top, fifty to sixty feet. Many of the minor disturbances of strata in the vicinity of the outcrop of the gypsum beds are doubtless due to dissolution in this manner.

There are abundant evidences, too, of crystallization after deposition. In the richer parts of the beds lenticular layers of clear white or transparent crystalline gypsum, an inch or two in thickness, occur, and the laminae above are arched in conformity with them. They may be seen by the side of the Split Rock road, a mile west of the "House of the Good Shepherd," and in nearly every plaster quarry. The rock of this lower bed is sometimes called "black plaster," as it is much darker colored, and this affects its commercial value, though the actual difference in purity is said to be slight.

The gypsum beds are exposed in many places in the vicinity of Fayetteville, in the town of Manlius, and south of Lyndon, in the town of Dewitt; also near Brighton, in Onondaga, and in the southern part of Geddes. They are also exposed along both banks of Nine Mile creek, and on the line of the Auburn branch of the New York Central railroad in Camillus.

The first discovery of sulphate of lime or gypsum in the State of New York, was made in 1792, by William Lyndsay, on Lot No. 90, in the town of Camillus. In 1808, a stock company was organized and began the business of quarrying and exporting gypsum, or land plaster, an industry that for many years was second only to the manufacture of salt in its importance to Onondaga county. It has declined somewhat in late years, but recently discovered processes of making prepared wall plaster, into which gypsum enters largely, as the "Adamant," "Eureka" and "Paragon," promise to increase the demand for it.

When the gypsum is to be used as land plaster, it is quarried by the ordinary methods used in soft rock, then broken with sledges into pieces convenient for handling, and hauled to the mill in carts. It is then broken in stone-crushers or crackers, and ground fine by the use of mill stones. It is then ready for use. For the manufacture of wall plaster it is calcined, becoming, when pulverized, plaster-of-paris.

The principal men or firms who quarry and grind plaster, are: Thos. W. Sheedy, who has a mill at Fayetteville, and a quarry east of Fayetteville. He also buys rock plaster. Output, 2,000 tons annually. Bangs & Gaynor, Fayetteville, buy most of their stock from quarries in vicinity. Output, 5,000 tons. Lansing & Son, Dewitt, quarry two miles west of Fayetteville, mill on the bank of the Erie canal. Output, 2,000 tons. F. M. Severance & Co., Dewitt, quarry at the "Heard" beds, two miles west of Fayetteville. Output 4,000 tons of rock plaster, shipped by canal out of county. Robert Dunlop, mill one-half mile north of Jamesville, quarry one and one-half miles northeast from mill; grinds and sells 2,000 tons annually.

PLATE VI

THE STROMATOPORA BED IN ALVORD'S QUARRY, MANLIUS

E. B. Alvord & Co., Jamesville, buy and grind 2,000 tons. A. E. Alvord, Syracuse, buys and grinds 3,500 tons.

There are a number of small quarries in Manlius and Dewitt, besides these mentioned, but their product is sold to the mill owners and dealers, and the output is included in the amount stated.

Mr. A. E. Alvord opened a quarry near Brighton, two and one-half miles south of Syracuse, but is not operating it at present. None of the quarries in Camillus are now worked. L. D. Sherman, at Marcellus falls, grinds about 300 tons annually; quarries near the Marcellus station.

So far as known, the bed of gypsum quarried by F. M. Severance on the Heard farm is the thickest in the county, measuring sixty-five feet including some thin intercalated beds of shale. A few feet of dolomitic limestones at the top of the Salina group have very obscure lines of deposition, but split easily into thin slabs with a somewhat conchoidal fracture. These are profusely scattered over the surface of the ground in the regions of the outcrop of this horizon, and are utilized as material for farm fences, etc. The needle cavities are very common in them, but fossils, except *Leperditia alta*, are wanting, or at least very rare.

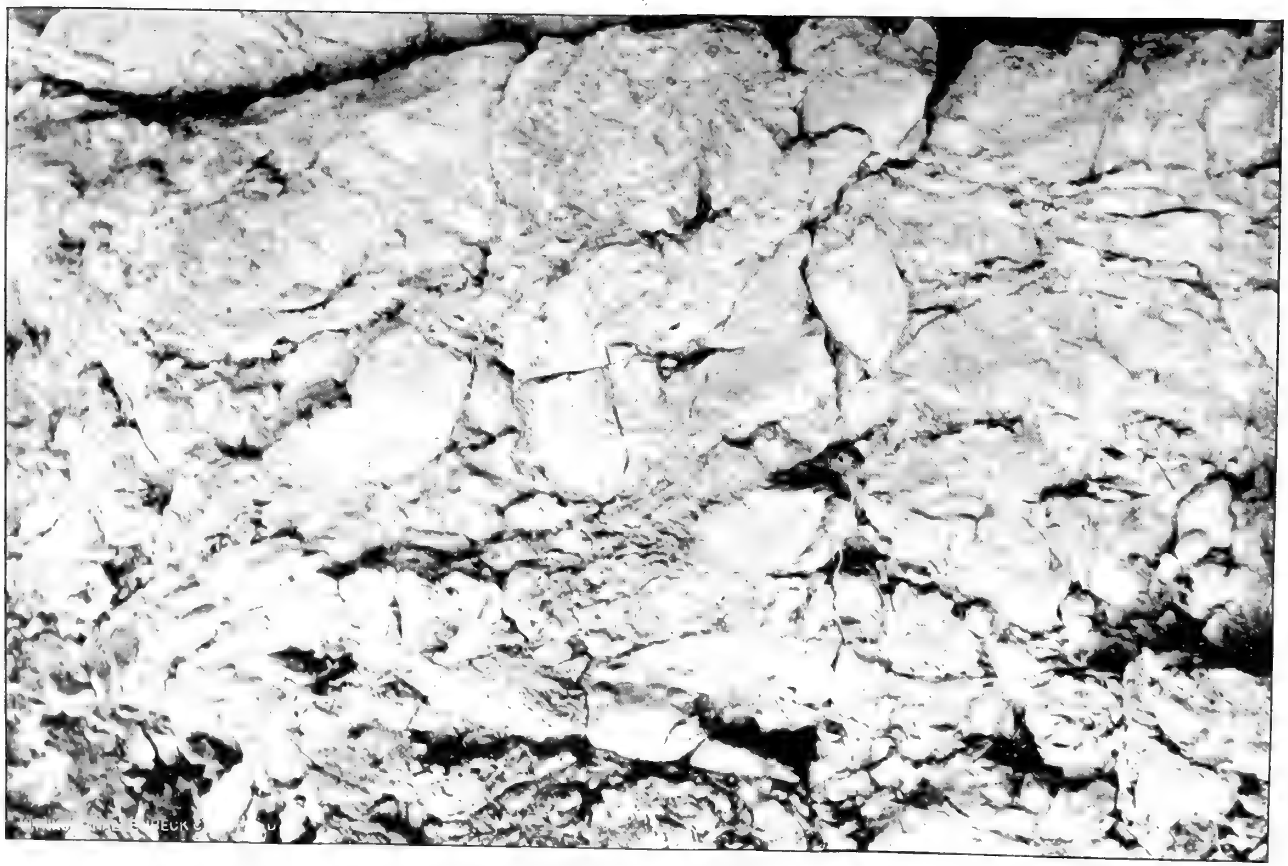
Lower Helderberg Group.

The hydraulic limestone beds of Onondaga county, provisionally referred to the Lower Helderberg group, are composed almost entirely of even courses of very dark blue, fine-grained limestones, from one to five feet thick. Exposure changes the color to a medium light, dull, bluish grey, and makes the lines of bedding very distinct. With two or three exceptions, all of the beds are composed mainly of calcic carbonate and contain but a small amount of magnesian, or clayey matter, as compared with the "Magnesian deposit" below. They are known as the blue lime beds, and from them almost the entire output of quicklime of the region is taken. A few courses contain too much impurity for use in the manufacture of quicklime, and are utilized as building stone. The rock splits easily along the lines of deposition, and breaks across them with a straight, even fracture. In some localities, masses of *Stromatopora* occur, and the rock loses its regular structure. The two beds of hydraulic limestone which give the name to this group, lie near the top of it, separated from each other by one to four feet of impure, blue limestone. The upper layer is a little more than four feet thick at the eastern boundary of the county, becoming thinner till it pinches out entirely in the Split Rock quarries, but reappearing near Marcellus falls in Watkins' quarry, where it is two feet, ten inches thick, and attaining a thickness of four feet, two inches in Corrigan's quarry at Skaneateles falls, near the western line of the county. Here it is separated from the lower bed by a shaly parting of only a few inches, the whole making practically one bed, nine feet, six inches thick.

At Manlius, the beds are separated by four feet, two inches of blue limestone; at Street's quarry, near Onondaga hill, by one foot, eight inches; at Marcellus falls, by one foot, seven inches, and at Skaneateles, the beds practically come together. The lower stratum of water-lime at Jas. Beahan's quarry, in Manlius, is four feet, one inch thick; E. B. Alvord's quarry, in Jamesville, four feet, five inches; at Britton and Clark's, near Brighton in the Onondaga valley, five feet, two inches; at Walker's quarry, near Marcellus falls, it is five feet, three inches; and at Corrigan's, at Skaneateles falls, the part of the bed that appears to be this stratum is five feet, one inch thick. At Split Rock, the upper bed is well exposed and measures two feet, two inches thick at the southeastern part of the quarry. It is separated from the Onondaga limestone above by only a thin nodular shaly parting, which here represents the Oriskany sandstone. It thins out and entirely disappears in the western part of the quarry. The place of the lower stratum of water-lime is here occupied by a bed of blue limestone nine feet, one inch thick. But twenty-one feet, eight inches below the upper layer, there occurs a layer one foot, five inches thick that is hydraulic limestone, though of an inferior quality. It was not observed elsewhere. This hydraulic limestone is brittle, clinking, compact, fine and even grained, dark colored, sometimes black in the interior, but, when exposed, quickly becoming a dull light grey with a slightly brown tint. It splits into small, thin, conchoidal slabs on the planes of deposition, which are very obscure. The contact lines above and below are very sharply defined. Sometimes the bed is divided into two or more layers, and the proportion of clayey matter is not quite uniform. The only fossil observed in the water-lime, or cement rock was found in the upper layer at the southeast end of the Solvay Process Co.'s quarry at Split Rock. This was an impression of one of the thoracic segments of an *Eurypterus* measuring two and nine-sixteenths inches in length, seven-eighths of an inch at the ends and one-half inch in the middle. It showed the segment to have been slightly pustulose.

The peculiar property of hardening under water possessed by this limestone when calcined and pulverized, was discovered about the year 1818 during the construction of the Rome and Salina section of the Erie canal. A

PLATE VII



THE STROMATOPORA BED; BRITTON AND CLARK'S QUARRY, TWO MILES SOUTH OF SYRACUSE

quantity of what was supposed to be ordinary quicklime, from the "blue lime" beds of the Helderberg escarpment persistently refused to slack on the application of water, as required in the usual process of making mortar. This circumstance led Judge Benjamin Wright and Canvass White, civil engineers employed on the canal, to thoroughly examine the rock strata and they employed Dr. Barto, of Herkimer county, to assist them in a series of experiments which resulted in the knowledge of the great value of hydraulic cement, and of the method of preparation and the character of the strata from which it is derived. It was first used on the canal in 1819, and subsequent to that year all of the masonry on this construction was laid in water-lime. It immediately took rank as an important resource of Onondaga county and maintains that position to the present time.

The quarries from which the cement rock is taken, are usually located near the top of the Helderberg escarpment, where the superjacent beds of limestone are comparatively thin. After these have been removed and utilized as building stones or made into quick-lime, the hydraulic limestone is loosened by blasting-powder and heavy bars, and broken into pieces of as nearly uniform size as possible and convenient for handling, then loaded on cars or carts and hauled to the kilns. The kilns are egg-shaped wells, ten feet in diameter at the top, twelve feet in the middle, three and one-half feet at the bottom, and twenty-eight to forty-two feet deep, with an opening at the bottom, from which the contents can be taken out at will. There are usually several kilns built in an embankment of very heavy masonry, so constructed against a hillside that the raw material can be conveniently conveyed there from the quarry, and burned lime easily removed from the bottom of the kiln.

Great care is used in the selection of the material and the construction of the kilns, to enable them to withstand the long continued fierce heat. Onondaga limestone is most commonly used, Oriskany sandstone occasionally. Generally, but not always, a lining of fire-brick is put in. When a kiln is ready to be filled, a cord of dry, hard, four-foot wood is put into the bottom and covered four inches deep with coarse anthracite coal, then a layer one foot thick of the limestone, succeeded by another layer of coal, partly coarse and partly fine. This is repeated till the kiln is filled to the top, which requires about ten tons of coal and fifteen cords of stone, equal to 1,500 bushels of lime. Then the fire is started at the bottom, and gradually works its way upward until the whole mass is glowing with heat. After two or three days the gate or door in the bottom is opened, and through it the lime, now in ragged clinking masses, is drawn to the amount of 250 to 300 bushels per day, fresh coal and rock being constantly added to keep the kiln full to the top. This is continued as long as desired, or until repairs are needed.

The material is next taken to the mill, where it is reduced by stone crushers, especially constructed for this purpose, to such a degree of fineness that it can be fed evenly through a hopper to the millstones where it is pulverized to the fineness of flour. It is now hydraulic cement, and ready for use. It is shipped in bulk, or packed in barrels or sacks.

Although the two layers previously described comprise all of the water-lime rock of commercial value in this county, the quantity of raw material in sight and convenient of access is practically unlimited. One cord of stone makes 100 bushels of cement, and the output can easily be increased to meet all demands.

The following are some of the principal producers:

Thomas W. Sheedy. Mill and three kilns one mile north of Fayetteville; quarries on Dry hill, southeast from Fayetteville: also buys raw material. Output, 15,000 barrels.

Bangs & Gaynor. Mill and four kilns at Fayetteville, quarries on Dry hill, and buys raw material. Output, 40,000 barrels.

James Beahan estate. Mill and four kilns one mile north of Manlius, by the side of the Chenango branch of the West Shore railroad; quarry 100 rods south of mill. Output, 50,000 barrels.

A. E. Alvord, of 223 E. Water street, Syracuse. Nine kilns and large quarries on the east side of the West Shore railroad, at Manlius village. The mill is at Syracuse. Output of cement, 45,000 barrels.

Brown's quarry, operated by Eaton Bros., at Edward's falls, on West branch of Limestone creek, one and one-half miles southwest from Manlius. Mill with water power and one kiln. Output, 7,500 barrels.

Robert Dunlop, one-half mile north of Jamesville, has five kilns, and a mill run by water power on Butternut creek; quarry on the hill east of the works. Output, 80,000 bushels.

E. B. Alvord & Co. have a mill and two kilns in the village of Jamesville; quarry one-half mile south of works on east side of Butternut creek. Output, 21,000 barrels. This firm has large quarries and four kilns on the west side of the valley near the reservoir, at which operations are suspended at present.

Britton & Clark have a mill and seven kilns near the Delaware, Lackawanna and Western railroad, at the north end of the Jamesville rock-cut. The

PLATE VIII

THE WATERLIME LAYER IN BRITTON AND CLARK'S QUARRY

rock is brought down in cars by gravity from the quarry, which is 100 rods south of the works. Output, 100,000 bushels.

L. H. Walker has a cement mill, run by water power, near Marcellus falls. The kiln is on the east bank of the creek, and the quarry at the top of the bluff behind the kiln. Output, 3,000 bushels.

P. C. Corrigan has a mill and two kilns at Skaneateles falls, and two quarries, one on each side of Skaneateles outlet. Output, 12,000 bushels.

In H. E. Alvord's quarry, at Manlius, the top of the upper layer of hydraulic limestone is forty-six feet, four inches below the bottom of the Oriskany sandstone, which appears in the low bluff a short distance east of the principal excavation. This space is occupied by dark bluish or black bituminous limestones in "runs" or layers from one to nine feet thick, of the same general character as that next below the water-lime courses. The layers are usually separated by thin seams of carbonaceous matter.

At the foot of the hill west of the cemetery, one mile south of Onondaga valley, two thin, non-persistent nodular layers of chert occur. No chert was observed elsewhere in this horizon. Several species of fossils occur in these beds, though not all that are found in the upper layer appear in the lower.

In Alvord's quarry, a layer nine feet, eight inches thick at the thickest place, forms the "cap" of the quarry. It is exceedingly rough and scraggy, and very striking in appearance. It is composed largely of the fossil *Stromatopora*, and is very pure, making, when burned, a very superior quality of quicklime. This layer is very persistent, appearing prominently at every exposure of this horizon, except in the vicinity of Split Rock. The fossil is very abundant also in many exposures in strata below the water-lime courses. At Severance's gypsum quarry, in Dewitt, it may be seen not more than fifteen feet above the top of the massive bed of gypsum. *Leperditia alta*, *Spirifer Vanuxemi*, and *Stropheodonta inequistrialis*, also occur above as well as below the water-lime layers. The upper layers at Manlius contain several species of corals, cyathophylloid and favositoid, and a few brachiopods.

At Jamesville, in E. B. Alvord's quarry, on the west side of the valley, there are thirty-one feet of limestone between the upper water-lime bed and the Oriskany sandstone. *Stromatopora* is very abundant through the upper twenty feet.

At Britton & Clark's, south of Syracuse, on the east side of Onondaga valley, the same strata have a thickness of twenty feet. On the opposite side of the valley, two miles west, they are eleven feet, six inches thick, and at

Split Rock, the water-lime layer is separated from the grey Onondaga limestone by only two inches of coarse lumpy shales.

At Walker's quarry, at Marcellus falls, five miles west from Split Rock, eleven feet of fine dark limestone intervenes, which at Corrigan's, at Skaneateles falls, six miles further west, has increased to twenty-one feet, nine inches, and the *Stromatopora* bed, two feet, six inches thick, appears in characteristic form.

Economically considered, at least, all of the limestones lying between the gypseous shales and the Oriskany sandstone belong together. A large majority of all the quarries in the county are located in this horizon. From the purer layers, especially the *Stromatopora* beds locally known as the "diamond rock," is derived all of the quicklime produced in the county, and the whole group furnishes an unlimited supply of easily worked, durable building stone and road metal that is easy of access, and contributes very largely to the prosperity of the county, and gives employment to a large number of its citizens. The Lower Helderberg or "blue" limestone is used principally as cellar or foundation stone, the Onondaga or grey limestone being generally preferred for cut work and dimension stone. Grace church on University avenue, Syracuse, and St. Mark's church, in the western part of the city, both handsome edifices, are built of this rock in broken ashlar, trimmed with hammer dressed Onondaga limestone. The large flouring mill at Manlius, the Onondaga county almshouse at Onondaga Hill, and many other buildings used for business purposes or as residences were constructed of stone from these beds. It is much used also for road making, as it breaks easily into sharp angular fragments, making excellent material for that purpose, and for mixing with cement and sand to make concrete. A. E. Alvord has a steam crusher at his quarry on the north side of Rock Cut, near the Delaware, Lackawanna and Western railroad, which gives employment to seventy-five men. The output from this plant last year was 27,000 cubic yards. Britton & Clark's annual output averages 5,000 cubic yards, and it is produced in smaller quantities at several other quarries where it is broken with hammers.

The process of manufacturing quicklime from the "blue lime" layers is the same as that employed in making cement from the water-lime layers, except that it is not necessary to grind the calcined rock, as it slacks on the application of a suitable quantity of water, and becomes a fine white powder, and is then ready for use. Some of the principal producers of quicklime are:

PLATE IX

LIME KILNS AND CEMENT MILL OF BRITTON AND CLARK, NEAR BRIGHTON.

H. E. Alvord of Syracuse, quarry and kilns at Manlius. Annual output, 200,000 bushels.

James Beahan estate, quarry and kilns at Manlius. Output, 75,000 bushels.

E. B. Alvord & Co., Jamesville, 50,000 bushels.

Britton & Clark, Rock Cut, 50,000 bushels.

All of the limestone used by the Solvay Process Co., of Syracuse, in the manufacture of soda-ash, amounting to more than 250,000 tons annually, is taken from "blue lime" beds in the large quarry operated by the company at Split Rock, about five miles southwest from Syracuse.

Very little blasting powder is required in quarrying these beds for building stone. In the flexing and tilting to which they have been subjected, they have been much shattered, owing to their rigid, brittle character, so that vertical cracks, joints and crevices are very frequent. By the use of heavy pinch bars large blocks are dislodged. These are roughly reduced with heavy hammers to such sizes and shapes as may be desired, then hauled to their destination where the facing stone or ashlars are finished with chisels and light hammers, the rest being laid into the wall without further dressing.

During the century of occupancy of this region by white men, a very large number of quarries have been opened along the line of outcrop of these limestones, at first, to supply local demand in the building of the villages which sprang into being when the Seneca turnpike was the great east and west thoroughfare across the county, following very closely the brink of the great escarpment. Some of them were abandoned, but a large number of new ones, more conveniently situated in regard to transportation, were opened when the building of the Erie canal and the railroads and the rapid growth of the city of Syracuse created a new and immense demand from another direction.

The following are the names of the owners of quarries who produce building stone from the "blue lime" beds:

A. E. Alvord, Manlius	200	Cords.
James Beahan estate, Manlius	200	"
E. B. Alvord & Co., Jamesville	250	"
Robert Dunlop, Jamesville	100	"
Britton & Clark, Syracuse	2500	"
Isaac Cole, East Onondaga	1000	"
John Connolly, East Onondaga	1500	"
C. H. Russell, East Onondaga	1000	"
George Redhead, East Onondaga	500	"

Patrick Knox, East Onondaga, ...	50	Cords.
L. C. Dorwin, Dorwin Springs, ...		"
D. McNeil, Street's quarry, Onondaga hill, . . .	1500	"
John Kearny, North of Onondaga hill, ...	200	"
Solvay Process Co., Split Rock, ...		"

Oriskany Sandstone.

The line of separation between the top of these limestone beds and the base of the superjacent formations, is very distinctly marked. A thin seam of arenaceous brownish shale, or soft sandstone, which weathers out and crumbles away on exposure, separates the fine dark limestones from a bed of coarse, light grey, sometimes pinkish sandstone, which is nodular in the lower two or three inches, and usually has flattish pebbles of dark rock embedded in it, but is compact above. In some localities it is well cemented and durable, at others it turns dark-colored and crumbles easily. Its position in the escarpment is well toward the top, and generally only the edge of the layer is exposed.

At Manlius, the lower fourteen inches of a layer two feet, three inches thick, is characteristic Oriskany, gradually changing to a calcareous sandstone and then to a pure blue-grey limestone, identical in appearance with the overlying Onondaga limestone. At Alvord's quarry southwest from Jamesville, it is a layer of friable sandstone, weathered to dark brown. At Britton & Clark's and at Russell's, it is substantially the same as at Manlius. It is exposed, and large loose blocks abound, on the side of the hill a short distance southwest from L. C. Dorwin's quarry, one mile south of Onondaga valley.

Here it is a pure sandstone, very light grey with a pink shade, containing many impressions of fossils, *Spirifer arenosus* largely predominating. The stratum is here four to four and one-half feet thick. In the Street quarry north of Onondaga hill, it appears at the west end as a coarse conglomerate about six inches thick. At Split Rock, there is but a trace of it in the seam of nodular calcareous shale which separates the blue lime from the grey beds.

At Walker's quarry, Marcellus falls, a layer of granular limestone five feet, three inches thick, is arenaceous toward the bottom, the lower four inches being characteristic Oriskany. The whole layer is brownish grey after exposure. It is very remarkably developed in the northern part of the town of Skaneateles, on the ridge east from Marysville. It is well exposed above Corrigan's quarry as an unusually clean sandstone, very light

PLATE X

THE ONONDAGA LIMESTONE IN THE SPLIT ROCK QUARRY.

grey or pink, weathering white and containing, especially toward the bottom of the beds, impressions of great numbers of *Spirifer arenosus* and associated fossils.

The greatest thickness observed in this county was eighteen feet at this place. Good exposures occur a mile or two northeast, and in the vicinity of the road leading from Skaneateles to Elbridge. Vanuxem states its thickness here to be thirty feet. Fragments, large and small, easily recognized as from this bed, are found scattered over the fields clear to the south line of the county. Mr. Graham says that in the Tully salt wells the Oriskany sandstone is fifteen to eighteen feet thick, light-colored, coarse and gritty, wearing away the corners of the drills so that they "get out of gage" and make a smaller hole.

The economic value of the Oriskany sandstone to this county is not great. It was quarried in the town of Skaneateles and used in the construction of the lock on the Erie canal at Jordan, also for cellar and foundation stone, and occasionally for lining in lime kilns. The proximity of the Onondaga limestone which can be worked much more cheaply appears to be the main cause of its disuse.

Upper Helderberg Group.

The strata of this formation are represented in this county by a bed of light grey, glistening, semi-crystalline limestone, separated by thin seams of carbonaceous shales into layers from an inch to two feet, six inches thick, and which maintain their character and thickness over large areas. Many of these layers are compact and composed almost entirely of calcic carbonate, but others, and they are not confined to any particular horizon, are shaly and contain more or less argillaceous matter. Both the compact and the shaly layers contain fossils in great abundance, especially corals and crinoids. Many species of brachiopods and gasteropods are common everywhere in the beds. Flattened nodules of dark bluish black chert or hornstone, sometimes in continuous layers, also occur throughout the entire mass, though more common in the upper part.

At Manlius, in Alvord's and Hinsdell's quarries, a layer of chert occurs in the stratum of limestone superjacent to the Oriskany sandstone; also in the lower layers at the Reservation quarry, and at every exposure of the Onondaga limestone as the lower part of the formation is frequently called, as well as in the upper part to which the name Corniferous was given on account of the presence of the hornstone. The rocks of this epoch have a total thickness in Onondaga county of about sixty feet at the eastern boundary, increasing to seventy feet at the western. At the Tully wells they are seventy-five feet thick, according to Mr. Graham who superintended the drilling. The Corniferous limestone is the surface rock over a narrow belt at the top of the Helderberg escarpment, rarely showing more than a few feet in the face of the cliffs, though at the west end of the great chasm of the Green lakes, two miles north of Jamesville, the upper twenty-five feet of the vertical wall is of Onondaga limestone. At Dry hill in Manlius, along both sides of Onondaga valley, at Split Rock, and in fact at almost every exposure it has been worn away, almost or quite, to a thin edge, evi-

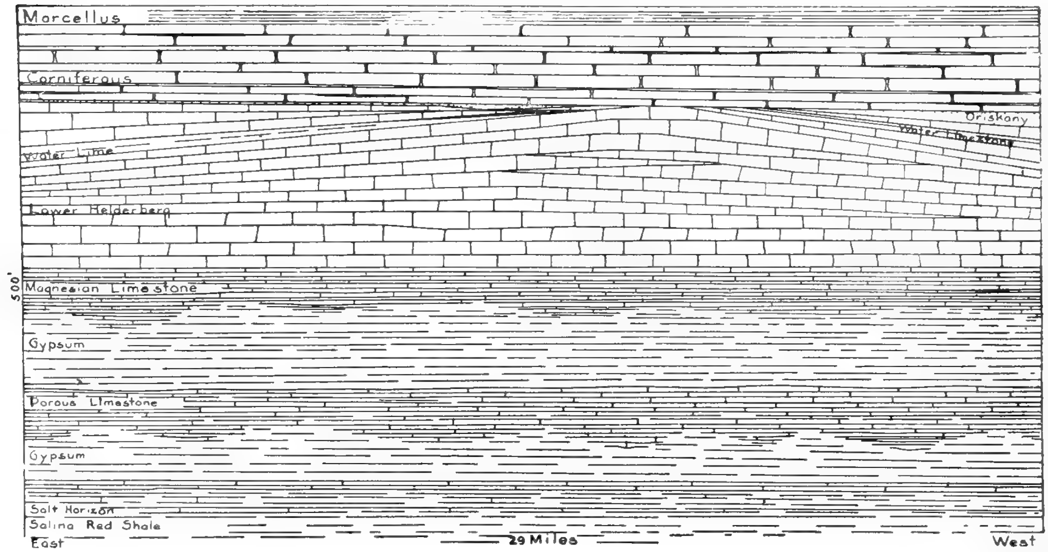


FIGURE 8. East and west section across Onondaga county, showing the position of the limestones in the Helderberg escarpment.

dently by glacial action, as glacial polishings and grovings are abundant. By reason of its elevated position it was subject to the full power of the denuding forces, and huge blocks were torn loose, tossed about and scattered in the wildest and most fantastic manner. On the hillsides along the north and south valleys, immense limestone boulders abound for many miles, and some were carried to the tops of the highest hills. The window and door sills of the stone store at Pompey hill were cut from a large block of Onondaga limestone found a short distance away, on the very summit of the hill, six miles south and at least one hundred feet above the bed from which it was torn. The line of outcrop extends for the entire width of the county, with elongations toward the south along the sides of the valleys. East of Manlius,

PLATE XI

The Split Rock quarry, looking west.

on Dry hill, there is a large area where the rock is bare or but slightly covered; also northwest from Jamesville, in the vicinity of the Green lakes, and about Split Rock.

The Corniferous limestone is of great economic value as a building stone. It is strong and durable, can be quarried without difficulty and dressed into any desired shape, as it is soft and tough under the chisel and dressing hammer. It is capable of receiving a high polish. It is bright looking, clean and handsome, and does not fade or change color on exposure, and is abundant without limit. Many large buildings in the county are constructed of this stone, and it is used very extensively for trimming and ornamenting brick buildings. Large slabs of it are used for flagging on the principal business streets of Syracuse. It is much used in monumental work in the cemeteries, and for curbings, hitching posts, horse blocks and the like.

Quarries near Manlius and at Split Rock supplied large quantities of heavy cut stone for locks and culverts along the Erie canal, as far west as Rochester, where it was used in the construction of the aqueduct across the Genesee river, and from these and the numerous other quarries which have been opened all along the ledge, has been taken the material for the bridge abutments, culverts and other stone work required in the building of the several railroads which intersect the county, and also the highways in the vicinity.

Operations have practically ceased in a large number of the grey lime quarries, and the business is confined to a few of those most favorably located in regard to accessibility and cheapness of transportation into Syracuse. The manner of quarrying the Corniferous limestone differs somewhat from that employed in the blue limestone quarries, and is substantially as follows:

The soil and shale or undesirable rock is "stripped" or cleared away over the surface of the layer to be used. Lines are then drawn which indicate the size and shape of the block or slab required. Along these lines a row of holes one inch in diameter, and four to six inches deep are drilled, a foot or less apart, a "wedge and feathers," two half-round pieces of iron, are then inserted in each hole, and the wedges carefully driven so that the strain shall be uniform for the entire length of the line and until it is sufficient to cause a fracture. The slab is then removed by the use of large derricks, and the process is repeated. The blocks and slabs are generally, but not always, hauled from the quarries in the rough state; the smaller ones to stone yards where they are dressed and the heavier ones to the places where they are to be used.

The largest quarry now in operation in the Corniferous limestone is at the Indian Reservation in the Onondaga valley, three miles south of Syracuse. Kelly Bros. operate the principal part of it. They employ thirty-five men, and their annual output is 12,000 cubic yards. Patrick McElroy works the south end of the quarry. He employs eight men a part of the year, taking out 750 cubic yards during the season. The section exposed here embraces thirty-seven feet, four inches. The bottom is about five feet above the Oriskany sandstone. The top layer is shaly. Fossils are exceedingly abundant at these quarries, especially in the shaly layers.

In the Solvay quarry at Split Rock, the Corniferous section shows at the southwest corner, twelve feet, ten inches of compact or shaly layers of limestone with shaly partings. Dimension stones are quarried from the compact layers. John Kearney, near Onondaga hill, quarries 1,250 yards annually, and Job James, in the same locality, 250 yards. A. E. Alvord owns a large quarry one-half mile east of Manlius, where the section shows seventeen feet, six inches of the lower part of the Corniferous limestone, nearly all of which is in compact layers of convenient thickness.

There are several other grey lime quarries in the vicinity of Manlius, but the expense of transportation precludes extensive operations at present. E. B. Alvord & Co. operate a small quarry at the base of the Corniferous limestone, one mile south of Jamesville, on the east side of the Reservoir. William Maylie's quarry, one-half mile southeast from Marcellus village on the Cedarville road, is in the upper layers of the Corniferous, as are also John Clancy's and Martin Hogan's in the same vicinity.

The section in Maylie's quarry shows seventeen feet, two inches. At the top, four feet, three inches is shaly and very fossiliferous; the other layers are quite compact. Several thin nodular layers of black chert occur. Some of the lower layers of limestone are quite bituminous and very dark colored, but weather to light grey. The cut stone for the dam at the foot of Otisco lake was taken from Maylie's quarry. Mr. Maylie also burns quicklime, running one kiln. Nodules of iron pyrites in some localities very injuriously affect the value of these upper beds for building purposes, but at these last mentioned quarries the rock is quite free from it. John Keenan's quarry a few rods south of Corrigan's, at Skaneateles, shows about four feet of hard limestone next to the Oriskany sandstone, and above that five feet of shaly limestone in which are a few hard layers three to four inches thick. The material for the Glenside mills was quarried near the mills. J. H. Ketchum's quarry one-half mile south of Skaneateles falls near the creek,

PLATE XII

THE SPLIT ROCK QUARRY, LOOKING EAST.

in the horizon of the middle of the Corniferous strata, shows a section of twelve feet in even compact layers one to two feet thick. One layer of black chert two inches thick is persistent.

Many prominent buildings in the city of Syracuse have been built of Onondaga limestone. Among them are the Onondaga County Court House, on West Genesee street, built in 1857; St. Mary's Cathedral, built in 1874; Reformed Protestant Dutch Church, on James street, built in 1884; May Memorial Church, on James street, built in 1884; St. Paul's Cathedral built in 1884; the Post-Office building, on East Fayette street, built in 1884; the W. S. Peck block, on West Water street, built in 1887; the City Hall, on East Washington street, built in 1892; the Onondaga County Savings Bank, corner of Salina and Genesee streets; the Hall of Languages, Syracuse University; Senator Horace K. White's residence on James street, one of the most elegant in Syracuse, is built of medium-sized blocks of grey limestone, laid in broken ashlar style.

Hamilton Group.

Overlying the Corniferous limestone, and constituting the surface rock over nearly all that part of the county south of the great limestone ledge, are the soft shales and fine thin sandstones of the Hamilton group, the lowest division of which is the Marcellus shale, so named because of its favorable exposure in the town of Marcellus. The transition is abrupt, the black shale being in immediate contact with the grey limestone below. In the lower seven feet it is more or less calcareous owing to the presence of immense numbers of a minute pteropod, *Styliolina fissurella,* and at one horizon indurated, forming a thin, non-persistent layer of very dark laminated, impure limestone. Except in these calcareous portions, where they are blue-black, the shales are very bituminous and fetid, black with a brown streak, and become rusty on exposure by reason of the abundance of iron in their composition, and fissile, with very thin laminae. Fossils, especially *Liorhynchus limitaris*, are quite abundant in some of the calcareous layers. Thirteen feet above the top of the Corniferous limestone there occurs the layer of hard, dark impure limestone, about two feet, six inches thick, known as the Goniatite limestone on account of the abundance and great size of this fossil. The stratum is usually composed of two layers, the lower one the thicker. Adjacent to the shales the limestone is compact and even, but in the middle part it has the appearance of being concretionary, and when broken presents a rough, scraggy surface.

The fossils are most abundant in the lower part of the upper layer. Specimens of *Goniatites Vanuxemi*, which show the original adult shell to have been from eight to twelve inches in diameter, are common; also orthoceratites, two inches in diameter and a foot long, and many other interesting fossils.

The limestone is slightly exposed on the hill east of Manlius village, south of Eagle, but very much better in the southwest corner of the town of Manlius, along the Jamesville turnpike. In a small ravine near the schoolhouse in District No. 8, at a fall about fifty rods from the road, the limestone is well exposed, accessible, and very rich in fossils. It can be traced along the ridge toward the west for nearly a mile, though this being a region of flexures, it is easily lost sight of.

It crops out near the highway a mile northwest from Onondaga hill, also along the road between Loomis hill and Howlett hill. There are several outcrops between Marcellus and the Onondaga valley near the Cedarvale road, and also on the road between Marcellus falls and Marysville.

Next above the Goniatite limestone is a bed of fissile shale or slate, forty to fifty feet thick, black and ferruginous like that below, but not calcareous, and very rarely containing a fossil. Irregularly disposed in this bed, though more abundant at some horizons than others, are many large concretions, some of them very symmetrical flattened spheres, while others are elongated, nodular and frequently geodic septaria.

The shale above gradually loses its slaty, bituminous character, becoming softer and more argillaceous, the color changing to a bluish grey, the concretions smaller and less abundant. The change is so gradual that any line of separation between the Marcellus shales and the Hamilton shales must be an arbitrary one. It has been placed at 200 feet above the Corniferous limestone, which is a liberal allowance for the thickness of the Marcellus. Neither the limestones nor the shales are of appreciable economic value.

All the experience of men who have spent time and money in the vain search for coal in these beds has not even yet entirely destroyed the belief that it exists in large quantities, the belief resting on the presence of occasional thin seams of coaly remains of plant life, and the general carbonaceous appearance of the shales.

The Hamilton shales and sandstones are the surface rocks over an area equal to about one-third of the county—an area embracing the southern parts of the towns of Pompey, Lafayette, Onondaga, Marcellus and Skaneateles, and the northern parts of Fabius, Tully, Otisco and Spafford, and ex-

PLATE XIII

CORNIFEROUS LIMESTONE, RUSSELL'S QUARRY, EAST ONONDAGA.

tending into the deep valleys of Skaneateles, Otisco and Tully lakes, Labrador creek, Keeney's creek and Limestone creek, quite to the southern boundary. Throughout this entire region of high hills and deep valleys, the rock is generally but thinly covered with drift, and the soil is largely composed of disintegrated shales, especially along the sides of the hills.

At the base of these Hamilton strata is a mass of soft argillaceous shales, brownish or bluish grey, with layers of olive or light blue color; some thin layers are bituminous. Calcareous concretions are not uncommon. Fossils occur sparingly in the lower part, but more and more abundantly toward the top.

The thickness of this part of the Hamilton group, which embraces the Ludlowville shales, is between 300 and 400 feet. It is exposed in the Limestone creek valley, north of Delphi; also in the vicinity of Watervale, and in the Butternut creek valley, in the vicinity of Onativia station, in the Onondaga creek valley north of Cardiff, and in many places in the southern parts of the towns of Marcellus and Skaneateles.

A large portion of the upper Hamilton rocks is composed of soft shales, similar to those just described, but intercalated with them are beds of coarser arenaceous shales and schistose sandstones in which fossils are exceedingly abundant, masses of them supplying calcic carbonate sufficient to cement the loose and rather friable material into firm hard rock. These hard layers frequently appear on the sides of the hills, forming terraces and escarpments distinguishable for long distances, and show plainly the southerly dip of the strata. These terraces are developed to a remarkable degree on the sides of the valley of Onondaga creek south of Cardiff, where six can be distinctly seen on the west side. One of them rises as a bold escarpment on the hill west of the village of Delphi. Several occur also on both sides of the Otisco valley south of the lake, and in many other places.

The sandy layers are exposed at the top of Pratt's falls, and between there and Pompey hill, and at Conklin's falls and Delphi falls, in Fabius in a ravine west of the dam at the foot of the DeRuyter reservoir, also in the valley between Fabius village and Keeney's settlement. The ravines about Cardiff and in the vicinity of the Tully salt wells are excellent places in which to examine them and to collect fossils, and the same is true of the Otisco valley, particularly at the mouth of the Bucktail ravine. The whole series of the upper Hamilton shales and sandstones is well exposed at the south end of Skaneateles lake in the numerous ravines, and along the shore.

On the east shore, two and one-half miles from the head of the lake, near Staghorn point, is a very remarkable bed of fossil corals. It is a solid mass of cyathophylloid or cup corals, together with other genera. It is five feet thick at the thickest place, and is exposed along the shore, near the level of the water, for a distance of a quarter of a mile or more. Thousands of specimens, some of them ten or twelve inches long, and sufficiently suggestive of staghorns to give the name to the point, are in sight in the layer or loose in the water. This coral reef, or a similar one at about the same horizon, is exposed at Lord's hill, several miles northeast, and along the hillside west of Otisco lake. From its position it seems probable that this bed is the eastern extension of the Encrinal band of the western counties, which abounds in cyathophylloid corals of the same species.

At the top of the group there are about fifty feet of soft dark shales, which contain iron pyrites and become rusty brown on exposure. Calcareous concretions and thin non-persistent calcareous layers composed entirely of fossils are common. The color and character is maintained, though the beds become thinner, as far west as Livingston county, where they form the upper ten feet of the Moscow shales. A good exposure of this horizon is by the roadside, one-fourth mile north of Tully centre, on the upper road. Another is at Tinker's falls, near Labrador pond; also on the dugway road, from Spafford village to Skaneateles lake. The Hamilton shales have had a very important part in the composition of the fertile soil of Onondaga county, but the direct economic value of the group is very small, and is confined to a few of the sandy layers that are durable enough to serve as building stone.

Pompey Academy was built in 1834, of stone quarried on M. Beard's farm, one and one-half miles north of Pompey hill, and the material for the two stone buildings used as stores were from the same quarry. Another quarry on the Dowlett farm, one-quarter mile southwest from the same village, supplied the stone for the Dowlett residence, and the brown-grey slabs, covered with impressions of large lamellibranchs and brachiopods, have been built into all the cellar walls and stone fences in the vicinity. The material for the dam at the foot of the DeRuyter reservoir was quarried from a hard layer near the west end.

The Tully limestone, the last division of the rocks of the Hamilton group, is composed of several thick layers of hard, light blue limestone and intercalated beds of calcareous shales, which appear in the southern tier of towns, and separate the brown-grey Hamilton shales from the black Genesee slates. Some parts of the limestone are quite pure and even grained, but the

CITY HALL, SYRACUSE — [illegible]

larger portion, though quite hard, is a lumpy, rubbly mixture of limestone and a small amount of clayey matter, which breaks easily with a very irregular vertical fracture, and on exposure is inclined to crumble. At most exposures the upper and lower layers are shaly. It is exposed on the hillside west of the Tully lakes, where it forms a sharply defined terrace, which gradually rises toward the north into a bold escarpment nearly 100 feet high. It has

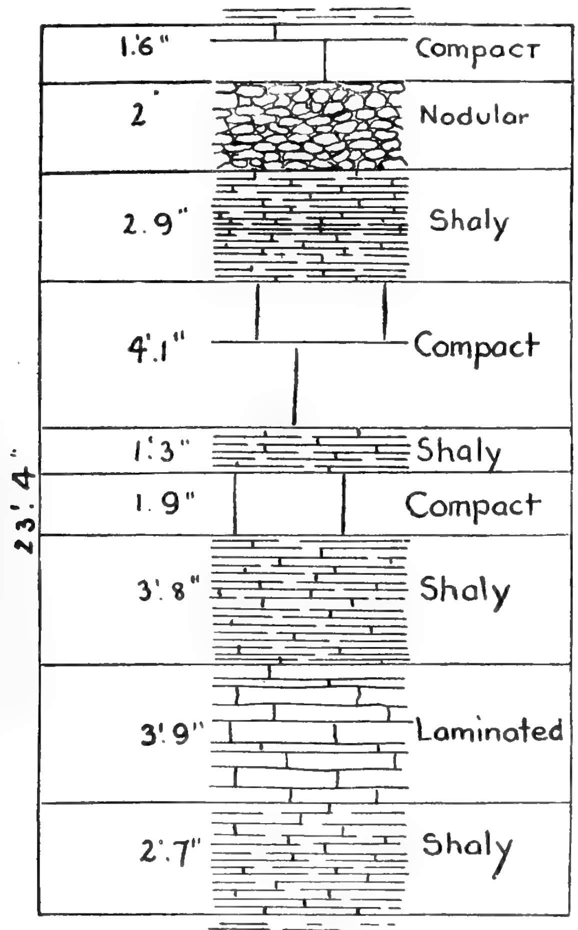


FIGURE 9 The Tully limestone section at Carr's quarry, Tully, N. Y.

been quarried for building stone and burned into lime at this place. At Carr's quarry, the upper shaly part is covered; the thickness exposed is twenty-three feet, four inches. Barrett's quarry near by is not now operated. The Solvay Process Co. quarried in this ledge for stone used in building the dam and gateways at the foot of Crooked lake. Ousby's quarry, one-half mile east of Tully village, is not operated, and but a part of the limestone is exposed.

There are no other good exposures of the limestone in the eastern part of the county, but at Tinker's falls, just over the line in Cortland county, near Labrador pond, it forms the crest of the fall, which is sixty feet high and projects over the shales beneath in the shape of a crescent, which is eighteen feet wide in the middle. The upper part is hard limestone, mostly rubbly; the lower ten feet, nearly all shaly. The total thickness exposed is twenty-nine feet, six inches. There is a small outcrop in the southeast corner of the town of Fabius.

The terrace reappears, though less distinctly seen, on the north side of the Vesper ravine, and continues with one interruption—that of the Otisco creek—to a point about one mile northeast of Otisco centre, where the outcrop on the Kingsley farm is the most westerly exposure in the county. According to Mr. E. B. Knapp, the limestone is twenty-two feet thick, and its altitude 1,500 feet, A. T.

In the Bucktail ravine, near Spafford Hollow, the Tully limestone is the crest of a high fall, and it is exposed in a small ravine near by. It is also exposed near the highway one mile southeast of Borodino, where it is unusually rich in fossils, one horizon being a crumbling mass of sections of crinoid columns, and orthoceratites a foot long and two inches in diameter occur. The strata here are in a disturbed condition, as though they had been undermined and had fallen with a sliding movement. The Nunnery schoolhouse, one-quarter of a mile south from this exposure, was built fifty years ago from Tully limestone quarried near by.

From this point south along the east bank of Skaneateles lake, it appears in several ravines. Where the highway crosses the ravine, above Colonel Jenney's cottage, there is a fall and a vertical exposure where, including a few feet above the bridge, the limestones measure thirty-two feet, ten inches. An excellent exposure for examination is in the dugway road leading up from Spafford landing. An outlier, which is quite extensive, occurs in the hill north of the village of Tully. The limestone is exposed near the mill dam in the bed of the small stream that runs through the village. It would seem from the elevation and position of Pompey hill, that the Tully limestone should be found there, but such is not the case.

Chemung Group.

All the rocks of the Genesee epoch and that part of the Portage epoch which includes the lower Black band and the second Black band, as those formations appear in Ontario and Livingston counties, are repre-

sented in Onondaga county by a bed of bituminous black shale with slaty laminæ, which is exposed to a small extent in the high hills in the south part of Fabius, Tully and Spafford, with a spur extending into the eastern part of Otisco, and an outlier in the southern part of LaFayette. Fossils, except plant remains, are exceedingly rare, and concretions, so abundant at this horizon further west, are seldom seen in this county. There are few good exposures of the entire section. One, however, occurs in the road leading up from Spafford's landing on Skaneateles lake. The bed here is ninety feet thick. It is exposed in the ravine east of Ousby's quarry, near Tully village, and the upper part in "King's gulf," one-half mile south of Ousby's. The upper part is somewhat less bituminous here than at Spafford. Outcrops of this bed occur at various places on the sides of South mountain

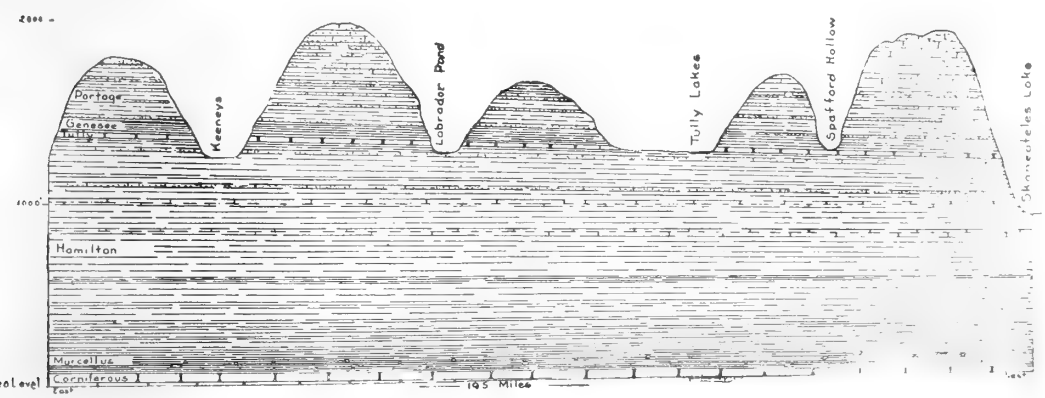


FIGURE 10. The east and west rock section along the southern boundary of Onondaga county.

in Fabius, and considerable time and money has been expended in digging into it, in the vain belief that, beyond exposure, it would be found to be coal. Nothing of economic value has yet been discovered in these black slates.

In the absence of any well defined line of separation between the Genesee slate and the Portage shales in the western counties, this bed of black slate may be assumed to belong to the Genesee. The light colored Portage shales with flaggy layers and thin sandstones are the surface rocks over the steep sides of the highest hills in the extreme southern part of the county, and also occupy a part of the high plateaus usually found at the summits. About twenty feet next above the Genesee slates are soft light bluish or olive shales, some layers fissile, others blocky, non-fossiliferous so far as known. Above these, eighty-five feet of rather hard blue shales with a few thin sandstones in which no fossils were observed, then a bed of sandstones and hard shales. At "King's gulf" these sandstones contain *Aulopora* in large quantities.

besides *Spirifer*, two species of goniatites, etc. Above this is a succession of hard, sandy, bluish shales and thin bedded sandstones, aggregating 155 feet in thickness. The sandstone layers in the upper part of this division have been quarried for flagstone near the village of Spafford. In some of the layers of shale which separate these sandstones at the quarry, specimens of *Strophomena mucronata* and a small *Orthis* are quite abundant, and other species occur sparingly. This quarry is 260 feet above the top of the black shales, and is in the Ithaca beds of the Portage group. This horizon is not exposed in King's gulf, but near the top of the hill directly east, in the highway leading from Tully to Truxton, a layer of sandstone crops out which contains many Chemung fossils. This layer is 265 feet above the *Aulopora* beds and 370 feet above the top of the black slate. Overlying it and outcropping in many places, are hard shales and sandstones, which cap all the high hills on the southern boundary line of the county, the greatest thickness being 300 to 350 feet, all belonging to the Chemung group. Although these upper sandstones are suitable for building stones, and in some places for flagging, they are not quarried. The loose blocks and slabs scattered about the fields supply the demand, which is entirely local.

The quarry at Spafford was operated vigorously at one time, and produced some very fine flagging, which was taken down the hill to Spafford's landing, thence to Skaneateles by boat. It is not now operated. A factory located at Manlius manufactured whetstones from a layer of Portage sandstones in Labrador hill, or South mountain. They were called "Labrador stones," and had a large sale, but their manufacture has ceased. Many flags from the *Aulopora* beds may be seen in the sidewalks in Tully. They were quarried a few miles south, at Preble, in Cortland county.

Quaternary Era.

The deposits of the Quaternary era consist of the earlier drift material brought from the north, with additions from the local limestones and shales carried by a southward movement and spread over all the south part of the county, even to the tops of the highest hills, where granite boulders and blocks of Medina sandstone, together with Lower Helderberg and Onondaga limestones, are common. This drift is generally coarse and unassorted, and the few beds of sand or clay found in sheltered positions are small and of little importance.

The valleys of Limestone and Butternut creeks in the town of Fabius, and of Onondaga creek in Tully, are choked by immense deposits of unstrati-

PLATE XVI

Delph. Falls; Hamilton shales.

fied drift to the height of 1,250 to 1,300 feet, A. T. The Limestone creek has cut a deep gorge through the mass between the DeRuyter reservoir and Delphi. A large deposit of this character near Apulia separates the waters of Butternut creek from those which flow southward to the Tioughnioga river. The Onondaga valley in the town of Tully is closed by a mass of drift piled in great disorder to a height of 400 to 450 feet. The surface is very uneven, especially on the west side, and the Tully lakes lie in the depressions, some of them draining into Onondaga creek, and others into the west branch of the Tioughnioga. The mass is unassorted gravel, usually very coarse, containing a large proportion of limestone pebbles and boulders, with other material brought from farther north.

Here and in all the higher parts of the county, sand, suitable for building purposes, is found only in small isolated deposits, which are well distributed, however, and sufficient for the requirements of the inhabitants. The most important sand beds are those along the sides of Onondaga valley, between the Indian Reservation and Syracuse. They are from fifty to one hundred feet thick, the top of the formation being a little more than 500 feet, A. T.

On the east side, in the vicinity of Brighton, the deposit is very large, varying in quality from fine sand suitable for stone work to the coarser grades and fine gravel. At Dorwin's springs on the west side, there is a large deposit at the north end of a broad terrace which extends out into the valley, and there are others farther north. Digging out and hauling the sand into the city of Syracuse furnishes employment for a considerable number of men. Some of the principal owners and dealers are:

L. C. Dorwin, who leases his sand pit, from which are taken annually 25,000 cubic yards.

Benjamin Clark, pit near cemetery south of Onondaga valley; output, 1,000 cubic yards.

Frank Patterson, Brighton, 6,000 cubic yards of sand, of which 2,000 cubic yards are shipped out of county; also sells 2,000 cubic yards of gravel annually.

George Kleinheinz, Brighton; 3,000 cubic yards annually.

James McComb, Brighton, 300 cubic yards annually.

Hugh Scott, Brighton, 600 cubic yards annually.

Samuel Irving, Brighton, 200 cubic yards annually.

Lucian Cross, Brighton, 400 cubic yards annually.

Richard Crandon, Brighton, 400 cubic yards annually.

The principal part of this sand is used in the construction of buildings, cement sidewalks, and pavements in the city of Syracuse. The Adamant Plaster Co. uses 4,000 cubic yards; the Eureka Plaster Co. uses 4,500 cubic yards, with capacity recently increased to 7,000 cubic yards; and the Paragon Plaster Co. uses 6,000 cubic yards annually in the manufacture of wall plaster prepared ready for use, which is to a large extent shipped out of the county. In the northern towns good sand is found abundantly sufficient for local use, though no large deposits were observed.

Clay beds of the Champlain epoch occur in all the valleys in the county south of the line of the limestone outcrop. Many of them show by their red color that they were derived, in part, at least, from the Salina shales. A large deposit of this stiff red clay occurs at the south end of the Onondaga valley in the vicinity of the salt wells, at a distance of seventeen miles from the nearest present exposure of the red shales and 200 feet higher. University hill in Syracuse, is partly composed of the red clay, generally mixed with fragments of shale and limestone. In the middle of Onondaga valley, in the southern part of the city of Syracuse near Brighton and Midland avenues, there is an extensive deposit of clay which is owned by the Syracuse Pressed Brick Co. It is on the flat in the middle of the valley, at an elevation of about 450 feet A. T. When the alluvial soil which is eight to twelve inches thick is removed, a bed of reddish brown clay two and one half to three feet thick is found, from which bricks of a rich dark red are made. The next one and one-half feet below includes the irregular contact line between the upper bed and the second one, and this material is made into ordinary building bricks which are of various shades of red or buff, and sometimes mottled. The second stratum of clay from the top is three feet thick. It contains less iron, and bricks made from it are light buff. They are burned hard, and like the dark red ones from the upper layer, are used as facing brick.

The lower bed is dark bluish brown, and is made into ordinary building brick. The company employs forty men and fifteen boys during the season. The output in 1895 was 4,000,000. This company has recently purchased 113 acres of land east of the city on which are large clay deposits, and expects in the immediate future to manufacture on a large scale bricks from these beds.

On the north side of the city just beyond the corporation line there are several brick yards. The owners are:

Preston Bros., 7th and North streets; employ eighteen men. Annual output, 2,000,000.

G. W. Peck & Son, 7th and North streets; fifteen men. Output, 1,500,000.

PLATE XVII

Clay beds of the New York Brick and Paving Company, at Newbridge, on the Seneca river.

John Brophy, Brewerton Plank Road; fifteen men. Output, 1,500,000.

F. H. Kennedy, 7th and North streets; ten men. Output, 1,000,000.

C. & L. Merrick, Whiskey Island, out E. Court street; thirty men. Output, 3,000,000 and 500,000 ornamental pressed brick.

The Onondaga Vitrified Brick Co. at Warner's, manufacture $5,000 worth of roofing and drain tile from clay beds adjoining the works.

A clay bed about 200 acres in extent lies west of the railroad station at Jordan. Edward Heighhoe owns eleven acres of it, and manufactures drain pipe and horseshoe tile to the value of $2,000 annually, and employs three men.

One hundred thousand bricks are made annually from a bed in the village of Baldwinsville.

On the east side of the Seneca river, one-half mile north of Newbridge, is situated the bed of stratified clay several acres in extent and at least twenty-five feet thick, from which is obtained the material used by the New York Brick and Paving Co., of Syracuse, in the manufacture of vitrified bricks for street pavements. The top of the bed is twenty feet above the river, and has an elevation of 385 A. T. It is covered by two feet of sandy loam. The upper part is composed of nearly level layers of clay four to six inches thick, brown or pinkish in the middle, becoming lighter colored toward the upper and lower surfaces, and which are separated by a thin light drab layer one-half to one inch thick, composed of very fine white sand, generally, but not always, mixed with a little clay, which produces a characteristic and striking banded effect. When a mass falls over from the vertical walls of the excavation the clayey layers separate on the sandy planes and slide on each other like flagstones. This part of the bed is ten to twelve feet thick. Beneath it the clay is of a bluish brown. The lines of bedding are less distinct, and are much flexed and folded. It has been excavated to the depth of twelve feet without reaching the bottom. Concretions are quite common in some of the more calcareous layers three to five feet from the top of the bed. The most common form is that of flattened spheroids, two to four inches in diameter and one-half to one inch thick. Generally faint traces of a slender root can be seen in the center. In many cases only an outer rim one-half to one inch wide has become indurated, the interior having been affected only to the extent of a slight discoloration that appears in the form of narrow brownish concentric bands. Besides these curious and rare ring concretions, other symmetrical forms occur, that are solid and composed of thin concentric layers. Occasional irregular accretions of calcareous material about some small central object are to be found throughout the entire bed.

A brickyard was started by Ammi Crawford in 1829, at this place, long known as Brickyard Point. Tile and a small amount of pottery were made here about 1846. Since the organization of the New York Brick and Paving Co. the clay has been transported to Syracuse by canal and manufactured into vitrified or paving brick, without the addition of any new material, by the ordinary method employed in making bricks for building purposes, except that the application of a higher degree of heat is required.

The following analysis of this clay was kindly furnished by Mr. J. L. Breed, general manager of the company:

Silica,	57.03
Alumina,	14.644
Sesq. ox. Iron,	3.369
Ox. Manganese,	.185
Magnesia,	3.468
Lime,	9.298
Organic matter,	11.700
Potassa,	.296
Loss,	.010
	100.000

The company employs forty men. The annual output is 10,000,000 bricks, of which 8,000,000 are used in paving streets and 2,000,000 in buildings. Five miles of the streets of Syracuse are paved with these brick. The company also manufactures acid proof brick and tile for the lining of digesters used in the manufacture of paper.

Deposits of marl and marly clay are found in the towns of Fabius and Tully in the vicinity of the lakes, ponds and swamps, the calcic carbonate being derived from the large amount of comminuted or pulverized limestone in the drift. Marl is found in large quantities in and about all of the small lakes in the limestone section of Dewitt and Manlius, and in Onondaga and Cross lakes. Cicero swamp contains a very large bed, and others occur in the marshy tracts in the towns of Dewitt and Manlius. Other large deposits of an exceptionally pure quality have been found in Camillus, Elbridge and the southern part of Van Buren, near the Erie canal. The marl from some of these beds is very pure calcic carbonate. When made into bricks and burned it makes exceedingly white, clear lime. It has been utilized for this purpose to a slight extent, and it has been considered as of some value as a fertilizer. Its chief economic value at present is due to the fact that it is the

PLATE XVIII

CLAY BEDS AT RIVERSIDE.

principal ingredient in the composition of "Portland" cement, which is an artificial water-lime, having the property of hardening or "setting" under water.

The American Portland Cement Co. has a plant in the town of Elbridge, two miles east of Jordan, and owns fifty acres of marl and clay lying on both sides of the Erie canal, and another bed of marl near Jordan station. The marl bed at the works is from eight to fifteen feet thick, and has the appearance of a bed of pure white clay. Entire specimens of recent fresh water shells are very abundant in it, and also in the bed of marly bluish clay beneath it, which is the other important component in the cement.

The process of manufacture is briefly as follows: After the muck has been carefully removed, the marl is dug out and conveyed to the works, where it is thoroughly mixed by machinery with water and a definite proportion of clay, together with a small amount of other material, and pressed into the form of long rough bricks. These are placed on small platform cars, in layers crosswise, with a space between to allow circulation of air; then taken to a large room through which is driven a strong current of air heated to a temperature of 150°, where they are rapidly dried and become hardened so that they can be hauled. They are then placed in large circular kilns, with alternate layers of coal and subjected to a high degree of heat for three days. When sufficiently cool, stone crushers and mill stones reduce the calcined mass to the consistency of fine flour. It is then ready for use.

The American Portland Cement Co. at its Jordan works has twelve kilns and employs seventy-five men. It manufactures 2,500 barrels of cement per month. In the town of Camillus, one-half mile south of Warners, the Empire Portland Cement Co. owns extensive marl and clay beds and manufactures Empire Portland Cement on a large scale. The marl bed one-half mile west of the works is six to seven feet thick, covered by two to twelve inches of black muck. Beneath the marl is a bed of bluish marly clay two and one-half feet thick. Steam is employed in excavating the marl and clay and hauling the loaded cars to the works. This establishment turns out 400 barrels of finished cement per day and employs 110 men. The large plant of the Warner Cement Co., located on marl and clay beds one mile west of Warner's, is not in operation at present. Nearly all of the cement produced in the county is exported. The amount of marl and clay in the county adapted to the manufacture of artificial cement is practically unlimited.

Deposits of carbonate of lime in the form of travertine, sometimes called "basswood limestone," "horse-bone" and "petrified moss," derived from the same sources as the marl, are common throughout the county except in the northern tier of towns. These deposits are usually found where some subterranean stream of water surcharged with lime carbonate comes to the surface, forming a spring around which, as the water is evaporated by exposure to the sun and atmosphere, the travertine is deposited, sometimes with earthy and vegetable matter, but frequently free from them. The proximity and abundance of lime in more convenient forms deprive this material of the economic value it might otherwise have.

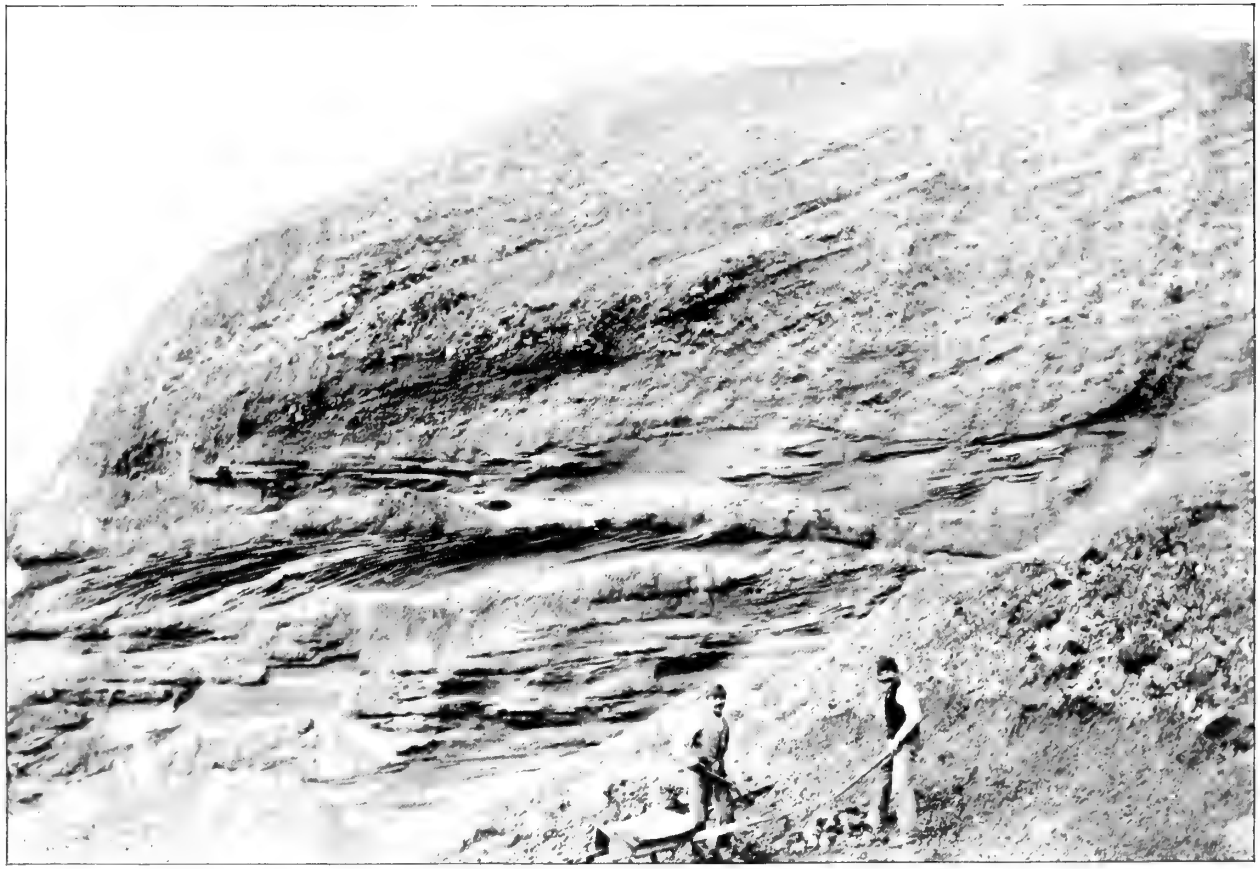
Masses of conglomerate, or "hard pan," formed by infiltrating calcareous waters depositing lime carbonate in sufficient quantities in beds of gravel or coarse sand to produce cementation, are common. A remarkable instance is exposed in Hopper's glen, near Onondaga valley, where a small stream has cut through a bed of very coarse gravel fifty feet thick, which is so firmly cemented that it does not disintegrate on exposure; but as the softer material beneath it has been removed by the action of the stream, it has fallen into the ravine below in enormous masses. Some of the larger are thirty to forty feet in their longer diameter.

Condition of the Rock Strata.

The general southward dip of the strata, about forty feet per mile, is apparent without the use of instruments. Except in the vicinity of the limestone escarpment, the undulations which are of frequent occurrence are low and long, for that reason easily escaping notice, unless observed along the shore of a lake where comparison with the level surface of the water brings them more plainly to view. Approaching the line of the great outcrop of the limestones from either the north or the south side, it is found that the flexures are sharper and more numerous, and that along the entire length of the escarpment in this county, and including a belt three to five miles wide, evidence of profound movement and disturbance of the strata appears at nearly every exposure. Vertical faultings of more than a few inches were not observed, but overthrusts producing dislocation of the strata to the amount of several feet, anticlines with extensive longitudinal fissures at the summit several inches wide, chasms and jointings, are numerous.

In Beahan's quarry, near Manlius, as shown in the south wall, the strata dip to the southwest for twenty rods at the rate of three feet per one hundred, then for two rods the floor is level to the foot of an inclination that rises for four rods, one foot in ten, and continues at a somewhat lower angle for some distance further, covered by drift. One hundred rods south of Beahan's,

PLATE XIX



Pattison's sand bank, near Brighton.

in Alvord's grey lime quarry, a fissure four inches wide has been worn at one point to a foot in width, by the surface water that poured through here to unknown depths below; and thirty rods east of the quarry occurs a chasm three or four feet wide, partially choked by dislodged blocks of limestone. By the side of the railroad midway between Beahan's and Alvord's lime kilns the summit of an anticlinal fold in the upper part of the Gypseous shales is exposed; and near Tod's gypsum quarry the magnesian limestones of a low ridge have been extensively flexed and fractured. On the south side of the road leading from Manlius to Jamesville, near its crossing with the town line of Dewitt, the top of the Corniferous limestone is exposed in the bottom of the ravine near the schoolhouse, and in another ravine one-half mile to the west. A steep upward inclination toward the south beginning near the road is continued twenty-five or thirty rods, elevating the strata at least sixty feet.

In Britton & Clark's quarry a thirty-foot section of an anticline shows several vertical fissures, the widest being eight inches, extending below the

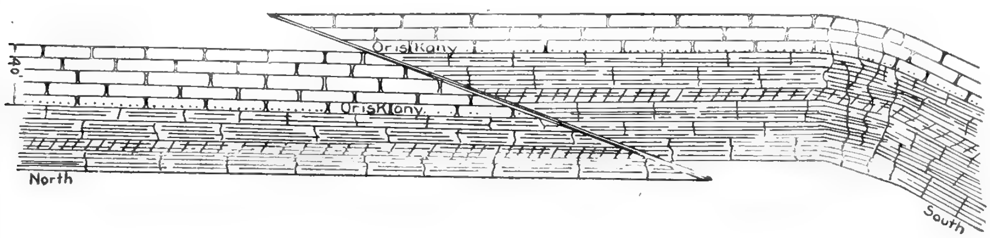


FIGURE 11. Overthrust flexure and fault in C. H. Russell's quarry at East Onondaga.

bottom of the quarry. At C. H. Russell's quarry near East Onondaga, the floor at the west end shows a fine syncline, and at the opening in the south wall near the east end, the fracture plane of an upthrust fault is exposed. The dip of the fracture plane is twenty degrees toward the south, and the displacement of the strata is forty-two feet. The floor of the quarry south of the fault for about one hundred feet is level, then dips to the south again at an angle of twenty-eight degrees, twelve feet to the end of the excavation. The wall of House's quarry south of the old arsenal at East Onondaga, can be seen from the opposite side of the valley, showing the arched strata of an anticline. At the Reservation quarries, the limestones show little disturbance except near the southwest corner. In the vicinity of Bellevue heights, the magnesian limestones where exposed are folded and broken, and at Decker street there is a fissure ten inches wide filled with brecciated travertine. At Split Rock the strata are but slightly folded, though some wide and deep fissures occur. A mile southeast from the village of Marcellus, in the deep valley leading toward Cedarville, the top of the Corniferous limestone is exposed over a large area, and the undulations are very apparent.

In Wm. Maylie's quarry at this locality, an overthrust fault displaces the strata two feet, two inches. The dip of the fracture plane is eighteen and one-half degrees. This quarry is three miles from the north edge of the Helderberg escarpment.

Walker's quarry near Marcellus falls exposes a north and south section 200 feet long, in which the limestones dip toward the south, thirty-six feet. At the north end of the quarry, which is near the summit of the anticline, there is a fissure two feet wide, and six rods north another, now partially filled with large blocks of limestone, that is four feet wide.

All of the quarries above mentioned are in the Corniferous and Lower Helderberg limestones, and the flexures and fractures described are in the upper part of a bed of hard rocks 250 to 400 feet thick.

On the north side of the escarpment, the rocks of the Gypseous shales and the horizon of the salt beds, wherever exposed, are in the same disturbed condition, but the most apparent effect of the flexing is the reduction of the thin bedded or shaly limestones of that horizon to a loose mass of uncemented breccia. In grading a street in the western part of the city of Syracuse a bed of limestone was found to be so finely broken to the depth of five feet that it was plowed without difficulty.

The well known exposure on Green street, in Syracuse, in which appear the *eruptive dikes* of peridotite is the most interesting one in this connection, and perhaps in the whole county.

The high ridge that separates the Onondaga and Butternut creek valleys extends from Tully to the southeastern part of the city of Syracuse, ending one-half mile north of the University of Syracuse, which is situated on the terminating slope of the ridge, at an elevation of about 600 feet A. T. At the foot of the slope is an alluvial plain three-fourths of a mile wide, having an elevation of 402 feet A. T. On the north side of this plain there rises to the height of 150 feet an elevated, uneven tract bounded on the west by the Onondaga lake basin, and extending two or three miles toward the north and east. On the south side the slopes are generally quite steep, but more gentle on the west and north sides. This elevated tract has the appearance of being, and doubtless is, composed largely of drift material, but in the southwest part of it, at least, the bed rock lies near the surface, though there are no natural outcrops. In an effort to modify the grade of Green street north of

PLATE XX

THE PERIDOTITE (KIMBERLITE) DIKE ON GREEN STREET HILL, SYRACUSE.

Lodi street a few years ago, a cut was made exposing a section of the rocks, 200 feet long and 12 feet high at the highest point.

In the fall of 1895, a ditch for water mains was dug seven feet below the street grade, enlarging for a few days the exposed section to that extent. The rocks uncovered are the thin bedded and shaly magnesian limestones that occur immediately above the horizon of the rock salt beds, and lie on the southwestern slope of an anticline, the outlines of which are obscured by the drift. They are much flexed and broken by the eruption of the material com-

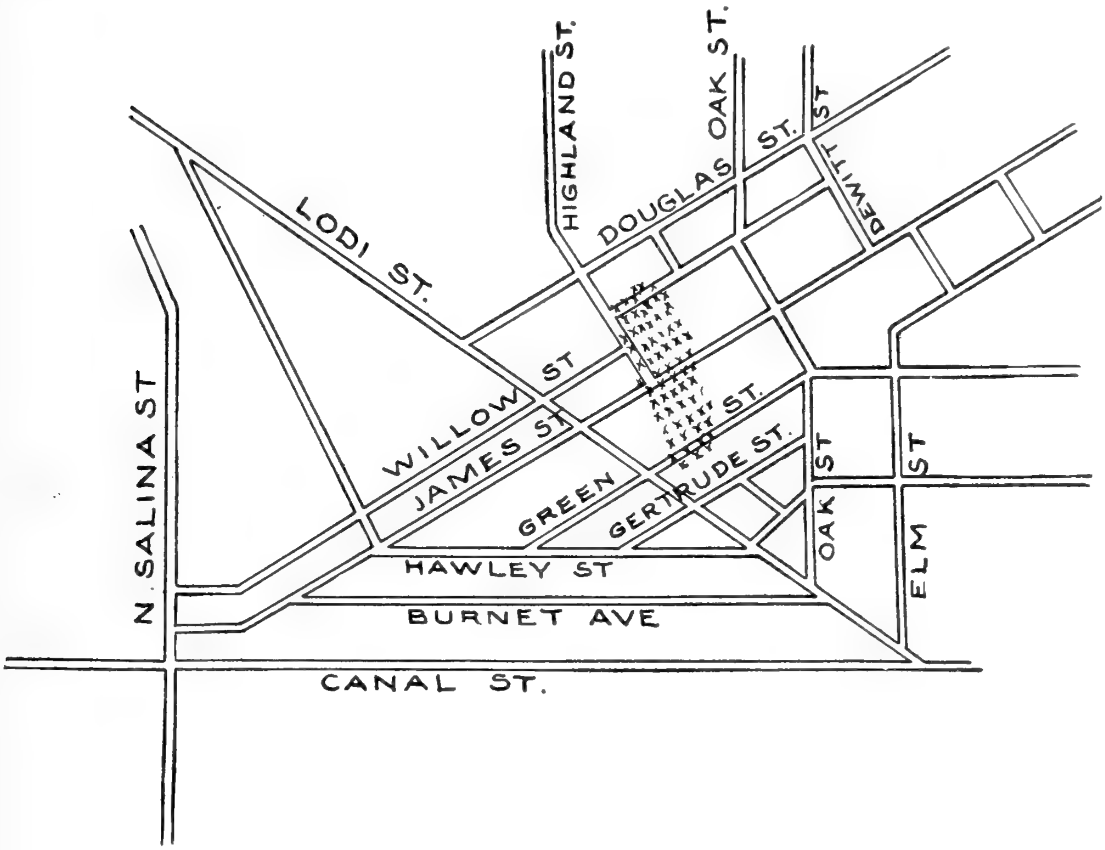


FIGURE 12. The location of the peridotite dike in the city of Syracuse.

posing the dikes. The principal dike is twelve feet, four inches wide at the surface of the road bed, and approximately the same to the bottom of the dike. Above the sidewalk the width increases to the top of the bank, where it is twenty-five feet, and a layer eight to ten inches thick is spread over the surface of the rocks for several rods toward the east, thinly covered by the soil. Another and much thinner dike occurs about one hundred feet west of the main one, and there are evidences of two others, also small. The middle portion of the main dike is composed of quite firm and hard, dark green peridotite, but adjacent to the walls and in the smaller dikes and the overflow layer it has decomposed and is now very soft and friable and greenish yellow in color. The main dike is exposed also on the south side of Green street, but for only a few rods south of that point. It extends in a northerly direction across James street, and has been traced by Mr. P. F. Schneider as far as Highland street, a distance of a little more than a quarter of a mile.

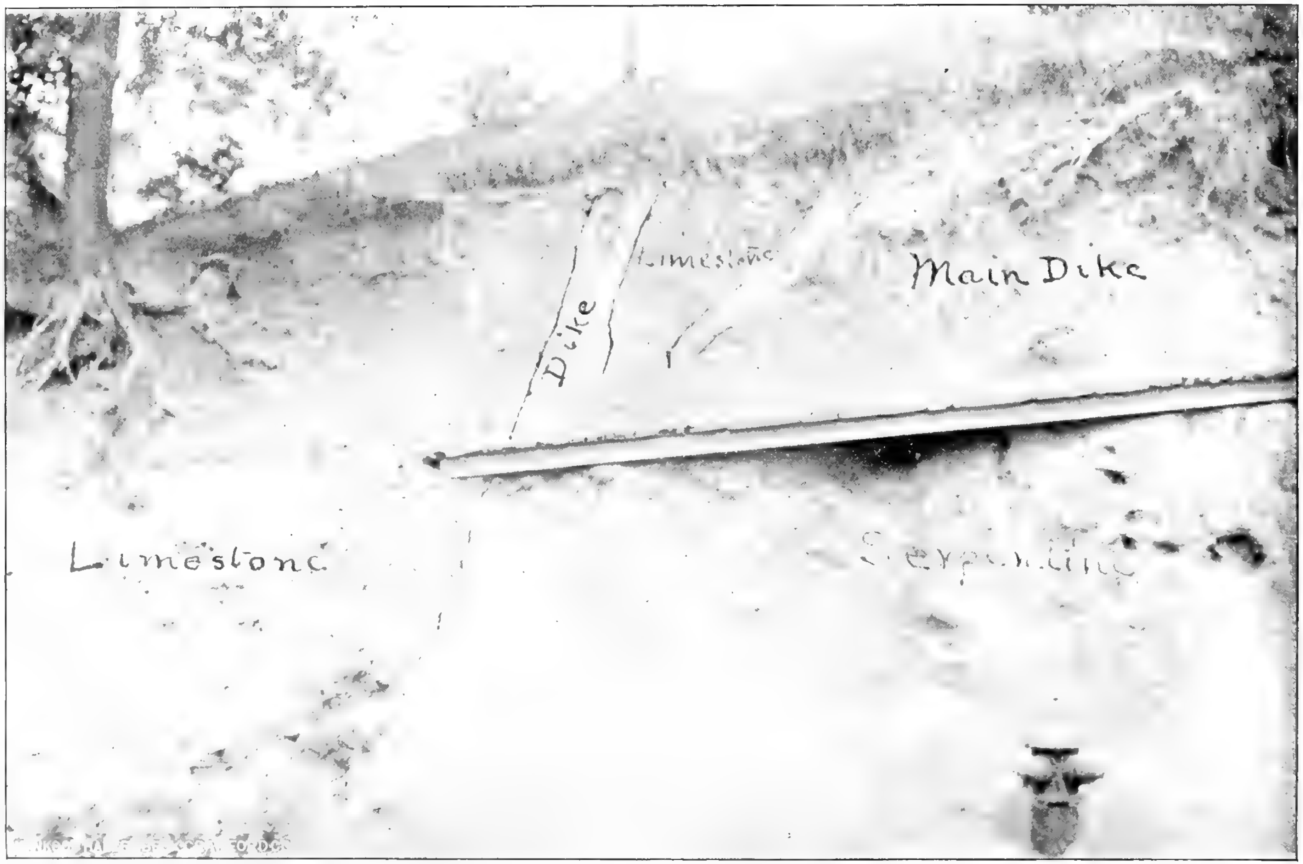
A water pipe ditch dug near the west line of lot No. 805 James street, and another on the premises of Mr. Hiscock on the opposite side of the street exposed, and was excavated through, the decomposed overflow layer of this eruptive to drab limestone beneath. The excavation for the foundations of a barn on Green street, six rods east of the main dike, exposed a layer of the same character, ten inches thick, spread over the shaly limestones. Grading Elm street, which runs parallel with the dike nearly one-half mile to the east, has exposed the rocks, and shows that the inclination of the strata corresponds to the general slope of the hill.

The position of the dikes as exposed at Green street is on the southwest slope of the hill, and sixty feet higher than the low land at the south. The elevation increases somewhat toward the north. Evidences of the eruption have been found in this place, over a section one hundred rods in length and twenty to twenty-five rods in width.

The occurrence of the eruptive rocks in this region was first recorded by Vanuxem (Annual Report, 1839; Final Report, 1842) and Beck (1842). The original locality "on the Foot-street road to the east of Syracuse," was lost sight of, and the rock was afterward known only from the few specimens which had passed into the collections of some of the older educational institutions. From such material its nature was studied and its eruptive character demonstrated by the late George H. Williams (*American Journal of Science*, 1887, and *Bull. Geolog. Society of America*, Vol. 1). A new exposure of this rock was brought to notice by Mr. Schneider, in 1895, at DeSono station on the West Shore railroad, about one-half mile south of Dewitt Center, and an account of its occurrence and nature published by Messrs. Darton and Kemp ("A Newly Discovered Dike at Dewitt, near Syracuse, New York. Geologic Notes by N. H. Darton. Petrographic Description by J. F. Kemp"; *American Journal of Science*, vol. 49, pp. 456–462, 1895).

On account of the disturbed condition of the strata, any figures given in regard to the dip can be only approximately correct. From data gathered from the records of the Solvay Process Co.'s wells at Tully it was found that the upper surface of the Corniferous limestone has a southward dip of forty

PLATE XXI



THE PERIDOTITE (KIMBERLITE) DIKE ON GREEN STREET HILL, SYRACUSE.

feet, seven inches per mile. In Dr. Englehardt's record of the state well drilled in 1884 at the south end of Onondaga lake, it appears that the Niagara limestone was reached at 208 feet below sea level. As it appears at the surface nine and one-half miles north of the well at an elevation of 375 feet A. T., there is apparently a dip of 61 + feet per mile. Using the record of the Gale well on the north shore of the lake in like manner, the result is 54 + feet for the dip of the limestone. This increase of dip is explained partly, at least, by the fact that the thickness of the red shales and the rocks of the salt horizon increases rapidly toward the south as shown by the well records. On an east and west line the dip of the top of the Corniferous limestone is hardly measurable. By comparison with known exposures in Genesee county it is found to average ten inches to the mile toward the west for the whole distance. The average westerly dip of the Tully limestone to Ontario county is 7 + feet per mile.

So far as can be determined by the data at hand, the rock salt beds have no dip, but are practically level on an east and west line. Some small gas springs occur in the vicinity of Skaneateles lake and Otisco lake, and at other localities in the Hamilton shales, but the quantity of gas is not large enough to be of commercial value. The amount found in the Tully salt wells was also slight. Large leases of land in the towns of Lysander and Clay have recently been made by a company intending to sink wells to the Trenton limestone for gas, but as yet no drilling has been done.

Table showing the Economic Products of the Rocks, and of the Sand, Clay and Marl Beds of Onondaga County.

NAME OF PRODUCER.	LOCALITY.	PRODUCT.	AMOUNT.	No. OF MEN.	VALUE.
T. W. Sheedy	Fayetteville	Building stone.	50 cords	12	$200
T. W. Sheedy	Fayetteville	Cement	15,000 bbls.	....	6,000
T. W. Sheedy	Fayetteville	Plaster	2,000 tons	....	5,500
Bangs & Gaynor	Fayetteville	Cement	40,000 bbls.	25	16,000
Bangs & Gaynor	Fayetteville	Plaster	5,000 tons	....	13,750
Lansing & Son	Fayetteville	Plaster	2,000 tons	5	5,500
F. M. Severance & Co	Fayetteville	Plaster	4,000 tons	10	11,000
James Beahan estate	Manlius	Cement	50,000 bbls.	25	20,000
James Beahan estate	Manlius	Quicklime	25,000 bbls.	....	10,000
A. E. Alvord	Manlius and Syracuse	Quicklime	200,000 bu.	100	20,000
A. E. Alvord	Manlius and Syracuse	Cement	125,000 bu.	....	12,500
A. E. Alvord	Manlius and Syracuse	Crushed stone	27,000 cu. yds.	....	31,000
A. E. Alvord	Manlius and Syracuse	Building stone.	200 cu. yds.	....	800
A. E. Alvord	Manlius and Syracuse	Calcined gypsum	3,500 tons	....	6,625
Eaton Bros	Manlius	Cement	7,500 bbls.	....	3,000
Robt. Dunlop	Jamesville	Cement	80,000 bu.	20	8,000
Robt. Dunlop	Jamesville	Plaster	2,000 tons	....	4,000
Robt. Dunlop	Jamesville	Building stone.	100 cords	....	300
E. B. Alvord & Co	Jamesville	Cement	20,000 bu.	20	2,000
E. B. Alvord & Co	Jamesville	Quicklime	50,000 bu.	....	5,000
E. B. Alvord & Co	Jamesville	Plaster	2,000 tons	....	4,000
E. B. Alvord & Co	Jamesville	Building stone.	250 cords	....	1,000
Britton & Clark	Syracuse	Cement	100,000 bu.	30	10,000
Britton & Clark	Syracuse	Quicklime	50,000 bu.	....	5,000
Britton & Clark	Syracuse	Building stone.	2,500 cords	....	10,000
Britton & Clark	Syracuse	Crushed stone.	5,000 cu. yds.	....	5,750
Kelly Bros	Indian Reservation	Building stone.	12,000 cu. yds.	35	60,000
P. McElroy	Indian Reservation	Building stone.	700 cu. yds.	5	3,500
Thos. Coughlin	Indian Reservation	Building stone.	400 cu. yds.	3	1,800
C. H. Russell	East Onondaga	Building stone.	1,000 cu. yds.	8	4,500
Cash Worden	East Onondaga	Building stone.	200 cu. yds.	2	900
John Connolly	East Onondaga	Building stone.	500 cu. yds.	4	2,250
D. & G. Story	Onondaga Castle	Building stone.	800 cu. yds.	5	3,500

Table showing the Economic Products of the Rocks, and of the Sand, Clay and Marl Beds of Onondaga County.—Continued.

NAME OF PRODUCER.	LOCALITY.	PRODUCT.	AMOUNT.	NO. OF MEN.	VALUE.
John Kearney	Onondaga hill	Building stone.	1,450 cu. yds.	8	$5,800
Sam'l Street	Onondaga hill	Building stone.	1,500 cu. yds.	10	6,000
L. C. Dorwin	Dorwin springs	Building stone.	800 cu. yds.	5	3,500
Isaac Cole	Bellevue avenue	Building stone.	1,000 cu. yds.	6	4,500
Geo. Redhead	East Onondaga	Building stone.	500 cu. yds.	4	2,250
Patrick Knox	East Onondaga	Building stone.	50 cu. yds.	1	225
Solvay Process Co	Solvay	Quicklime	9,000,000 bu.	3,000	900,000
Solvay Process Co	Solvay	Salt	14,000,000 bu.	....	1,120,000
Solvay Process Co	Solvay	Building stone.	5,000 cu. yds.	....	20,000
Wm. Maylie	Marcellus	Building stone.	200 cords	2	800
John Clancy	Marcellus.	Building stone.	50 cords	1	200
Martin Hogan	Marcellus	Building stone.	50 cords	1	200
L. H. Walker	Marcellus Falls.	Cement	4,000 bu.	3	400
P. C. Corrigan	Skaneateles Falls.	Cement	20,000 bu.	5	2,000
J. H. Ketchum	Skaneateles Falls.	Building stone.	100 cu. yds.	1	500
O. Whitney	Cicero	Building stone.	50 cu. yds.	1	200
C. Diedrich	Lysander	Building stone.	50 cu. yds.	1	200
J. Carr	Tully	Building stone.	50 cu. yds.	1	200
N. Y. State	Salt Spr. reservation.	Salt, 1894	3,227,254 $\frac{32}{56}$ bu.	....	258,180.37
Onondaga Brick Co	Syracuse & Van Buren	Bricks	10,000,000	40	60,000
Onondaga Brick Co	Syracuse & Van Buren	Drain tile, etc.	....	....	5,000
Central City Brick Co	Syracuse & Kirkville	Pressed brick	1,500,000	25	15,000
John Brophy	Salina	Bricks	1,500,000	18	8,250
F. H. Kennedy	Salina	Bricks	1,000,000	10	5,500
N. Y. Brick & Paving Co	Syracuse & Newbridge	Paving bricks	8,000,000	40	90,000
N. Y. Brick & Paving Co	Syracuse & Newbridge	Building bricks	2,000,000	....	10,500
G. W. Pack & Son	Salina	Building bricks	1,500,000	15	9,000
Preston Bros	Salina	Building bricks	2,000,000	18	11,000
Syracuse Pressed Brick Co	Syracuse	Building bricks	4,000,000	50	30,000
C. & L. Merrick	Salina	Building bricks	3,000,000	25	18,000
C. & L. Merrick	Salina	Pressed bricks	500,000	....	6,000
Edward Heighhoe	Jordan	Drain tile	....	3	2,000
Frank Patterson	Brighton	Sand and gravel	8,000 cu. yds.	....	7,200

Table showing the Economic Products of the Rocks, and of the Sand, Clay and Marl Beds of Onondaga County.—Concluded.

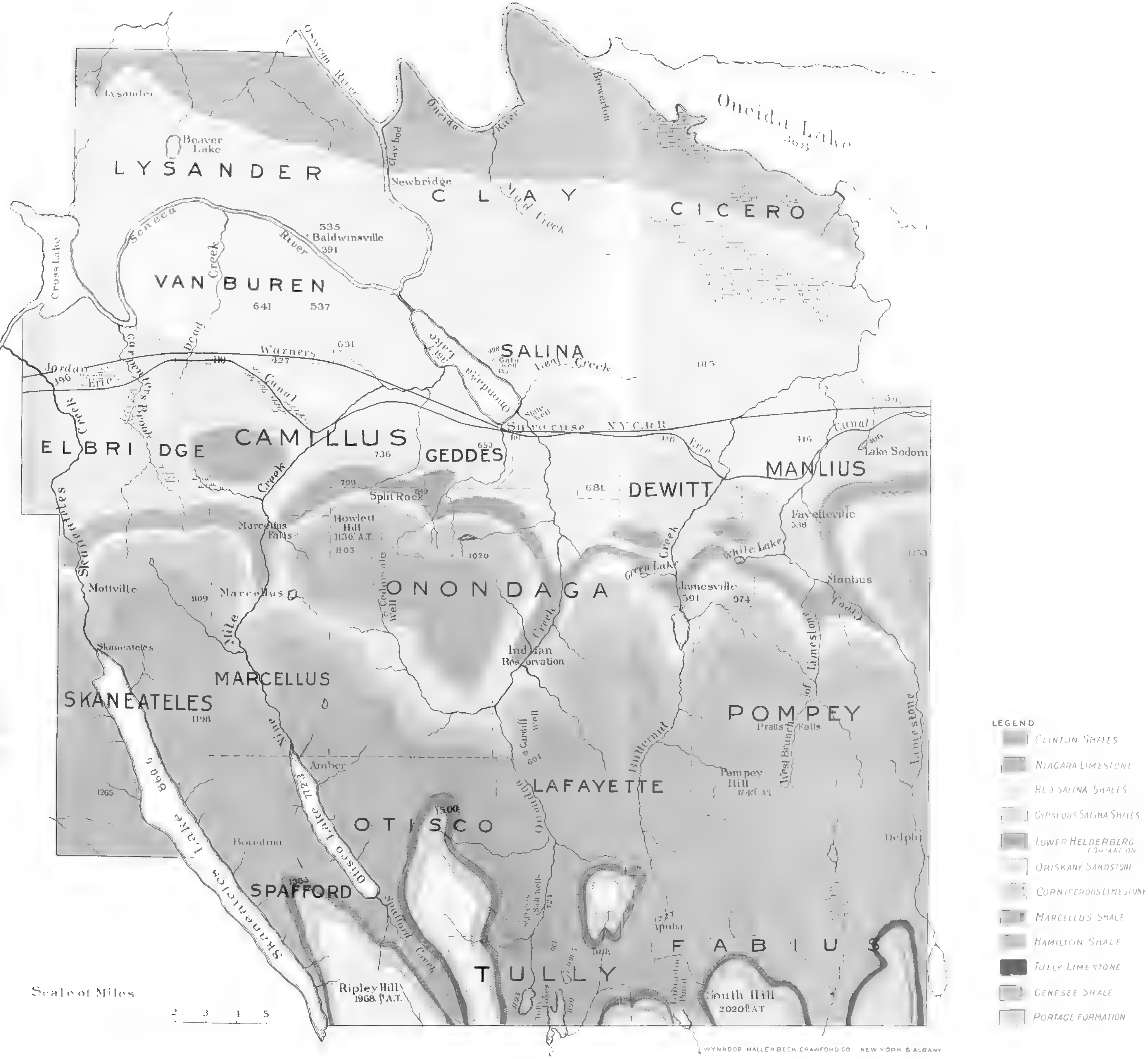
NAME OF PRODUCER.	LOCALITY.	PRODUCT.	AMOUNT.	NO. OF MEN.	VALUE.
Geo. Kleinheinz	Brighton	Sand	3,000 cu. yds.	....	$2,500
B. Clark	Onondaga valley	Sand	1,000 cu. yds.	....	800
L. C. Dorwin	Dorwin's springs	Sand	25,000 cu. yds.	....	20,000
R. Crandon	Brighton	Sand	400 cu. yds.	....	320
Lucian Cross	Brighton	Sand	400 cu. yds.	....	320
Samuel Irving	Brighton	Sand	200 cu. yds.	....	160
Geo. Moore	Brighton	Sand	800 cu. yds.	....	640
Hugh Scott	Brighton	Sand	600 cu. yds.	....	480
American Portland Cement Co	Jordan	Portl'nd cement	30,000 bbls.	75	75,000
Empire Portland Cement Co	Warner's	Portl'nd cement	117,000 bbls.	110	300,000

Summary Statement of the Economic Products of the Geologic Formations in Onondaga County.

		Product.	Value.
Champlain Period	Marl beds.	Portland cement.	$375,000
	Clay beds.	Brick and tile.	206,000
	Sand beds.	Sand.	33,745
Chemung Period	Portage Group.	Building stone and flagging.	
	Genesee Shale.		
Hamilton Period	Tully Limestone.	Building stone.	
	Hamilton Sandstones.	Building stone.	
	Marcellus Shale.		
Upper Helderberg Period	Corniferous Limestone.	Building stone.	90,000
Oriskany Period	Oriskany Sandstone.	Building stone.	
Lower Helderberg Period	Water-lime Group.	Quicklime.	936,000
		Cement.	77,900
		Building stone.	42,400
		Crushed stone.	36,750
Onondaga Period	Gypsum beds.	Gypsum.	50,000
	Salt beds.	Salt.	1,378,180
	Salina Red Shales.	Brick and tile.	87,000
Niagara Period	Niagara Limestone.	Building stone.	400
	Clinton Shales.		
			$3,353,950

Table of Elevations.

LOCALITY.	TOWN.	LOT No.	A. T.	AUTHORITY.
South hill	Fabius	34	2,020	Gardiner's survey.
Apulia R.R. station	Fabius	21	1,227	Gannett.
Well 4, Group F	Tully	18	721	Trump.
Well 1, Group A	Tully	28	901	Trump.
Ripley hill	Spafford	32	1,968	Gardiner.
Limestone ledge	Spafford	12	1,365	E. B. Knapp.
Kingsley's	Otisco	95	1,500	E. B. Knapp.
Pompey hill	Pompey	65	1,742	Geddes.
E. O. Clapp's farm	Pompey	5	128	Gardiner.
Cardiff salt well	La Fayette	57	601	Trump.
Chas. Carpenter's farm	Onondaga	96	1,105	Gardiner.
D. Cossitt's farm	Onondaga	118	1,020	Gardiner.
Split rock	Onondaga	....	849	Geddes.
Howlett hill	Marcellus	17	1,136	Gardiner.
M. Seeley's farm	Skaneateles	22	1,109	Gardiner.
W. P. Giles's farm	Skaneateles	66	1,265	Gardiner.
R. R. Hoxie's farm	Skaneateles	45	1,198	Gardiner.
Jordan, canal	Elbridge	....	409	Gannett.
Jordan, West Shore R.R	Elbridge	....	396	Gannett.
Jordan, N. Y. C. R.R	Elbridge	....	401	Gannett.
Fairmount	Camillus	36	736	Gardiner.
M. Sherwood's farm	Camillus	48	799	Gardiner.
Dr. Draper's farm	Geddes	150	653	Gardiner.
N. Y. C. R.R. station	Syracuse	....	403	Gannett.
West Shore R.R. station	Syracuse	....	400	Gannett.
D. L. & W. R.R. station	Syracuse	....	399	Gannett.
Erie canal	Syracuse	....	401	Gannett.
Mt. Olympus	Syracuse	187	681	Gardiner.
Chestnut ridge	Salina	110	498	Gardiner.
Collamer	Dewitt	12	485	Gardiner.
Ira Green's farm	Dewitt	95	974	Gardiner.
Jamesville R.R. station	Dewitt	....	591	Gannett.
Dewitt center	Dewitt	....	410	Gannett.
Eagle hill	Manlius	79	1,253	Gardiner.



GEOLOGICAL MAP OF ONONDAGA COUNTY

By D. D. LUTHER.

1895.

Table of Elevations.—Continued.

LOCALITY.	TOWN.	LOT No.	A. T.	AUTHORITY.
Kirkville	Manlius	38	507	Gardiner.
Kirkville, N. Y. C. R.R. station	Manlius	....	423	Gannett.
Kirkville, West Shore R.R. station	Manlius	....	422	Gannett.
Fayetteville R.R. station	Manlius	....	538	Gannett.
E. Davison's farm	Van Buren	42	631	Gannett.
C. H. Kingsley's farm	Van Buren	22	537	Gannett.
Memphis	Van Buren	....	410	Gannett.
Sorrel Hill	Van Buren	20	641	Gannett.
Warner's	Van Buren	....	427	Gannett.
M. Davis' farm	Lysander	81	535	Gannett.
Baldwinsville R.R. station	Lysander	....	391	Gannett.
Oneida lake	....	....	368	....
Skaneateles lake	....	....	860½	....
Otisco lake	....	....	772¼	....
Onondaga lake	....	....	361.7	....
Tully lake	....	....	1,190	Trump.
Crooked lake	....	....	1,193	Trump.
Tully Green lake	....	....	1,191.5	Trump.
Lake Sodom	....	....	406	....

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

GEOLOGICAL MAP.)

THE STRUCTURAL AND ECONOMIC GEOLOGY OF ERIE COUNTY.

JAMES HALL, *State Geologist.* | IRVING P. BISHOP, *Assistant.*

1895.

James Hall, *State Geologist*,

Sir:—In this report are included the results of geologic studies in Erie county, N. Y., begun during the summer of 1895 and continued to the close of that year. The purpose of the investigation was to ascertain the boundaries of the formations for the geologic map of the state, and to collect data regarding economic products derived from rocks found within the county.

Respectfully yours,

IRVING P. BISHOP.

Buffalo, N. Y., *January* 1, 1896.

PLATE I

Genesee and Portage rocks in Eighteen-mile creek, at North Evans. The pier in the middle foreground rests upon the top of the Genesee; the next pier to the left rests on the top of Cashaqua shales.

The Structural and Economic Geology of Erie County.

By Irving P. Bishop.

Physiography.

Erie county, in central-western New York, is bounded on the north by Niagara county, on the east by Genesee and Wyoming counties, and on the south by Cattaraugus and Chautauqua counties. The western limit is the international boundary from the lower end of Grand Island, to a point where the boundary line makes a right angle with a line drawn to the mouth of Cattaraugus creek. It is separated from Niagara county by Tonawanda creek and the west branch of Niagara river; and from Cattaraugus and Chautauqua counties by Cattaraugus creek.

The extreme length of the county, north and south, is forty-three and one-half miles, and its greatest width is about thirty-nine miles. The land surface contains 1,071, and the lake portion about 160 square miles, giving it a total area of about 1,230 square miles.

Topographically, the county comprises three provinces. They are—*first*, a low and nearly level plain on the north, extending from the Niagara river and Tonawanda creek to the limestone terrace; *second*, a slightly higher plain having the limestone escarpment for its northern boundary and extending southward to a line drawn through Bay View, Spring Brook and Marilla; and *third*, a region of rolling hills rising gradually to the height of 1,500 feet or more above tide, and occupying almost all of the southern half of the county.

The Northern Plain. This plain includes nearly the whole of the townships of Grand Island, Tonawanda, Amherst and Clarence and the northern half of Newstead. Along the Niagara river the banks form clay escarpments averaging about twenty feet in height and dropping abruptly to the edge of the water. From the top of the bank the county extends southward in an almost level plain, unbroken by hills or ridges, to the foot of the limestone escarpment.

The Middle Plain. The middle plain rises abruptly from the northern plain, presenting throughout the greater part of the northern boundary an escarpment of limestone varying from twenty to one hundred feet in height. South of this, the surface is gently undulating with a few lower hills, generally presenting smooth surfaces. On this plain, Murder creek, Ransom creek and Ellicott creek take their rise and flow northward across the lower plain to Tonawanda creek. The other streams which traverse the middle plain are Cayuga creek and its branches, Buffalo creek, Cazenovia creek and Smoke creek, the last three of which have their sources in the hill region to the south.

The Hill Region. The elevated region comprising the remainder of the county consists essentially of a high plateau gashed by streams which have eroded much of the original surface and left it a succession of valleys and ridges.

In the vicinity of Chaffee, East Concord and westward, this tableland has attained the height of nearly 1,500 feet A. T. From this there is an abrupt slope into the valley of the Cattaraugus creek, with a more gradual descent toward the north and west. From the Buffalo and Southwestern railway toward the lake, the descent is very gradual and the surface smooth or gently undulating, terminating at the lake shore in abrupt bluffs. Along the southern crest of the plateau and extending into the Cattaraugus valley are immense piles of glacial debris, giving rise to a peculiarly knolly topography. The principal streams flowing westward from this region are the Big Sisters creek and the two branches of Eighteen-Mile creek. In their upper courses these have steep-sided valleys, and in the lower courses deep gorges with precipitous walls of rock. The ridges between the streams have smooth tops on approximately the same level.

STRATIGRAPHY.

The rocks exposed in Erie county range from near the bottom of the Salina shales to near the top of the Portage group. The members in their order are shown in the following table:

Portage group	Upper. Lower.
Hamilton group	Genesee slates. Hamilton shales. Marcellus shales.
Upper Helderberg group	Corniferous limestone. Onondaga limestone.
Water-lime group.	
Salina group.	

The thickness of the above rocks as ascertained by deep borings and measurements will be given at the close of the chapter on natural gas.

The Salina Group.

The rocks of this group are not well exposed in Erie county, the best section being found in Genesee county, east of Erie county, where the Tonawanda creek crosses the outcrop of Corniferous and upper Salina beds. The creek here breaks over the edge of the Corniferous limestone and hydraulic limestone, forming the Indian falls. Just below the fall, the rock is a thick-bedded limestone containing nodules of gypsum and weathering with a cavernous, irregular surface. Below that, the rock is shale, mostly gypseous in character, sometimes reddish, but more often grey or bluish. On the Indian reservation, near the mouth of the ravine, a limited amount of gypsum is quarried, blue-grey or mottled in color and of fair quality. About half a mile above the West Shore railroad bridge is an outcrop of red and grey gypseous shales which continue through the reservation to the iron bridge near the Indian church. Below this is a stratum composed of hard, thin-bedded calcareous rock, containing minute lenticular cavities and casts of crystals. The rock exposure extends about 200 yards below the bridge.

Within the limits of Erie county, the Salina rocks are mostly covered with drift. The most complete section is found in the bed of Murder creek at Akron. From Falkirk down to Main street are the water-lime rocks. Below the railroad bridge, shales crop out in the bed of the creek for two miles or more. The thickest exposure of these showed three feet of light-colored calcareous shale, weathering to light pink, beneath which were four to six feet of harder, greenish shale. A small exposure of shale is reported in the same creek opposite the end of the road leading east to the Indian reservation, but I was unable to visit it.

An outcrop of thin-bedded hydraulic limestone occurs on the farm of Martin Racquet, about one-half mile south of East Amherst near the Transit road, where it is used for macadam.

On Grand Island there are two outcrops. The more northerly is at Edgewater, about 200 yards below the boat-landing. The rock here is:

(1) Black shale in the river-bed.

(2) Greenish shales containing nodules of gypsum, one and one-half feet.

(3) Light-colored, soft, friable gypseous shales, five feet.

The exposure extends 300 yards down the river-bank.

The other outcrop is at the extreme southern end of the island, where the river separates into two channels. The rock is a thin-bedded, impure limestone, weathering like the water-lime, and containing minute lenticular cavities. Fragments of such rock are plentiful in the drift about Buffalo, and it is probable that this stratum is the source from which these fragments were derived.

On the Canadian side of the Niagara river, from a point about opposite Strawberry island to the International bridge, there is an almost continuous exposure of shales, nearly all of which are more or less gypseous and often spongy, as if mineral matter had been removed by solution. A short distance above the bridge, water-lime appears in the river-bed and can be traced to a point opposite to, or a little above, the stone church.

The Hydraulic Limestones.

The northern edge of the Corniferous limestone, together with the Onondaga limestone and the upper part of the hydraulic limestones, form a well-defined escarpment running in a general southwesterly direction from the Genesee county line to the city of Buffalo. For the greater part of that distance this escarpment is approximately parallel to the Bloomingdale and Williamsville roads, as is seen by the accompanying map. Within the city it follows the general direction of Main street from the almshouse to near the New York Central railroad belt line at Rodney and Fillmore avenues. After crossing Main street, it passes near the corner of Oakwood and Woodward to Oakwood and Parkside and enters the park at the stone quarry, crossing from there into the cemetery at the corner of the iron fence near Agassiz place. From here it sweeps around in a curve to Scajaquada creek at Main street bridge, and passes out of sight beneath the drift on the left bank, about 300 feet below the bridge. By examining sewer cuttings, holes for telegraph poles and other excavations, the edge of the Corniferous limestone is found to lie between Potomac and Bird avenues on Norwood avenue, and appears near the Niagara river at the corner of Auburn and Niagara streets, where there is a good outcrop. On the Canadian side of the river, the edge of this limestone should be near the ferry landing. The rock is well exposed a short distance above.

The hydraulic limestone is usually visible at the base, or north side, of this escarpment as a stratum of variable thickness in the face of the cliff, but occasionally forms a terrace ranging from a few feet to 200 yards in width, and approximately parallel to the escarpment. This terrace is most conspicuous between Williamsville and the Buffalo city line. In the Bennett-Pierce tract the hydraulic limestone is found near the surface as far north as the swamp, and I am informed by Mr. David F. Day, that it occurs near the surface at the deer paddock in the park. Sewer and other excavations have thrown up this rock along Bird avenue, near Elmwood, and in several places near the Niagara river in the vicinity of Auburn and Bouck avenues. The rock is not eroded to its base so that a complete section is nowhere visible. The thickness has been ascertained from well sections given elsewhere in this report.

UPPER HELDERBERG GROUP.

Onondaga Limestone.

In Erie county, this formation appears as a thin band lying between the hydraulic limestones and the overlying Corniferous limestone. In color it ranges from blue-grey to a very light grey. It varies greatly in thickness, being from three to five inches at the Main street bridge over Scajaquada creek, Buffalo; seven feet in Forest lawn cemetery; five and one-half feet in the park quarry, and thirty-five feet in Fogelsonger's quarry at Williamsville. At Young's quarry, two miles further east, it is thirty to thirty-five feet thick, but thins out rapidly beyond to a thickness of three to five feet. Speaking broadly, we may say that the formation is concretionary in character, the deposits at Fogelsonger's and Young's being merely lenticular masses of unusual size. Small lenses a few feet in diameter are frequent and usually extend downward into the hydraulic limestone without any corresponding depression above, showing that they had their origin while the latter was yet in process of deposition. The larger nodules are remarkably rich in organic remains. At Fogelsonger's quarry the rock in many places is a solid mass of cyathophylloid and favositic corals, the latter frequently having their cavities filled with petroleum and bitumen. Single specimens were noticed four feet in diameter, and large areas of the quarry bottom showed little else than these fossils.

The Corniferous Limestone.

The northern edge of the outcrop of this formation is marked by the escarpment already described. A deposit of drift from ten to fifty feet thick covers the southern edge, so that actual contact with the Marcellus shales above is not found within the county. At Corfu, three miles east of the county line, the borings for gas passed through thirty feet of Marcellus shales. According to this, the Corniferous limestone should be found about a mile north of that village. The most southerly outcrop of this limestone near the county line is near an abandoned railroad track two miles northeast of Crittenden. A small exposure occurs on the edge of a marsh just northwest of South Newstead. Half a mile below Mill Grove, near a dam across Ellicott creek, is a good exposure of the same rock, and other outcrops occur in the bed of the same stream for three miles below and, again, near Wilhelm. The limestone is found in Cayuga creek at Kieffer's quarry near the Transit road, about a mile west of Lancaster, and in numerous places below, the last exposure being at the end of Clinton street, where the creek unites with Buffalo creek. The deep wells at the Snow Steam Pump Works near Bailey avenue and Seneca street, at the Atlas Oil Refinery, and at the Buffalo Chemical Works on Buffalo creek and Abbott road, all started on the Corniferous limestone as bed-rock. It is found in the Ohio basin, near the lake, and was found by the engineers when sinking piles for the Lehigh docks and trestles, near Lake Erie.

The *Stafford limestone* of the Marcellus formation, is exposed at Wende station on the Lehigh railroad, one and one-half miles south of Mill Grove. As this stratum lies about twenty feet above the top of the Corniferous limestone, the boundary between the latter and the Marcellus shales must be at about half-way between Mill Grove and Wende. An outcrop supposed to be of this Stafford limestone occurs on the farm of Martin Martin, one-half mile east of Alden Center, and the drift in the bed of the most northerly branch of Ellicott creek, near Alden, contains abundant fragments of black shale as far east as the county line.

At Lancaster, the contact lies between the lower bridge and Kieffer's quarry. The Stafford limestone crops out in the bed of Buffalo creek, opposite the end of the Winchester road, and the Corniferous appears at the junction of the same stream with Cayuga creek, less than two miles away. Dr. H. U. Williams informs me that a limestone scored with glacial scratches was uncovered while grading the road-bed for the Buffalo, Rochester and Pittsburg railroad, some years ago, at the point where it diverges from the Western New York and Pennsylvania, and the Lake Shore railroads. Although I did not find the exposure during either of two visits made for the purpose, the excavations being filled with water, I have no doubt that the rock in question was the Stafford limestone. When the gas-well was sunk in South park, less than a mile and one-half southeast, the drill passed through "about thirty feet of shale below the drift, and then several feet of limestone and shale mixed;" conditions which confirm the view expressed.

At Stony point, on Lake Erie, fragments of the jet black shale of the lower beds of the Marcellus are numerous among the boulders which cover the beach, showing that they were derived from rocks farther north. The boundary between the two formations must therefore lie between here and the Lehigh docks, and it is very probable that Stony Point itself marks the extension of the Stafford limestone into the lake. It may be assumed, therefore, that the boundary between the Corniferous limestone and Marcellus shales, as laid down on the accompanying map, is a very close approximation to the actual one.

HAMILTON GROUP.

Marcellus Shales and Limestone.

The best section within the county of the lower Marcellus beds occurs in the vicinity of Lancaster. In Cayuga creek, just above the lower bridge, is a layer about two feet thick, of a firm, jet black shale containing some iron pyrites in crystals and concretions. This is overlaid by a foot or more of grey limestone which had been mostly quarried out and could not be accurately measured. From the bridge up to near the Lake Como dam, the rock does not show. Just below the dam, the black shale crops out, capped by the Stafford limestone, which was at one time quarried here. A careful estimate, based upon the thickness of the rock in sight, the fall of the stream, and the measured height of a dam in the village, shows that the rock from the lowest visible stratum is from fifteen to twenty feet below the Stafford limestone. On a little brook running through the centre of the village, there is a fine exposure of the Stafford limestone. In sight, at the base of this, is a two-foot layer of jet black bituminous shale, smelling strongly of petroleum and containing pyritous concretions. Above this are the limestones in layers of the following thickness:

LOWEST—	12	inches,	containing *Orthoceras*.
	6	"	" "
	14	"	
	10	"	
	18	"	
	14	"	with a little flint at the top.
	14	"	
	12	"	
	Total, 9 ft. 4 in.		

Above Lancaster, the shales are black, thin-bedded, friable and show very regular jointing. Farther up, the layers become more calcareous, forming, at the mouth of Little Buffalo creek, a stratum of impure limestone. Shales of blue-grey color occupy the bed of the creek at intervals for three or four miles to the eastward.

Besides the outcrops of Stafford limestone already mentioned, there is a disused quarry of that stone in the field northeast of South Buffalo station on the Western New York and Pennsylvania railroad, and fragments of it were thrown up in digging the sewer and water trenches on the Indian church road, near Seneca street. The only places where the orthoceratite layers were noticed are at Lancaster and Wende. Other exposures of Marcellus rocks in the county are in the bed of Ellicott creek between Wende and Alden Center and above Alden Center near the Erie gravel pit; also in the southern branch of the same creek north of Alden village. In Buffalo creek it is in sight at intervals from the end of the Winchester road to within a mile of Blossom. It occurs on Cazenovia creek, at the Park just above the Cazenovia street bridge, and for some distance above the covered bridge two miles farther up the creek. It was also found in laying the water pipes for South Park, 700 feet east of South Park avenue, at the city line, within two feet of the surface, and in the bed of a small brook near by. At West Seneca, outcrops occur in the bed of Smoke creek, between the White's Corners road and the Western New York and Pennsylvania railroad, and again on the lake shore at Bay View. From here it forms the lake bottom near the shore for several miles up the lake.

Hamilton and Genesee Shales.

The transition from the Marcellus to the Hamilton shales is very gradual, the shale changing from black to blue-grey through almost imperceptible gradations. There is, however, in several places within the county, a stratum always calcareous and usually much harder than the rocks below, which seems to furnish a boundary between the formations.

A mile east of Alden, in the bed of the creek above the culvert is a layer of impure limestone three and one-half inches thick. Below this, the rock is a soft shale, having *Styliola fissurella* as its most conspicuous fossil, with an occasional cephalopod. The layer of limestone is not very fossiliferous, and has the appearance of some of the Marcellus rock. Less than six feet above is a shale containing excellent specimens of *Spirifer mucronatus* and *Athyris spiriferoides*. Just above this is a concretionary layer, less than a foot thick, containing characteristic Hamilton fossils, and immediately over the last a third calcareous layer, containing the usual Hamilton trilobites, orthoceratites and brachiopods.

PLATE II

View in Eighteen-mile creek at North Evans, one hundred yards below the lower railroad bridge. The Styliola layer appears in the bed of the creek on the left. The long pier of the bridge, shown in Plate I, is seen through the arch.

A large fragment of limestone of several tons weight and containing numerous Hamilton fossils was noticed in Cayuga creek near Town Line. It evidently had its origin in that vicinity, although the parent rock was not found.

At Blossom is a four-foot layer of a limestone sufficiently durable for bridge work. It contains the fossils common to the horizon of the Encrinal limestone and Moscow shales, including an abundance of cyathophylloid corals. Examination proved that it lies just above a well-marked Marcellus outcrop. On the west branch of Smoke creek, a mile below Windom, a hard calcareous shale, eighteen inches thick, occurs in the same relative position as the preceding limestone. Another outcrop is seen where a little brook crosses the Mile Strip road about 200 yards east of the Hamburg turnpike. The rock here is a fairly good limestone. At Bay View the corresponding horizon is represented by a soft calcareous shale about two feet thick, capping the cliff a short distance south of the hotel.

While by no means certain of the continuity of this calcareous stratum throughout the county, in the absence of evidence to the contrary I have provisionally assigned it to the horizon of the beds termed the "Basal limestones" by Professor J. M. Clarke, and have used it as a basis of measurement in determining the thickness of the Hamilton and Marcellus rocks.

At Eighteen Mile creek, near Lake Erie, the Moscow and Genesee shales have thinned out, leaving the Encrinal limestone near the top of the series.

The rocks here above the Encrinal limestone are:

Blue Moscow shale, resting on the Encrinal, . .		15 ft. 4 in.	Hamilton.
A layer of iron pyrites $\frac{1}{4}$ to $\frac{1}{8}$ inch thick, sometimes merely a stain of rust, believed to represent the Tully limestone.			
Blue shale, ...		1 ft. 2 in.	Genesee.
The "Styliola band," consisting here of			
(*a*). Hard Calcareous shale, ...	3 in.		
(*b*). Soft Shale, ...	2 in.		
(*c*). Iron grey limestone, containing fish-plates and crinoid stems, ...	4 in.		
(*d*). Firm iron grey limestone, composed largely of *Styliola fissurella*, .	8 to 12 in.	1 ft. 9 in.	
Black shale, about		14 ft. 0 in.	

Then follow twenty feet or more of olive-green shales with numerous concretions, capped by black shale extending to the top of the gorge.

The thin layer beneath the "Styliola band" is blue and contains Hamilton fossils, but is more fissile than the shale below, which contain trilobites. Mr. A. W. Grabau, who has made a very careful study of this layer, says, it appears to have the fauna of both the Moscow and Genesee beds, and may be regarded as a passage formation from one to the other.

The relation of the Encrinal limestone to the Styliola band and associated rocks at Eighteen Mile creek is well shown in accompanying photograph.

Owing to its position near the upper part of the group and the ease with which it can be traced, I have selected the Encrinal limestone as the horizon of reference from which the top of the Hamilton and Genesee may readily be found. It is easily recognized as a hard limestone, two feet or more thick, usually stained on the under surface with iron rust from the decomposition of pyrites, and containing large crinoid stems, some of which are nearly an inch in diameter. Excepting a few outcrops of the "Basal limestone," there is no other rock in Erie county from the Stafford limestone up to the Portage sandstones sufficiently durable for bridge or building purposes. The shales immediately above and for several feet below are always rich in fossils, among which cyathophylloid corals and brachiopods, *Atrypa reticularis, A. aspera, Athyris spiriferoides, Spirifer medialis* and *S. mucronatus*, are particularly abundant. Since it resists the action of water and other erosive influences better than shales, it is found in almost every gully and ravine which cross the outcrop. Along the lake shore westward from Eighteen Mile creek, it forms a conspicuous band in the face of the cliff, dipping beneath the surface of the water near Pike creek. The Styliola band may be seen above it, the two limestones approaching each other slightly near the western limit. East of Eighteen Mile creek, the Encrinal limestone caps the bluff for a short distance, and is next seen by the road near the house of Mr. Crocker, about two miles further on, reappearing again in the face of the bluff beyond. From here it can be easily traced to Wanakah, crossing the creek near the station just below the railroad bridge. At Hamburg-on-the-lake it is a half-mile, and at Athol springs about 200 yards east of the railroad. At Big Tree, it is exposed in the railroad cutting near Rush creek, and on the banks of the stream by the farmhouse above. At Windom, it is found for some distance along the sides of the ravine, being well exposed just above the bridge near the station and crossing the bed of the brook a quarter of a mile further up. It is here about thirty inches thick, in two layers, the lower of which is the thicker, and has three or four inches of pyrites at the bottom. The Styliola

PLATE III

THE ENCRINAL LIMESTONE IN EIGHTEEN-MILE CREEK; VIEW TAKEN FARTHER DOWN THE CREEK. THE STYLIOLA LAYER IS SEEN ABOVE ON THE LEFT OF THE PICTURE.

band crops out near the road to Duel's Corners, crossing the bed of a brook 200 yards above the bridge, about half a mile east of Hamburg station. It is here twelve to eighteen inches thick and lies six feet above the layer of pyrites representing the top of the Hamilton shales. The pyrites at this point and at other places eastward, is from two to four inches thick. I was unable to estimate the thickness of the Genesee, as it was partly hidden by drift.

The Encrinal limestone crops out in Smoke creek near the plank road, a mile north of Webster's Corners, at the top of a fall some thirty feet high. At Spring Brook it crosses Cazenovia creek just below the dam, appearing on both sides of the gorge for a mile below. The thickest portion measured was four feet from top to bottom, with one layer of eighteen to twenty inches.

The favosite corals here had their cells filled with crude petroleum and other bitumens so that a tablespoonful could be scraped with a knife from the surface of a single specimen.

The Styliola band is well shown for a mile above the dam, having about the same thickness as at Windom. It is here from four to six feet higher than the top of the Hamilton.

A small exposure of the Encrinal limestone is seen three-fourths of a mile east of Spring Brook station, where a small brook flows under the track of the Western New York and Pennsylvania railroad. It is next found where the covered bridge crosses Buffalo creek, two miles east of Elma.

The limestone crosses the creek just below the bridge, and is quarried along the bank and on top of the bluff farther down the creek.

The top of the Hamilton shales dips to the level of the creek, one-third of a mile above the bridge. . The pyrites layer varies from one to four inches thick, and lies five feet below the Styliola band. The latter is six inches thick, representing only the upper part. When the concretionary lower layer appears, as it occasionally does, along the bank, the whole thickness is increased to a foot and the upper part also becomes concretionary.

The bed of Little Buffalo creek, below Marilla, is filled with drift so that no bed-rock appears. The Encrinal limestone crops out in the bed of a small brook emptying into Cayuga creek on the north side near the town line between Alden and Marilla. It again appears about a mile from Alden village, south from the station, where the road passes a wood-lot. The rock has been quarried in a small way near the top of the hill, and an excellent spring issues from beneath an outcrop in the woods on the other side, a few rods from the road. Between here and the county line, I was unable to find any further exposure of this limestone.

Just south of the Erie railroad tracks, a mile east of Alden, is a good exposure of the Moscow shale with a fauna like that found near the Encrinal limestone at all points west; and in the absence of evidence to the contrary it is assumed that this limestone crosses the county line near the New York, Lake Erie and Western railroad. If so, the Hamilton must be thinner here than it is east or west of Alden. The Genesee slates in Erie county belong mainly to the part lying above the Styliola band, as already shown.

The Portage Group.

The Portage rocks crop out south of the foregoing, to the county line, no area of distinctly characterized Chemung strata having been observed by me within the county. The lower part consists of alternations of olive-green with bituminous black shales, including, rarely, a thin layer of argillaceous sandstone. Above these, the rocks become more arenaceous, passing somewhat abruptly into a series of shales alternating with argillaceous sandstones of varying thickness which furnish stone of considerable economic importance. The boundary between the upper and lower beds is therefore indistinct. North of a line connecting Wales Centre, East Aurora, North Boston and North Collins, no sandstone of consequence has been noticed, and none has been seen west of the Buffalo and Southwestern railroad, between the latter place and Gowanda. The streams flowing across the lower Portage outcrop have cut deep gorges with precipitous sides, but are almost destitute of waterfalls. The black shales contain many calcareous septaria, usually lenticular and of enormous size. Specimens six feet in diameter are comparatively common, and one measured nine feet in diameter by five feet in thickness.

The gorge of Eighteen Mile creek above North Evans, and of Cazenovia creek below East Aurora, show good lower Portage sections and furnish excellent specimens of septaria. The southern part of the county is covered with drift, which in some places is 500 feet or more in thickness. This has hidden the rock and broken the continuity of observations, so that complete sections of the Portage rocks like those made in Livingston and Wyoming counties have not been achieved. The valley of Buffalo creek, above Wales Centre, shows heavy sandstones and flags as far south as the town line between Wales and Holland.

Stone is quarried on the Joseph Myers farm, two miles east of Wales Centre, and also on the Ulrich farm on the Centre Line road, about one and

PLATE IV

RELATIONS OF THE ENCRINAL LIMESTONE AND STYLIOLA LAYER ON EIGHTEEN-MILE CREEK. VIEW TAKEN ABOUT ONE-FOURTH MILE FROM THE LAKE.

one-half miles southwest of Wales. The two branches of Cazenovia creek afford the best sections of the upper part of the Portage.

The argillaceous sandstone crops out along the road from Wales Centre to East Aurora, being quarried a mile east of the latter place on the farm of W. C. Cook. The layers are from eight to twelve inches thick with the characteristic surface markings. From East Aurora south, the heavy sandstones are found at intervals all the way to within a short distance of Holland. Two and one-half miles southeast of East Aurora, on the farm of Delavan Caulkins, a quarry is worked by Mr. Henry Strong. The rock here resembles the Warsaw bluestone and contains the vertical fucoids which are common in Portage strata. The principal layer is three feet, six inches thick. Mr. Strong also works another quarry on the north side of the valley, the stratum apparently corresponding to that in the Caulkins quarry. At South Wales is the best exposure of sandstone seen. It is located on the farm of Charles M. Brayton, about twenty rods east of the railroad water tank. The section here is:

Hard blue sandstone	2 feet.
Shale and thin sandstone mixed, about	20 "
Hard blue sandstone with vertical fucoids . . .	6 "

With thin sandstones and shales above.

Following the railroad south, these sandstones dip below the track at intervals, the last disappearing at the twenty-fourth mile post from Buffalo, two miles north of Holland. From here to Protection, the rock observed is a black fissile shale stained with iron. East of Protection, there is an outcrop of sandstone with layers a foot thick. Between Chaffee and the county line, the rock is blue shale with thin sandstones, none of which were thick enough for flags. This rock has the appearance of Portage. I could not hear of any stone quarries in this vicinity, although one or two were reported near Arcade, in Wyoming county.

On the west branch of Cazenovia creek, sandstones occur in several places, but are generally thinner than those seen on the east branch. They occur on the higher ground near Jewettville, on both sides of the creek. On the Phelps farm, two miles southwest of East Aurora, there is also a quarry of flagstone eight inches thick, from which blocks ten feet square have been taken. The stratum is comparatively thin, but is near the surface and easy to work. Below Griffins Mills are several layers from six to eight inches, with one at least twelve inches thick. A quarry of this stone is worked on the hillside, about half a mile farther east. Between here and West Falls there are no sandstones except a few thin flags among the shales. At the latter place there is a stratum about six feet thick, containing layers like those at Griffins Mills. From here to East Concord, all the rock in sight consists of shales and thin argillaceous flags.

A mile northwest of Springville, on the farm of Mr. F. A. Clark, is a quarry containing a six-foot layer of a grey siliceous sandstone, unlike any seen elsewhere in the county. In this stone I found several fossils, among which Professor J. M. Clarke recognized *Chonetes scitula, Productella speciosa, Orthothetes Chemungensis* (small variety), and a small *Spirifer* of the type of *S. mucronatus.* These, he says, are representatives of the Ithaca fauna, and not members of the normal Portage fauna. In the drift near by were fragments of a small branching coral which may have had its origin in this vicinity.

On the opposite side of the road, the same stratum of stone is worked in a quarry owned by Mrs. B. Wheeler. At Pike hill and Townsend hill, three miles southwest of Boston Corners, are quarries of heavy sandstone, which are described by Mr. Albert Pike, a former owner, as "grey sandstone," and may belong to the same horizon. Owing to the approach of winter I was not able to visit these quarries. In the vicinity of Boston and Boston Centre, the rock is mostly shale with no thick sandstones; but there is a quarry on the Zeller farm, four miles south of Boston Centre. At the viaduct over Cattaraugus creek, near Springville, the deep gorge of the river is cut through olive shales containing very little arenaceous matter.

From Shirley, near North Collins, to Collins, the argillaceous sandstones occur, being quarried on the farm of Daniel Sherman, two miles north-east of Collins. They appear to belong to the lower sandstones of the group. At Zoar, the Cattaraugus creek has cut a gorge through the Portage, exposing two strata of sandstone. The upper, near the top of the bank, is twenty to thirty feet thick and separated from a lower fifteen-foot stratum by about thirty feet of shale. Above Zoar, for five or six miles, the rock along the river is an olive shale with thin arenaceous layers, but no heavy sandstone. In the southern part of the county, a fucoid resembling the *Spirophyton caudi-galli* is very abundant, fine specimens occurring in the gorge at Zoar.

A few poorly preserved brachiopods were noticed in loose micaceous rock in the bed of a stream near Lawton's. From the appearance of the fragment the stone had been washed down from the eastward and possibly may have been derived from adjacent Portage rocks.

PLATE V

Portage sandstones at West Falls.

Quaternary Geology.

Wherever limestones are freshly uncovered in this region, their surface is found to be polished by glacial action, the striae extending from northeast to southwest. Excellent illustrations may be seen at Fogelsonger's quarry at Williamsville, in the Forest Lawn cemetery at Buffalo and at the Lehigh coal shed near Cheektowaga. At the last named place several acres were stripped of drift to expose the rock, which was used as the floor of the structure. The surface was slightly undulating, well polished, with grooves rarely exceeding half an inch in depth. One set of striae was noticed crossing the others, but it was of limited extent and evidently of local origin. The accompanying photograph, taken at the southern end of the shed, gives a fair idea of the glaciation here.

Up to the base of the Hamilton group the bed-rock is covered with clays, varying from a few inches to sixty feet in depth. The lower stratum is a blue clay filled with smoothed and striated bowlders. Above that is a red clay, seldom containing stones larger than a man's fist, and at the surface is a thin deposit of muck alluvium or stratified gravel.

A well on the farm of William P. Carr, near the lower end of Grand Island, shows the general succession of strata, as follows:

Loam	6 feet.
Red clay	20 "
Bowlder clay	14 "

A copious flow of water was struck at forty feet. The top of the well is ten to twelve feet higher than the surface of the river, which is here twenty-two feet deep. Another well, a mile and a half farther south, passed through similar strata. At Sour Spring grove, on Grand Island, opposite Tonawanda, the drift is sixty feet deep and in Tonawanda village fifty feet deep, as shown by boring in both places. At Getzville, it ranges from twelve to sixty-nine feet, the latter depth being found near a creek. At Rapids, a water well forty feet deep did not reach bed-rock. Along Buffalo creek, within the city of Buffalo, the superficial deposit is about fifty feet thick. Although the areas outside the river and creek bottoms are more thinly covered, numerous borings and excavations show that the average thickness of the drift over the area under consideration is not far from twenty-five feet.

The surface of the Hamilton and Portage rocks is covered with drift somewhat unevenly distributed but increasing in depth toward the south. The upper rocks of the Portage group from Chaffee to Gowanda appear to have been the dumping-ground upon which the great glacier deposited the most of its load. In the vicinity of Zoar, the borings for gas showed, in two wells, 325 and 379 feet of drift respectively, while the Kelly well passed through 515 feet, which is, within my knowledge, the deepest ascertained thickness of drift in the state. In connection with this it is interesting to notice that the greatest depth of drift in Wyoming county, 358 feet at Gainesville, is found near the top of the Portage group. Along the sides of the streams flowing through these deposits are many thick beds of clay which appear to be of finer quality than the great sheet which overspreads the lower levels. These clays are often laminated, when dry splitting like shale. Examples of these were noticed along the west branch of Cazenovia creek above West Falls and on a branch of Cattaraugus creek near Springville. There is also a good exposure back of the Lehigh coal shed at Cheektowaga.

Stratified sand and gravels occur in several places throughout the county, but in no order which would indicate a general system of deposition. An irregular strip lies about midway between the limestone terrace and Tonawanda creek nearly all the way from Getzville to Akron. Another extends from Orchard Park to Elma Center and for several miles west and east of these points. Large deposits were also noticed at Chaffee, Brant Center and other places in the southern part of the county. While these affect the character of the soil for agricultural purposes they are of small economic value. The deposits utilized by railroads for ballast are usually pockets of small extent and due to local causes. The Erie gravel pit at Alden will serve as a good type of this class.

Soil.

The northern plain has a soil consisting largely of clay loam which is somewhat heavy and holds water. Over large portions, however, and especially along Tonawanda creek, there are considerable areas of deep alluvial river-bottom which are extremely fertile and furnish good crops. The limestone ridge is well drained, has a larger proportion of gravel mixed with the clay and is better adapted to wheat and other cereals. The middle plain consists mainly of alluvial creek-bottom, well suited to market gardening to which it is chiefly devoted. Along the lake slope south of Buffalo the disintegrating shale forms, with glacial gravels, a soil well adapted to fruit raising, which is further favored by a mild, uniform climate due to the neighborhood of the lake. The tops of the hills southward are covered with stiff-clay which produces good grass and supports large dairying interests. In the

PLATE VI

Glaciated rock surface, Lehigh coal sheds, Cheektowaga.

vicinity of Chaffee, Springville and along the slope of the Cattaraugus creek, the deposits of glacial drift combine many elements of fertility and form a rich and productive soil. As a whole, the agricultural interests of the county are varied and include the principal branches suited to the climate of this state.

Springs.

The hydraulic limestones at the foot of the Helderberg escarpment furnish copious springs, often smelling strongly of sulphuretted hydrogen. The largest within the county are located below the Fogelsonger quarry at Williamsville. Within a quarter of an acre, sufficient water rises to run a grist-mill. In searching for a source of water supply for Williamsville during the past year the flow of water from these springs was measured by the engineers and found to be one and one-half million gallons daily.

In the bed of Murder creek at Akron, just below the dam, there are several springs, one of which fills a five-inch pipe with cold, sweet water. Another, twelve feet away, is strongly charged with sulphuretted hydrogen. The gas-wells at Akron, Clarence and Williamsville have also tapped sulphur water.

Preglacial Erosion.

The Niagara river, as it leaves lake Erie, breaks across the lower part of the Corniferous limestone opposite Fort Porter. The river bank meets the lake shore bluff near the New York Central railroad bridge over the canal, forming an obtuse angle. About a hundred yards below this bridge, between the railroad and the canal, is a small quarry from which stone has been taken during the past season for canal repairs. The freshly stripped surface of the rock I found to be smoothed and striated by glacial action down to within two feet of the bottom of the quarry, or to about the level of the canal tow-path. Below that were evidences of glaciation but partly hidden by earth so as to render it doubtful whether or not the striae extended lower. From the top of the bank to the lowest well-defined striae is thirty-seven feet, eighteen feet of which is drift, leaving nineteen feet of glaciated limestone below the surface of the rock escarpment.

The layers next to the river were slightly terraced and the edges afterward smoothed, showing that the rock was removed before glaciation took place. The bed of the river opposite this place, as shown by the United States Survey, is twenty-one feet below the surface of the river or approximately thirty feet below the level of the canal tow-path. Across the river, the limestone in sight is water-worn but not glaciated. The highest outcrop, however, is not more than five feet above the mean surface of the river. It may be assumed, therefore, that the present channel of the Niagara river at this point existed before the glacial epoch, and was at least twenty feet below the surface of the limestone cliff on the eastern side, and probably lower near the middle.

Half a mile down the river on the Canadian side, near the stone church, the water-lime is striated and smoothed by glacial action down to and beneath the water line of the river. Photographs showing these markings and those in the quarry on the American side are here given. It is certain, therefore, that the present channel of the upper Niagara cannot be more recent than the close of the glacial period, and probably was well defined to the depth of twenty feet or more before that time.

The rate of erosion going on now is difficult to estimate, very few data upon that point having been collected. In smaller streams flowing over the Corniferous limestone, the amount of erosion since the glacial period amounts to only a few inches. A view of the bed of Cayuga creek, near Bellevue, is inserted here for the purpose of illustration. The surface of the limestone under the bridge is glaciated on the right bank of the stream. Erosion has proceeded through the widening of joints, partly by the action of water, and partly through the agency of material carried along by the current. The stream is here quite rapid when at its normal height, but the depression in the channel shows that very little material has been removed. While the volume of water in the Niagara river is much greater than in the stream referred to, it is probable that erosion is there proceeding very slowly; and that a part of the central depression, where the river now is, was excavated before glacial time.

Preglacial Rivers.

It has been thought by Dr. Julius Pohlman and others, that a preglacial river of large size flowed into the depression now occupied by lake Erie at some point between the present mouth of Buffalo creek and Bay View. This opinion was based largely upon the fact that in driving piles for the Lehigh docks on the Tifft farm, the bed-rock was found to suddenly drop from about thirty-seven feet to over a hundred feet below the surface. As the rock to the northward was known to be Corniferous limestone, it was argued that a stream of larger size than Buffalo creek was necessary to erode

PLATE VII

Glacial markings in the bed of the Niagara river, Canadian side, at Fort Erie

a rock of such durability to the depth shown by the excavations. Since the matter is of considerable local interest, I have looked over the ground very carefully for evidences of such a stream, and have collected from contractors engaged in sinking piles, drilling and dredging, considerable data regarding the surface of the bed-rock.

The existence of a great river at any time near the present site of Buffalo creek or between there and Bay View is negatived by the appearance of rock at or near the surface in the places where this supposed river must have flowed. Stone has been quarried near Seneca and Chicago streets and at Bailey avenue and the New York Central railroad crossing; it crops out in the brick-yards on Clinton street near Bailey avenue, and at the end of Clinton street. It is found near Winchester, in Cazenovia park, and in several places between there and South park. It also is found in Smoke creek below West Seneca. Farther away from Buffalo, the outcrops of rock are so continuous as to preclude the possibility of a stream which, in its upper course, did not flow over approximately the same bed as one of these existing. At the Snow Steam Pump Works, near Buffalo creek, the limestone was found at fifty-two feet. The wells at the Atlas Oil Refinery and the Chemical Works touched it at about the same depth. At the upper end of the Hamburg canal, the distance to rock is twenty-three feet, and at the lower end twelve to fifteen feet. At the Glucose Works it was forty-two feet. Along the Ohio basin, on the south side, the drift is from twenty-six to thirty-seven feet deep, dipping towards the Lehigh docks. Mr. J. H. Leh informs me that the piles were driven here six feet apart from north to south, and that each pile had to be made a foot longer than the preceding one to reach bottom. The southern limit of the Corniferous limestone appears to be near these docks. At the railroad bridge across the Blackwell canal, on the side next the lake, the piles were driven to the depth of 120 feet without touching bottom. From the Hamburg turnpike bridge to the foot of Michigan street along the creek and canal in the vicinity of Ganson street, there is no rock nearer the surface than eighty or ninety feet. It is probable that this depression is continuous with the 120-foot depth at the railroad bridge and lies nearly at right angles with the general course of Buffalo creek at this point.

Within a few years the United States engineers have made a series of borings to ascertain the nature of the bottom between the southern end of the breakwater and Stony Point. The borings were 400 feet apart and approximately 1,000 feet from the shore, passing through the lacustrine deposits to rock-bottom. Between the end of the breakwater and a point opposite the Lehigh docks, the distance from the surface of the lake to bed-rock was from fifty-three to sixty-one feet. Sixteen hundred feet further on, the bottom was seventy-one and one-half feet below the surface, with a rise to fifty-nine feet within two stations. The deepest depression lies near Stony Point, where the rock was seventy-seven feet from the surface. Beyond this the rook rises quite abruptly, being only eleven feet from the surface at the last station near the shore. The lake charts show a depression in the lake bottom nearly opposite the Lehigh docks, which extends about 20,000 feet westerly into the lake. Along this, the water is about a fathom deeper than on either side. This depression is about 4,800 feet north of the deep depression already referred to and, of course, more recent.

From the above facts it is probable that the preglacial Buffalo creek entered the present lake depression between the present site of the Lehigh docks and Stony Point, cutting its way through soft Marcellus shales between the edge of the Corniferous and Stafford limestones.

The line where the rock suddenly drops off from thirty-seven feet to one hundred and twenty and ninety feet, is approximately the southward continuation of the bluff seen at the Front and may have had a similar origin; or it may be the extension of the southern limit of the Corniferous limestone into the lake. At present we have not sufficient data to determine this point.

There is no evidence to show that there ever was a great river here, or that the drainage before or since the glacial epoch was essentially different from that existing.

When the continent attained its present elevation at the close of the Champlain period, Buffalo creek probably made for itself a channel not very far from the old one, emptying into the lake near the present site of the Lehigh docks. The sheet of glacial clays and sand, covering the valley east of the lake to the depth of thirty to fifty feet, extended out into the lake depression, filling the ancient channel near Stony Point to about the same depth. Across this detritus the submerged current of the creek flowed, cutting a shallow channel and finally losing itself in the lake beyond. Winds drifted sand upon the beach along the lake front, forming a sand ridge higher than the land to the eastward, like that now forming. The combined action of wind and waves formed a bar at the mouth of the sluggish Buffalo creek, damming it and causing it to flow northward, the sand ridge separating it from the lake and determining its present course.

The Ancient Lake Shore Line in Buffalo.

Several deep excavations near Main street have given me, during the past summer, an opportunity of studying the stratification of the drift in the lower part of the city. The data collected, while mainly of local interest, throw some light upon the location of ancient lake levels.

In the cellar of the building on the White property, above Chippewa street, there were eight feet of sand at the surface with six feet of coarse gravel at the bottom. Both sand and gravel were laminated, the sand showing cross-bedding and the gravel beds sloping towards the lake. At the Guaranty building, corner of Pearl and Church streets, borings were made to ascertain the depth of bed-rock. According to the contractors, Messrs. Brown & Stebell, the drill passed from the level of the curb through

Loam	5 or 6 feet.
Sand and gravel to	52 "

The cellar of the Ellicott square building was excavated to the depth of nineteen feet, and three borings were made twenty feet deeper without finding rock. Sand to the depth of five feet was found in the corner between Main and South Division streets, extending about two-thirds of the way to Swan along Main, and about half-way to Washington along South Division street. Below the sand and covering the rest of the cellar bottom was clay, the lower part containing bowlders.

In the grade-crossing work at Main street and the Terrace, piles were driven on the east side of Main street to the depth of thirty feet, stopping in bowlder clay. On the opposite side of the street the piles were sunk to twenty-four feet. At the bottom the soil was very hard, the pile yielding only a quarter of an inch at each blow of the hammer. Near the liberty pole, the excavation showed clean sand on the upper side, and filling of rubbish, brick, etc., on the lower. Here was probably the original terrace from which the street took its name. From here to Pearl street was almost clean, fine sand, cross-bedded and laminated, showing the action of wind. From Pearl to West Seneca street, the bottom of the cut was through coarse gravel showing beach action of water.

Mr. C. D. Zimmerman informs me that within the recollection of his father the land below the Terrace was a swamp, and before the erection of the breakwater was flooded during heavy gales, up to where the Mansion House now stands, at the corner of Main and Exchange streets. The maps of the United States survey give the elevation at Exchange and Main streets as 600 feet above tide, or approximately twenty-seven feet above the surface of the lake. The 600-foot contour line from this point passes through Niagara square, keeps within a block of Niagara street on the east side as far as Maryland street, and there bends toward the lake again. It is quite evident that the sand deposits to the eastward of this are dunes formed by the wind, like those seen at Crystal beach, on the Canadian side, and may have travelled some distance from the original beach. The gravel deposits at West Seneca street and the Terrace, indicate that as an approximate ancient shore line and go to show that the lake has not subsided more than fifteen feet within the recent period. It is a curious fact that no shells or animal remains are found in any of the sand or gravel beds about the city.

Modern Geologic Changes.

Mr. David F. Day informs me that old maps and prints of the vicinity of Buffalo show islands near the head of the Niagara river between Horse-Shoe Reef lighthouse and the site of the present breakwater. The existence of such islands is also confirmed by the testimony of an acquaintance of his, an old resident, who remembered seeing them. At present, their site is marked by shoals covered by three to five feet of water. It is probable that the wind was the most active agent in effecting their destruction.

ECONOMIC GEOLOGY.

Stone Quarries.

The geologic formations which furnish stone suitable for building or bridge work within the limits of the county, are the following:

(1) The Hydraulic limestones.

(2) The Onondaga limestone.

(3) The Corniferous limestone.

(4) The Stafford limestone of the Marcellus beds.

(5) The Encrinal limestone of the Hamilton beds.

(6) The sandstones of the upper Portage.

The Hydraulic Limestones. The northern edge of the Corniferous limestone, together with the Onondaga limestone and the underlying water-lime, forms a more or less well-defined escarpment, extending from Buffalo through Williamsville, Clarence and Akron to the Genesee county line. In this whole distance there is hardly a mile in which stone has not been quarried for sale or local use. Since the face of the escarpment shows all three formations, they are usually quarried and sold together, so that the amount of hydraulic and Onondaga limestone used for building purposes cannot be separately

PLATE VIII

QUARRY IN CORNIFEROUS LIMESTONE, AT THE FRONT, BUFFALO. GLACIAL MARKINGS AT A AND B.

determined. At the works of the Buffalo Cement Co., at Buffalo, the overlying Corniferous, Onondaga, and a part of the water-lime are removed to reach the cement stratum. The best of these strippings are sold at the quarry for building purposes, and the company has just erected a crusher for converting the chips and refuse into road metal. The relation of these rocks in the last-named quarry may be seen from the following section:

Top; Flint and limestone, Corniferous,	3 to 9 feet.		
(6) Onondaga limestone,	5 "	8 inches.	
(5) Loose friable limestone,	0 "	6 "	
(4) Shale with gypsum crystals,	0 "	2 "	
(3) Hydraulic limestone, porous, locally known as "bullhead,"	7 "	0 "	
(2) Cement rock, used for burning,	5 "	8 "	
(1) Bottom, of impure hydraulic limestone.			

The "bullhead" stratum furnishes the greater part of the water-lime used for building purposes. It is light chocolate to yellowish white in color, and filled with cavities, irregular in shape, and ranging from the size of a kernel of corn to an inch or more in diameter. On account of its porosity, water and gases pass readily through this stone, and it is, therefore, not in favor for cellars or similar work.

The Onondaga Limestone. This formation expands near Williamsville into one or two lenticular masses from which it is quarried by R. & H. Fogelsonger and J. S. Young. Being composed almost exclusively of the remains of corals, crinoids and mollusks, it is of exceptional purity, as is seen from the following analysis by Hugo Carlson, of the Johnson Laboratory, Johnstown, Pa. The specimen was from the Fogelsonger quarry.

Carbonate of lime,	96.54
Carbonate of magnesia,	1.00
Alumina and oxide of iron,	.84
Silica,	1.17
Sulphur,	.101
Phosphorus,	.017

This stone cuts easily and is used for trimmings for buildings, water-tables, lintels, etc. A small amount is also sold for smelting purposes. The chips and waste are burned for lime. The two quarries sold last year 260 cords of building stone and 85,000 cubic feet of dressed stone. At Fogelsonger's quarry the limestone has been removed to the depth of twenty feet, and the thickness of the remaining part, as shown by drillings from a well in the quarry, is fifteen feet, making a total thickness of thirty-five feet. The rock at the Young quarry is of about the same thickness.

About 150 feet north of the Fogelsonger quarry, is another known as the "Syndicate" quarry, owned by Louis Wild, Joseph Mayer and Henry Smith, of Buffalo. At present the quarry is not worked.

The Corniferous Limestone. This formation furnished the greater part of the stone quarried within the county. The largest quarry interests are located within the limits of the city of Buffalo, and comprise two districts. The first includes the quarries near Main street, from the Almshouse to the Buffalo Cement Works. These are at present idle with the exception of the Grattan & Jennings quarry, which is selling a small quantity of stone. The second district, locally known as "Jammerthal," includes the region on both sides of Fillmore avenue, from LeRoy avenue to Delavan, and extending east along LeRoy to Worcester place, and along Delavan avenue to Dutton. The limestone is very cherty, and on that account hard to cut, but makes a very strong and durable building material. The layers are from twelve to twenty-four inches thick, and blocks can be obtained of almost any desired size. For this reason the stone is well adapted for railroad bridges, footing for piers and for other heavy work. It is also the principal material for cellar and foundation work for buildings of all sorts. The greater part of the stone quarried here is used in Buffalo and by the railroads which enter this city.

Besides the quarries already mentioned, there is a small one belonging to Cutter & Bailey near the New York Central railroad and Bailey avenue. Another, from which a few cords have been taken during the past season, is near the canal, just below the railroad bridge at the Front.

The greater number of quarries within the county, and outside of the city of Buffalo, are located near the southern edge of the Corniferous outcrop. The limestone contains less chert and is somewhat thicker bedded. The following section of Martin Keiffer's quarry, near Depew, illustrates very well the conditions which exist at that horizon. The quarry is situated near the north bank of Cayuga creek.

(1)	Top, fine sand,	48	inches.
(2)	Alluvium containing limbs of trees,	24	"
(3)	Surface of rock, rough like bed of stream,		
(4)	Layer of limestone,	24	"
(5)	Layer of limestone,	45	"
(6)	Layer of soft calcareous shale,	3	"
(7)	Layer of limestone,	18	"

PLATE IX

Stream erosion of Corniferous limestone, Cayuga creek, near Bellevue.
The rock in the left foreground has been removed by blasting.

(8)	Layer of limestone, ...	12 inches.
(9)	Layer of limestone, ...	$4\frac{1}{2}$ "
(10)	Layer of limestone, ...	14 "

Glacial scratches appear at the eastern end. The rest of the exposed edge is old, roughened creek-bottom. Statistics regarding the foregoing quarries will be found tabulated on a following page.

The Stafford Limestone. This rock furnishes a stone of good quality suitable for building or bridge work. It has been quarried in the bed of Buffalo creek at the end of Winchester avenue, below Gardenville, and at Lancaster. The only quarry from which stone has been taken during the past year is that of George Bingham at the latter place. No record has been kept of the quantity, which is not considerable.

The Basal Limestone. This stone has been quarried in a small way in the creek below the dam at Blossom. It is used there for foundations and to some extent in the abutments of the bridge across the creek.

The Encrinal Limestone. Since this limestone consists of one or two thick layers of a durable stone it has been quarried for culverts and abutments of bridges all along the outcrop. Owing to the limited quantity in sight at any one place, the supply has been largely exhausted except in ravines difficult of access. The only open quarry of consequence is in the valley of Buffalo creek, between Elma and Marilla. The quantity quarried here was not learned.

The Portage Sandstones. Although, as has been elsewhere shown, Portage bluestone of good quality is quarried in several places, no attempt has been made to utilize it farther than to supply immediate local demands. This is chiefly due to the fact, that Buffalo, the nearest market, is supplied with durable stone from its own quarries, or gets it cheaply from a distance by means of excellent lake and railroad facilities. In addition to the quarries here tabulated, the following were noted which were either not in operation or from which no statistics could be collected:

Phelps, ...	2 miles southwest of East Aurora.
———	East of Griffins Mills.
Joseph Myers, ...	2 miles east of Wales Center.
Ulrich, ...	$1\frac{1}{4}$ miles southwest of Wales.
Charles M. Brayton, . .	South Wales.
Zeller, ...	4 miles north of Boston Centre.
Pike and Townsend hills, .	3 miles southwest of Boston Corners.
Daniel Sherman, ...	2 miles northeast of Collins.

QUARRY OWNERS AND PRODUCT, CITY OF BUFFALO.

QUARRY OWNERS.	ADDRESS.	LOCATION OF QUARRY	KIND OF STONE.	AMOUNT.	GEOLOGIC FORMATION.	REMARKS.
Grattan & Jennings	D. L. & W. freight house, foot of Main st	Amherst st. near .. L. & W. railroad	Dimension and bridge	700 cords in '93	Corniferous	Only 70 cords in '94.
Buffalo Stone and Cement Co	Buffalo	Main st. near Erie railroad			Cornif. Onondaga and water-lime	Not worked at present.
Forest Lawn Cemetary	Buffalo	Forest Lawn Cemetery	Building and bridge	1,400 cords	Cornif Onondaga and water-lime	Also make road metal.
		Front near N Y C railroad	Heavy building	25 cords	Corniferous.	
John J Gesl	317 Leroy ave	Kensington near Fillmore	Building and railroad bridge	500 cords	Corniferous.	
Manser	Buffalo	Leroy ave. near Worcester pl.	Building		Corniferous.	Not worked at present.
Leroy Stone Co	Buffalo	Leroy ave near Worcester pl	Building		Corniferous.	Not worked at present.
E. J Ambrose	2135 Fillmore ave	Kensington near Worcester pl	Building and dimension.	500 cords	Corniferous.	
C Uebelhoer		Kensington near Fillmore	Building and bridge	2,400 cords	Corniferous.	
Anna Gehres	1968 Fillmore ave	Kensington near Fillmore	Building and dimension	5,000 cords	Corniferous.	
Cutter & Bailey	143 Washington st	Fillmore near Appenheimer	Building and dimension	3,050 cords	Corniferous	Have also small quarry on Bailey ave.
H Friedman	185 High st	Fillmore near Appenheimer	Building and dimension	2,000 cords	Corniferous.	
Schumacher & Liederman	Fillmore near Appenheimer	Fillmore near Appenheimer	Building and dimension.		Corniferous.	Just begun work.
John L Appenheimer	Appenheimer near Fillmore	Appenheimer near Fillmore	Building and dimension.		Corniferous	Not worked at present
Sebastian Schrier	285 Herman	Appenheimer near Fillmore	Building and dimension	1,200 cords	Corniferous	Leases quarry
Chas. Steinwach		Delavan and Fillmore ave			Corniferous.	No report.
Barber Asphalt Co	Austin Block	Fillmore near Appenheimer	Building	2,000 to 5,000 cords.	Corniferous.	Also make road metal.
Buffalo Cement Co		Main st. near Belt line	Building		Cornif. Onondaga and water-lime	No record kept.

PLATE X

Succession of the strata in Buffalo cement quarry, Buffalo.

A, Corniferous limestone; B, Onondaga limestone; X Loose limestone and shale; C, "Bull-head" rock; D, Cement rock.

QUARRY OWNERS AND PRODUCT IN ERIE COUNTY OUTSIDE OF THE CITY OF BUFFALO.

Quarry Owners.	Address.	Location of Quarry.	Kind of Stone.	Amount.	Geologic Formation.	Market.
R. & H. Fogelsonger	215 Oak st, Buffalo	Williamsville	Building and cut	200 cds building 85,000 cu ft cut	Onondaga limestone	Buffalo.
J. S Youngs	215 Oak st., Buffalo	Williamsville	Building	60 cords	Onondaga limestone	Buffalo.
H. L. & W. C. Newman	Akron	Falkirk	Building	100 cords	Onondaga, Corniferous and water-lime	Local.
J. Bieler	Clarence Centre	Clarence Centre	Building	50 cords	Onondaga and Corniferous	Local.
John Hiller	Mill Grove	Mill Grove	Bridge and culvert		Corniferous	Town of Alden.
M Souter	Cheektowaga	Cheektowaga	Building and culvert	100 cords	Corniferous	Local.
Lawrence Kaeser	Cheektowaga	Cheektowaga	Building and culvert	100 cords	Corniferous	Local
Nicholas Setter	Cheektowaga	Cheektowaga	Building and culvert	100 cords	Corniferous	Local.
Martin Kieffer	Depew	Near Transit road	Building and dimension	600 cords	Corniferous	Local.
Buffalo, Bellevue & Lancaster R.R Co	Bellevue	Bellevue	Railroad bridge and dimension		Corniferous	
A. Eyrsman	Wilhelm	Wilhelm	Building and bridge	350 cords	Corniferous	Local.
A W. Haskell	Bowmansville	Bowmansville	Bridge	225 cords in '94	Corniferous	Local.
Ernest Bowen	Bowmansville	Bowmansville	Bridge	125 cords in '94	Corniferous	Local.
Straub & Meyer	480 Hamburg st., Buffalo	Gunnville	Building	1,000 cords	Corniferous	Buffalo.
Geo. Bingham	Lancaster	Lancaster	Building		Stafford limestone	Local
W C Cook	East Aurora	East Aurora	Building	150 cords	Portage sandstone	Local
Delavan Caulkins	East Aurora	East Aurora	Building	200 cords	Portage sandstone	Local.
F. A. Clarke	Springville	Springville	Building	25 cords	Portage sandstone	Local.
Mrs. B. Wheeler	Springville	Springville	Bridge	200 cords	Portage sandstone	Local.

Road Metal.

Large quantities of crushed stone are used in Buffalo by the different companies engaged in laying asphalt pavements, concrete sidewalks and concrete work generally. It is used as the foundation of all asphalt pavement, of which the city now has over 200 miles. When a stone pavement wears out, it is, as a rule, replaced by asphalt. In this case, the old blocks, usually of Medina sandstone, are crushed on the spot and used as the basis for the street pavement. Chips from the Medina standstone quarries in Orleans county are also crushed and sent in by canal so cheaply as to compete strongly with the home product. It is, therefore, very difficult to estimate closely the amount consumed in the city. The Corniferous limestone is generally preferred to the Medina sandstone, for the reason that it is less absorbent, both of water and of paving material. For macadam pavement it is used entirely, the flint furnishing a substance which is very enduring, and the limestone serving to pack it firmly together. Neither of these materials splits readily or breaks up under hoofs or wheels. It makes, also, excellent ballast for railroads and is used for that purpose by some of the suburban electric railways. The Buffalo, Bellevue and Lancaster railroad has a crusher at Bellevue which furnishes ballast for that road and a large amount for surfacing the streets of Depew. The Buffalo Cement Co. have recently erected a steam crusher with a capacity of 450 yards a day, in which waste from their quarries, particularly the cherty rock from the edge of the Corniferous limestone, is reduced to road metal. The rock is wheeled in barrows directly to the mill, where it is crushed, screened and loaded by chutes directly into cars for shipment without further handling. The finer grades are used in concrete work, and the coarser are sold as ballast. The Barber Asphalt Co. has the largest plant in the city, at Fillmore avenue, near Appenheimer, where its quarries are located. It consumes the greater part of the product, but sells some to other parties. The Park commissioners have a crusher at the Central Park quarry, in which road metal for the park roads is prepared. During 1895, however, they purchased their supply of the Barber Asphalt Co. The Forest Lawn cemetery has a crusher in which material for the cemetery walks and drives is prepared. The stone is obtained from a quarry on the north side of the enclosure.

Statistics regarding road metal will be found in the following table:

PLATE XI

The Onondaga limestone, Fogelsonger's quarry, Williamsville.

PRODUCERS OF ROAD METAL.

Manufacturers.	Address.	Capacity per Annum.	Product per Annum.	Use.	Remarks.
Barber Asphalt Co	Buffalo	100,000 cu. yds.	80,000 cu. yds.	For paving	
Buffalo Park Commissioners	Buffalo		6,000 cu. yds.	For park roads	Statistics for '93. 1,500 yds in '94. None in '95.
Forest Lawn Cemetery	Buffalo		1,000 cu. yds.	For cemetery roads and paths	
Buffalo Cement Co	Buffalo	450 cu. yds. per diem		For railroad ballast, concrete and roads	Crusher just erected.
Buffalo, Bellevue and Lancaster railroad					No information received.

Hydraulic Cement.

Historical. As Erie county was among the earliest producers of hydraulic cement, the following facts, taken largely from "A History of Buffalo and Erie County, New York," by H. Perry Smith, are of interest:

The first cement manufactured in the county was made at Williamsville about the year 1825*, the quarry, kiln and mill being near the creek. In 1839, Jonathan Delano erected works at Falkirk, near Akron, in which he made about 2,000 barrels of cement the first year. He furnished the cement for the feeder dam at Tonawanda creek and for the Genesee valley canal. In 1843, the business passed into the hands of James Montgomery, who increased the output to 10,000 barrels a year. The business afterwards came into the possession of Enos Newman, a partner of Montgomery, and has been in his family ever since.

In 1854, H. Cummings & Son established a cement factory at Akron, which was operated for several years, and was succeeded in 1865 by another, managed by his sons. This was sold to the Akron Cement Co. in 1870–71, and the Cummings brothers erected another factory about two miles west of Akron. Since then it has been enlarged, until now it is one of the most complete in the state.

The first cement made in Buffalo was manufactured by Warren Granger near Scajaquada creek, in what is now Forest Lawn cemetery.

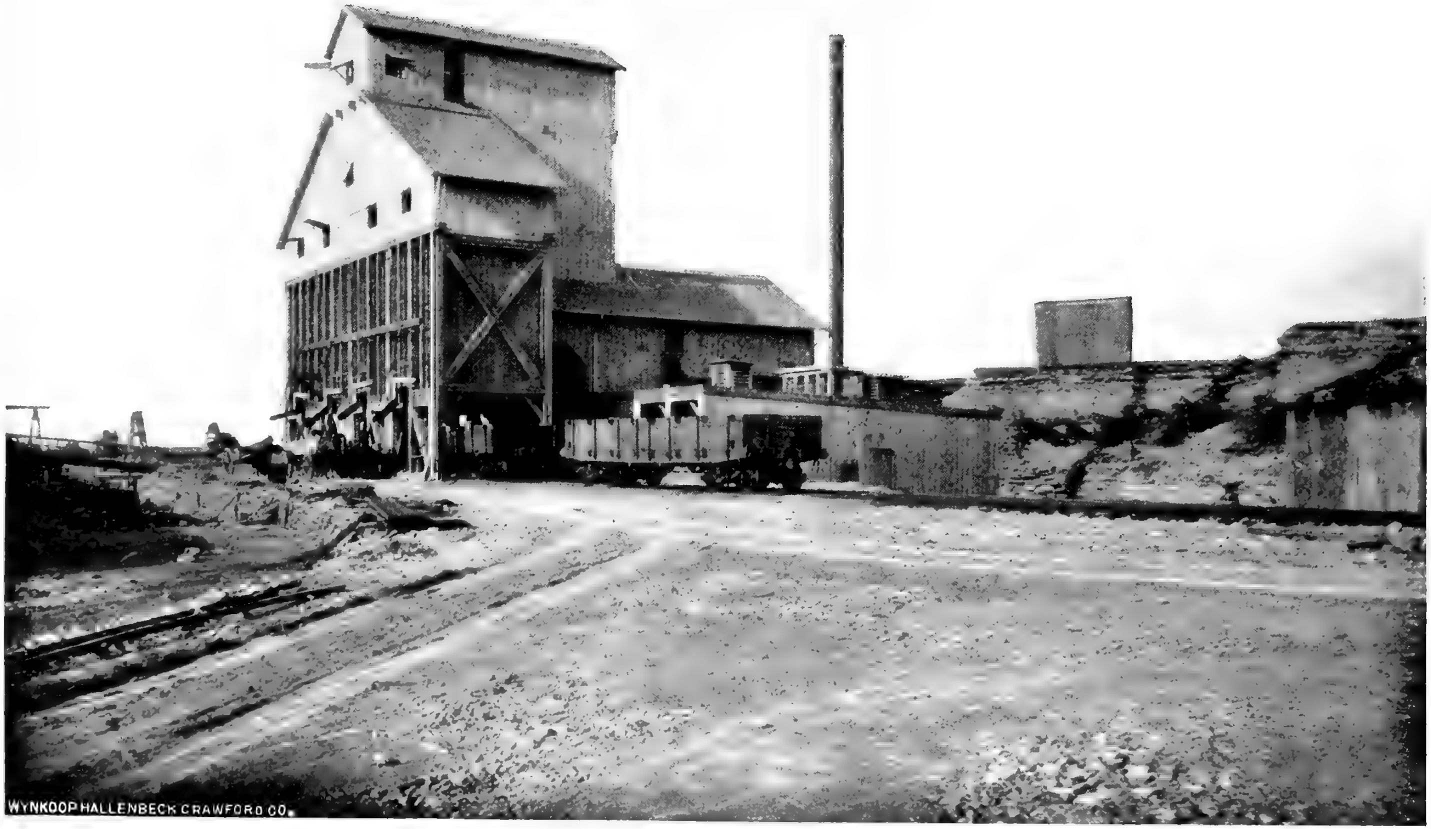
Regarding this, Mr. Uriah Cummings, to whom I wrote for information, says: "Warren Granger told me some twenty years ago that he started in making cement in Forest Lawn just below the Main street bridge, at which time, 1850, what is now Forest Lawn was his own farm."

In 1874, Lewis J. Bennett began the manufacture of cement at Buffalo Plains, near Main street. The business which has been carried on continuously ever since, is now in the hands of the Buffalo Cement Co., of which Mr. Bennett and his sons are officers.

Mining and Manufacture. The stratum of water-lime burned for cement varies in thickness from five to eight feet. It is a firm, fine-grained, compact rock of a blue-grey color, sometimes with a yellowish tinge, and weathering to a yellowish white. Three out of the four companies which manufacture cement obtain the rock by mining. The method employed at the Cummings Cement Works, at Akron, illustrates very well the process of preparing cement for market. The stratum is here seven feet thick, cropping out on the face of

* Mr. Uriah Cummings, who has looked up the matter very carefully, gives this date as 1824.

PLATE XII



WORKS FOR MAKING ROAD-METAL; BUFFALO CEMENT COMPANY, BUFFALO.

a high cliff some distance above the base. The cutting is made horizontally into the rock, pillars being left to support the roof. The drills are run by compressed air furnished by five pumps located near the mouth of the mine. Blasting is done with black powder, trams convey the rock to the kilns, where it is calcined and then ground by what is called the gradual reduction process. The calcined rock is passed through four mills, being screened after each grinding. The cement is then packed in bags and barrels for market. It is largely used for sewers, the foundation for asphalt pavements, cellar-bottoms and concrete work generally. This company furnished 600,000 barrels for a single contract, the building of the new aqueduct for New York City. The officers of the company are: President, Uriah Cummings; Vice-President, R. P. Cummings; Treasurer and Manager, P. Cummings; Secretary, Homer S. Cummings.

The works of H. L. & W. C. Newman are located at Falkirk, where they own 200 acres of cement rock. The stratum is here seven and one-half feet thick. The rock is mined as at the Cummings works. For blasting, dynamite is used instead of powder, and soft coal is used for calcining. They make from 135,000 to 140,000 barrels yearly.

The Akron Cement Works, at Akron, have 225 acres of land adjoining that of the Newmans, with a cement stratum eight feet thick. The rock is obtained by mining. One of the old workings is utilized for the growing of mushrooms, the uniform low temperature and darkness furnishing the necessary conditions for their growth. The officers of this company are: President, Hon. D. N. Lockwood, Buffalo: Secretary and Treasurer, Frank S. Coit.

The Buffalo Cement Co. has its quarries on Main street, near the Belt-line of the New York Central railroad. Blasting is done with black powder. Since the city is rapidly extending in that direction, coke is used as fuel to avoid objectionable smoke. The overlying rock is quarried and sold for building purposes and the refuse crushed for road-metal, thus minimizing the cost of stripping. A section of the rock exposed by the stripping is given elsewhere. This quarry is famous for the number and excellence of crustacean remains found in it. These occur almost exclusively in the cement stratum, and of course are obtained only when that is being worked. Mr. Fred K. Mixer, director of the museum of the Buffalo Society of Natural Sciences, has prepared for me the following list of species found in the hydraulic limestones near Buffalo, the greater number of which are from the Buffalo Cement Co.'s quarry:

Merostomata.

Eurypteridæ.

Eurypterus giganteus, Pohlman.
Eurypterus lacustris, Hall.
Eurypterus lacustris var. robustus, Hall.
Eurypterus remipes, DeKay.
Eurypterus pachychirus, Hall.
Eurypterus DeKayi, Hall.
Eurypterus (Dolichopterus) macrochirus, Hall.
Eurypterus (Eusarcus) grandis, Grote and Pitt.
Eurypterus (Eusarcus) scorpionis, Grote and Pitt.

Pterygotidæ.

Pterygotus Buffaloensis, Pohlman.
Pterygotus Cummingsi, Grote and Pitt.
Pterygotus bilobus, Huxley and Salter.
Pterygotus globicaudatus, Pohlman.
Pterygotus micropthalmus, Hall.
Pterygotus quadraticaudatus, Pohlman.
Pterygotus acuticaudatus, Pohlman.

Since the last named species was described, several specimens of it in a good state of preservation have been obtained, showing almost the entire animal. One in the museum collection shows all but the posterior end of the body with two-thirds of the tail. One set of antennae is preserved, and also portions of the swimming feet. This specimen is only a foot in length, but was probably a young animal.

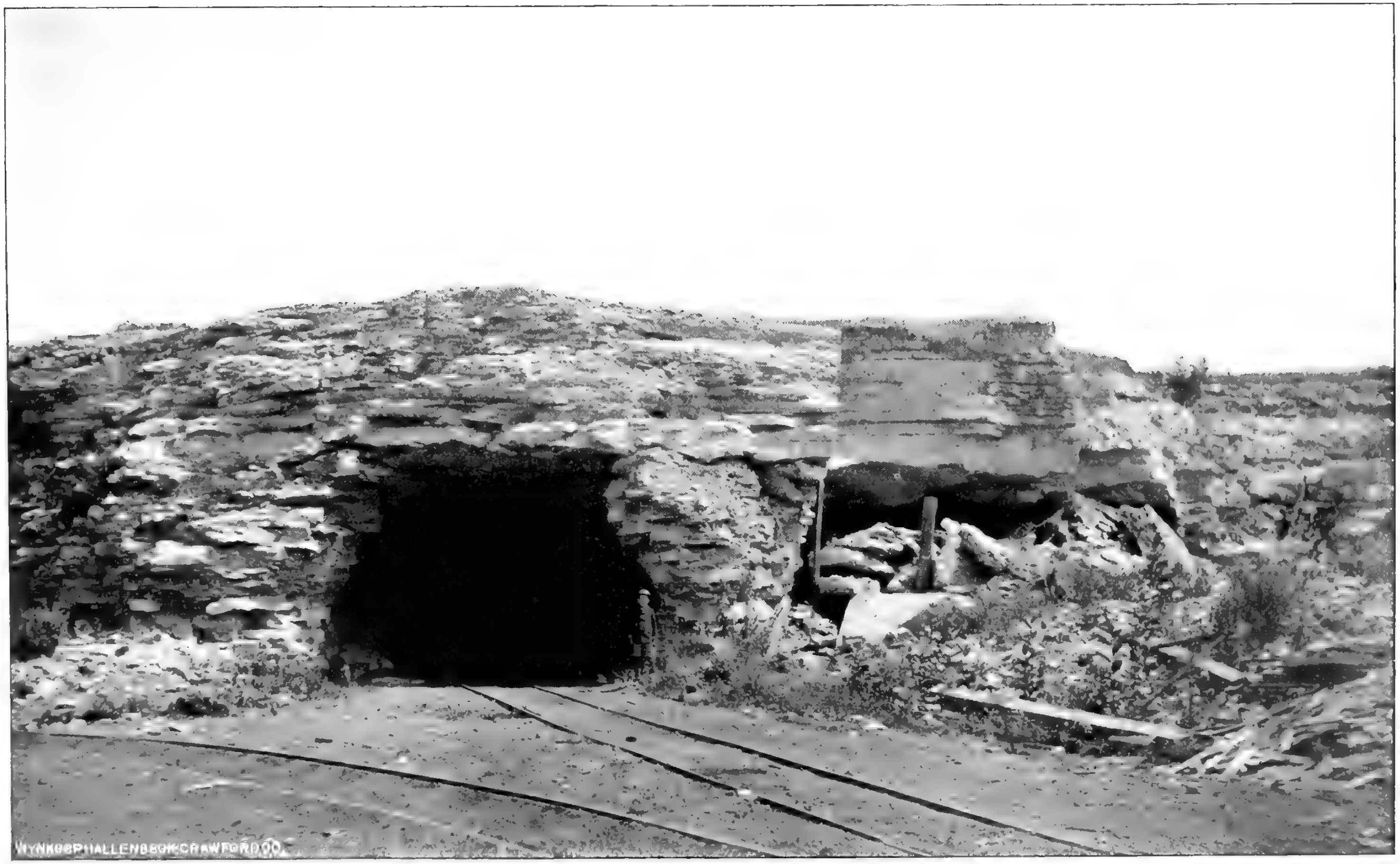
Phyllocarida.

Ceratiocaridæ.

Ceratiocaris grandis, Pohlman (specimen nine and one-half inches wide by five and one-quarter inches long).
Ceratiocaris acuminata, Hall.

Since the description of the last named species in the Bulletin of the Buffalo Society of Natural Sciences, vol. 5, a specimen has been found and is now in Mr. Mixer's possession, which shows the shape of the carapace very

PLATE XIII



Mines of the Akron Cement Company, Akron. The Onondaga limestone is seen capping the opening

well, except the pointed extremity, the eye being very clearly seen. The body and two caudal appendages are preserved on the same slab.

Entomostraca.

Leperditia alta, Hall.

Brachiopoda.

Five forms of Discina, probably including:
Discina (ampla) grandis, Hall (?).
Discina discus, Hall.
Lingula rectilatera, Hall.

Marine Algae.

Order *Floridea.*

Chondrites graminiformis, Lesquereux.
Bythotrephis Lesquereuxi, Grote and Pitt.

The officers of the Buffalo Cement Co. are: President, Lewis J. Bennett; Vice-President and Treasurer, P. J. Wood; Secretary, Leslie J. Bennett. The city office is at 110 Franklin street, Buffalo.

A statement of the interests concerned in cement manufacture is given in the following table:

CEMENT PRODUCERS AND PRODUCT, ERIE COUNTY, N. Y.

MANUFACTURER.	LOCATION.	THICKNESS OF STRATUM.	FUEL.	PRODUCT PER ANNUM.
Cummings Cement Co	Akron	7 ft	Loyal Sock coal	200,000 bbls.
H. L. & W. C. Newman	Falkirk	7½ ft	Soft coal	135,000 to 140,000 bbls.
Akron Cement Co	Falkirk	8 ft	Soft coal	140,000 bbls.
Buffalo Cement Co	Buffalo	5 ft. 8 in	Coke	300,000 bbls.

Quicklime.

The lime produced within the county is made from the Onondaga and Corniferous limestones. From the former, lime of excellent quality is burned in the kilns of R. & H. Fogelsonger, at Williamsville, and in those of J. S. Young, about a mile northeast of that village, the product of both being marketed together. Wood is used for fuel, aided somewhat at the

Fogelsonger kiln by natural gas from wells on the premises. The product marketed last year amounted to 20,000 barrels. The office of the company is at 215 Oak street, Buffalo.

The Consumer's Lime Co., Straub & Meyer, lessees, has three large kilns at Gunnville, N. Y., on the West Shore railroad. The rock is obtained from an outcrop of the Corniferous limestone about midway between its northern and southern boundaries. Crude petroleum from Ohio and Pennsylvania is used for fuel, and the kilns are kept running all the year round. In 1893 the product amounted to 30,000 barrels, the greater part of which was consumed in Buffalo. During the present year the output has been diminished, on account of the financial stringency which has lessened the demand for lime; but they were unable at the office to estimate how much the product had fallen off. The city address is 480 Hamburg street, Buffalo.

There is a small lime kiln at Harris hill, owned by A. Fiegel, which burns lime chiefly for local consumption. It has a capacity of one hundred barrels in twenty-four hours, but is not kept burning all the time. The fuel here is wood.

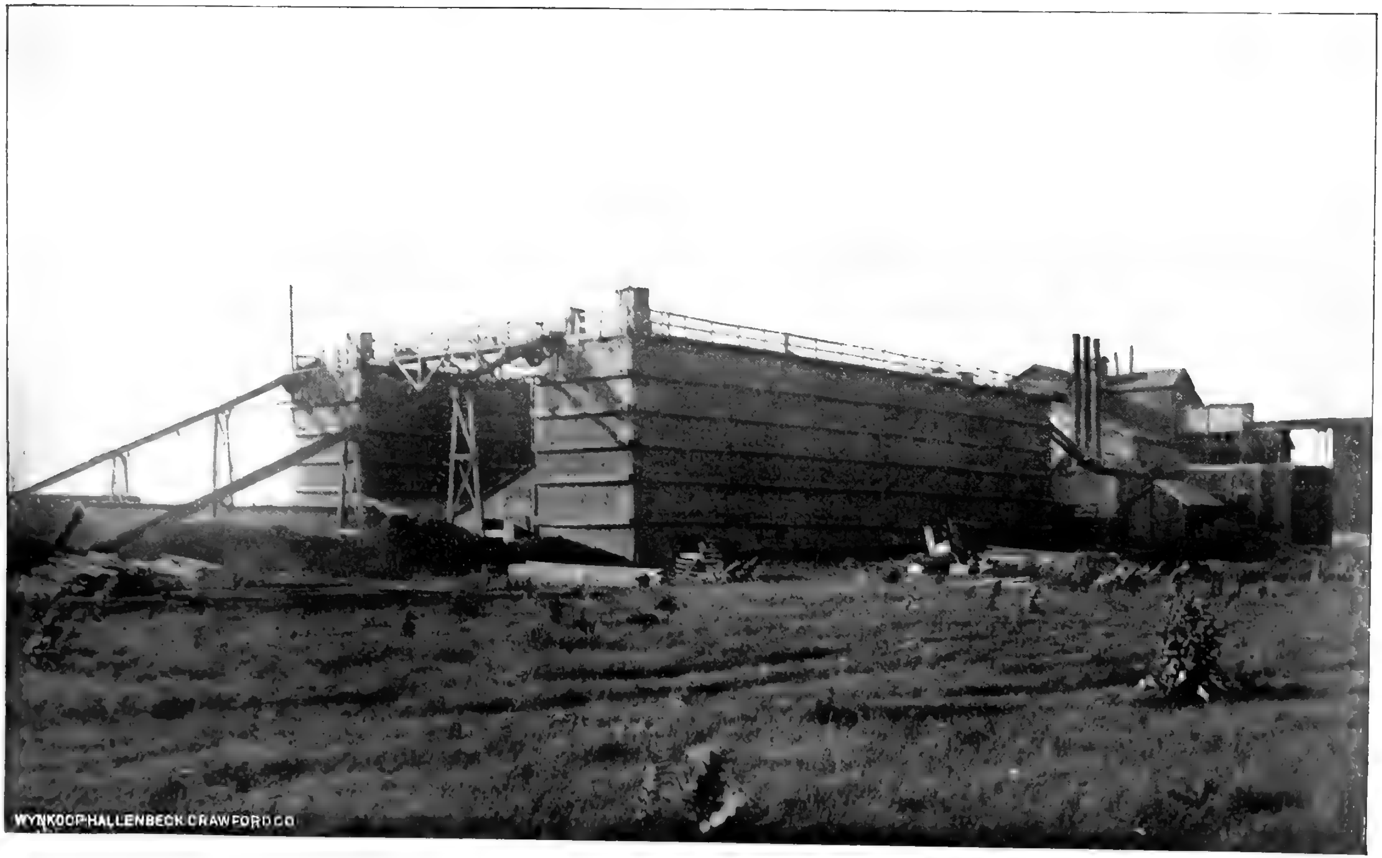
About half a mile north of Mill grove, at the east side of the road, is a small kiln, owned and operated by Mr. Shaw. Lime is burned here for neighborhood use whenever it is needed.

The preceding are all the lime kilns now in use within the county. Remains of old kilns were noticed in several places, notably at Young's old quarry, northeast of Williamsville; another about a mile north of that, near the Transit road; one east of Harris hill, on Main street, and one about two miles north of Crittenden, on the road to Falkirk.

Brick, Tile and Fire-Proofing.

While manufacturers generally use clay as the raw material from which to make the above products, two firms manufacture directly from shale. The rock selected in both cases is an olive shale of the Portage group lying, in one instance, above, and in the other instance below the lowest divisions of the Portage sandstones. The Jewettville Pressed Brick Co. grinds the shale in a mill. The product, having about the appearance and consistency of dry road dust, is then pressed in moulds with a Boyd machine, which gives a pressure of about three tons on four bricks. The firing is done in continuous, double down-draft kilns, of which four are used. The fuel is soft coal. From 10,000 to 12,000 is the usual make per day. The total output for a year was not learned. The plant is owned by Smith & Brush.

PLATE XIV



KILNS OF THE BUFFALO CEMENT COMPANY, BUFFALO.

John Lyth & Sons, 48 West Eagle street, Buffalo, have extensive works at Angola, in which the raw material used is shale. The rock is ground, moistened, pressed through the dies, dried and burned in dome-shaped, down-draft kilns. Mr. Lyth has furnished me the following statistics regarding the product of these works from October 1st, 1894, to October 1st, 1895:

Drain tile,	335,000 pieces.
Weight,	1,407½ tons.
Building brick,	471,000 pieces.
Weight,	3,375 tons.
Fire-proofing,	652,000 pieces.
Weight,	6,300 tons.

The greater part of the above was marketed in Buffalo. He is now furnishing material for the following large buildings which are in process of erection: Real estate building, Pearl street; Matthews building, Main street; Fuchs Bros. building, Washington street; Buffalo General Hospital extension, High street; Berrick building, corner Swan and Elliott streets.

The most extensive brick manufacturing interests within the county are located in the city of Buffalo, along both sides of Clinton street, from Scoville street to Bailey avenue, and beyond Bailey avenue in the district included by Bailey avenue, Clinton and Ogden streets and the New York, Lake Erie and Western railroad. The firms within these limits are F. W. Haake and the members of the Buffalo Brick Manufacturers' association. The latter organization has offices at 927 Clinton street and No. 2 Builder's Exchange. The following statement of producers, product and capacity of works was furnished by Mr. Warren H. Brush, the secretary of the association:

Firm.	Capacity.	Made in '95.
Brush Bros.,	180 M per day.	90 M per day.
L. Kirkover,	100 " "	80 " "
George Schmidt,	60 " "	60 " "
H. Ditchler,	60 " "	40 " "
C. Berrick & Sons,	80 " "	20 " "
Schusler & Co.,	40 " "	30 " "

Total output of stock and common brick in 1895, 40,515,000.

In addition to the above, Brush Brothers have a winter plant which can produce 30 M a day. This will not be in operation the present winter. The form of kiln was not noticed in all cases. Mr. Kirkover was using seven

Berrick kilns, and C. Berrick & Sons an equal number of Colwell kilns. As far as noticed all were up-draft.

At Pine hill is an extensive plant under the management of Jewett & Reynolds. In addition to common brick, they manufacture hollow brick and tile. They have three Millington machines for common brick, one Frey-Scheckler wire-cut machine, one Turner, Vaughn & Taylor direct-action steam press, and a four-mould Simpson press, which is not now in use.

The South Buffalo Brick Co., H. Bender, manager, near Gardenville, uses a Martin brick machine, and makes about a half million of brick yearly.

The Star Brick Co., Lancaster, is working one machine this year, and making two million brick, which is less than the usual amount.

The Lancaster Brick Co., office 95 Franklin street, Buffalo, has its works near Town-line. The clay bed is there thirty feet thick. The company has one stiff clay and three soft clay machines, the former a Frey-Scheckler. Five of the kilns are up-draft and two down-draft. Drain tile, mostly flat sole, with one octagon size, are produced to the number of 200,000 yearly, and also about 500,000 hollow brick.

A brickyard has been started during the past summer by Mr. J. F. Stengel on Grand Island, about a mile below the Bedell house. It is expected to produce 3,000,000 common and stock brick per annum.

A small brickyard at East Evans, and one, owned by Mr. Charles Seedorf, at Springville, are not now in operation.

Hall & Sons, 69 Tonawanda street, Buffalo, are the only firm making fire-brick within the county. They consume about 4,500 tons of material, which is brought here principally from New Jersey, with about ten per cent. from Pennsylvania. None of the material is obtained within the county.

Sewer Pipe.

The Buffalo Sewer Pipe Co., at Black Rock, is the only firm manufacturing sewer pipe. During the past year the amount sold amounted to 600 carloads, and the increase of stock on hand over the preceding year is estimated by the company as between fifty and one hundred carloads more. Some clay is obtained from Tonawanda, but the larger part, with the sand necessary to temper it, from South Amboy, N. J. The manager of this company is Mr. N. C. Barnum.

The names of the firms engaged in the foregoing industries, with the amount of clay products, are shown by the following summary:

PLATE XV

Upper stratum of the Corniferous limestone, showing bedding. Lehigh sheds, Cheektowaga.

COMPANY.	CAPACITY.	BRICK.	HOLLOW BRICK AND TILE.
Buffalo Brick Mfr's Association.	68,000,000	40,515,000	....
F. W. Haake........	7,000,000	7,000,000	....
Pine Hill........	4,000,000	3,000,000	Hollow brick, 500,000 (capacity, 6 million). Tile, capacity 3 mill. 2½ in. or 2¼ mill. of 6 in.
Lancaster Brick Co	10,000,000	4,000,000	200,000 drain tile, 500,000 hollow brick.
Star Brick Co	....	2,000,000	....
South Buffalo Brick Co........	....	500,000	....
John Lythe & Sons	....	....	335,000 pieces drain tile, 471,000 pieces building brick, 652,000 pieces fire-proofing.
Jewettville Pressed Brick	....	10,000 to 12,000 per day	....
Hall & Sons (fire brick)........	....	900,000	....
Buffalo Sewer Pipe Co........	....	....	Sewer pipe, 650 to 700 carloads.

Sand and Gravel.

Nearly all the sand and gravel consumed in Buffalo is brought by boat from the Canadian shore of lake Erie, near Point Abino. The dunes along the American shore, from Michigan street to Stony Point, furnish a small quantity, but it is not clean, and is difficult of access. Fox & Holloway, extensive dealers in sand, estimate the amount taken from this source to be approximately 5,000 cubic yards. The deposits at Pine hill have not yielded much during the year. At Gowanda is a bank of sharp sand, especially suited for mortar, which is controlled by the Buffalo Mortar and Fibre Co. Some of the railroads have gravel banks from which they obtain ballast. The following exhibit shows the approximate product for 1895:

PRODUCER.	LOCATION OF PIT.	PRODUCT IN CUBIC YARDS.
West Shore railroad........	Clarence	37,112
New York, Lake Erie and Western railroad	Alden	29,300
Kelly Sand Co........	Gowanda	10,800
Pine Hill Pits........	Pine Hill	2,000
Lake Shore........	Near Stony Point........	5,000

Natural Gas.

In this report I have endeavored to assemble all available information regarding the development and present condition of natural gas interests in Erie county. Recognizing the value of well records in determining the thickness of geologic formations, I have taken pains to secure as many as possible. The greater part are from the original "logs" of drillers and contractors, and, in the main, are accurate. Where no record has been kept, or if kept, lost, the data available have been given for what they are worth. These imperfect records always give a gas horizon or other geologic fact worth preserving, and usually the information of greatest economic value. With a few unimportant exceptions, the material included has not heretofore been published.

History. The first gas well put down in Erie county was sunk at Getzville in 1858 or 1859, and is said to be still furnishing a small amount of gas. Following the discovery of petroleum in Pennsylvania, more or less prospecting was carried on in the southern part of New York, and about 1860, Oil Creek parties secured leases in the town of Boston and drilled a well near Patchen. This appears to have struck a fair supply of gas; but as oil was the object sought, the gas was disregarded. About 1872 the Buffalo Gas Light Co. put down a well at their works, near the corner of West Genesee and Jackson streets, and struck a pocket of gas, which lasted only a short time. Another well was drilled near Boston Corners in 1878–79, which did not find oil or gas in paying quantities, but passed through fifty or sixty feet of rock salt. Strange to say, the owners appear not to have understood the importance of their discovery, for the well was abandoned. With salt worth $1.50 or more a barrel, the well would have been a more profitable investment than most oil wells.

The Buffalo Cement Co. made the first systematic search for gas within the city of Buffalo in 1883, putting down a well with a diamond drill to the depth of 451 feet 9 inches. A second well was sunk in the following year near the first, but this also gave very little gas. A third well in 1887 gave a good flow of gas, and was followed by several others. Encouraged by this, in 1889, Mr. Gerhard Lang drilled a well near his brewery, at Best and Jefferson streets. A fine flow of gas was found, and many other wells were immediately started in various parts of the city. Mr. George Rochefort, directly across Best street, got an excellent well, and the Erie County Pipe Line was organized to take the surplus gas from the Lang and Rochefort wells to dwellings in that vicinity. About this time Mr. Edward L. Everson struck a good supply of gas in a well bored in the rear of 971 Jefferson street, and,

PORTAGE SHALES; PIPE CREEK, NEAR WEST FALLS.

with three others, organized the East Side Fuel Co. with a capital of $20,000. The officers of this company were: President, Joseph Hottinger; Vice-President, Albert Everson; Treasurer, Edward L. Everson. This company was afterward absorbed by the Erie County Pipe Line organization. Shortly after the consolidation of the two companies, Mr. W. S. Carroll, who was a member of the Erie County Pipe Line Co., became interested in a gas well which was sunk on the Canadian side of the Niagara river, and this well was bought by the Pipe Line Co. As the supply of gas gave out at Best and Jefferson streets, other Canadian wells were acquired, until the greater part of the company's property was on that side of the river. The striking of a rich supply of gas in the Baker well at West Seneca, in February, 1891, started exploration in that vicinity.

In the following year, Philip Roth and the Argue Brothers, the latter being drillers and contractors, organized the South Buffalo Natural Gas Co. with a capital of $300,000. The Buffalo Natural Gas Fuel Co., said to be controlled by the Standard Oil Co., gave the South Buffalo Co. financial backing, under arrangements mutually advantageous.

In August, 1895, the latter company had forty-five wells, three of which would deliver 2,000,000 cubic feet of gas a day, three more that would produce 1,000,000 feet, and thirty that would produce less than 1,000,000 feet. About the first of January, 1896, the Buffalo Natural Gas Co., which has piped the greater part of its gas from the Pennsylvania fields, bought out the South Buffalo Co., and now controls all the gas wells near Buffalo, including the Canadian fields. At present it supplies fuel to about 9,000 customers.

Well Records.

Grand Island Well. (From Mr. A. B. Williams.) At Sour-Spring grove on Grand Island, opposite Tonawanda, a well was bored a few years ago to the depth of 3,129 feet, getting very little gas but much salt water at the bottom. Bed rock was found here at sixty feet, the rock being Salina shale.

Tonawanda Well. (From Mr. A. B. Williams.) At about the time the well was bored at Sour Spring, another was sunk in the village of Tonawanda, between the canal and the tracks of the New York, Lake Erie and Western railroad, on the property of Mr. A. B. Williams. Bed rock was found at fifty feet and a very little gas at 558 feet. No more gas was found to 1,100 feet where drilling was stopped.

The Getzville Wells. (From Mr. Franklin Getz.) At Getzville, six miles east of Tonawanda, is a group of twenty or twenty-one wells, in eighteen of which gas was found. The best of these have a pressure of about 200 lbs. in twenty minutes. The gas occurs at a depth of 430 to 475 feet in a soft white rock looking like gypsum. The product of these wells is piped to Tonawanda, supplying 250 families and yielding an income of about $7,000 a year.

Of this group, five wells are located close together near the station, and the others scattered about within three miles to the north and west. The drift here was twelve feet deep in the thinnest spot through which borings were made, and sixty-nine in the thickest, the latter being near the bed of Ellicott creek. All passed through essentially the same strata, and have similar records, barring slight local differences of dip and location. The following record of Well No. 17, located one mile west of the village, will answer fairly for the whole group. It was furnished by the contractor who drilled several of the wells, from memoranda made while the well was being sunk.

Record of Well No. 17, Getzville, N. Y. (Received from J. H. Lichtenburg, driller.)

Drift,		69	feet.
Sand and shale,	at	100	"
White sand and shale,	"	140	"
Flint shell (?),	"	170	"
Shale,	"	201	"
Salt water and sand,	"	206	"
Grey sand,	"	216	"
Shale,	"	220	"
Shale and sand,	"	225	"
Red sand,	"	230	"
Fine white sand,	"	250	"
Red sand and shale with sulphur gas,	"	265	"
Bottom of red sand,	"	270	"
Dark sand,	"	276	"
Salt water and sand,	"	285	"
Grey limestone,	"	300	"
Salt water and sand,	"	328	"
Red sand,	"	335	"

Flint shell (?) (cased to),	at	361 feet.
White sand,	"	370 "
Black sand,	"	405 "
Limestone,	"	465 "
Top of (white) gas sand,	"	474 "
Bottom of (white) gas sand,	"	481 "
Bottom of well,	"	492 "

Rock much like that at the top.

The Blocher Wells, Williamsville. (From Mr. John Blocher.) These are located on Evans street, near the eastern end of the village. Two produce gas and the other water. In boring the last the drill passed through:

Limestone,	6 to 8 feet.
Gravel and limestone alternating in beds of 3 or 4 ft. to	125 "
Dry limestones and shales, to	500 "

Water at 75 and 125 feet; dry all the way below.

This well was bored on the very edge of the limestone terrace, and the beds of gravel referred to were evidently crowded into crevices in the rock. Similar intrusion of gravel is seen in the quarry at the Front, in the city of Buffalo. Water in this well fills a three-inch pipe two feet above the surface of the ground, and half fills it at six feet. It is charged with sulphuretted hydrogen and some mineral matter.

The second well, lying about one hundred feet to the east of the one described, struck a strong vein of sulphur gas at 500 feet. Mr. Blocher thinks this flowed a quarter of a million feet a day on the start.

Well No. 3 is situated about 200 feet north of the others.

In this the distance to rock was		107 feet.
Top of Niagara limestone,	at	440 "
Top of Clinton limestone,	"	700 "
Top of Medina sandstone,	"	725 "
Through gas sand,		851 "
Total depth,		862 "

Cased to 165 feet. Water sufficient to fill an eight-inch pipe was found five feet above bed-rock. Twenty thousand feet of gas were found in the Clinton, but none in the Medina. Wells Nos. 2 and 3 are now together furnishing about 25,000 cubic feet of gas per day, most of which is used under the boilers at the power-house of the Williamsville and Buffalo Electric railway. (Record from driller, Mr. J. W. Stearns, Akron, N. Y.)

Well on the Brock Farm, Williamsville. (From H. H. Church, driller.)

Drift,	30 feet.
Shales and limestones,	400 "
Niagara,	90 "
Shale,	60 "
Clinton,	18 "
Red Medina (?) with a little gas,	140 "
Shale,	12 "
First white sand,	10 "
Black shale,	8 "
White, coarse Medina sand (very fair gas producer),	20 "
Red shale,	40 "
Total depth of well,	830 "
Rock pressure,	480 lbs.

Mr. Church says that the red shale in which the well stopped extends 980 feet below the white Medina.

Fogelsonger's Well, Williamsville, N. Y. Samples of drillings from this well have been arranged in a glass tube, and are in the possession of the Buffalo Society of Natural Sciences. The following record is compiled from an inspection of the drillings, and is based upon color and hardness as shown by fineness of comminution, and such other characteristics as could be seen through glass. The well was started in the Onondaga limestone, extending from the surface to fifteen feet.

From 15– 50	feet,	Bluish shale and water-lime.
50– 60	"	Brown water-lime.
60–105	"	Soft gypseous shales.
105–155	"	Soft rock, containing pieces of white gypsum.
155–190	"	Harder rock, light and dark chocolate color alternating
190–200	"	Grey shale.
200–210	"	Soft, light grey gypsum (?).
210–250	"	Darker, soft, gypseous shale.
250–265	"	Harder, light chocolate-colored limestone.
265–380	"	Bluish grey gypseous shale.
380–400	"	Darker gypseous shale.
400–420	"	Light-colored, soft, gypseous shale.
420–450	"	Softer, darker shales.
450–475	"	Limestone.

475–485 feet,	Softer calcareous rock, with gas at 485 feet.
485–495 "	Hard brown limestone (?).
495–505 "	Soft light brown shale.
505–540 "	Hard compact sandstone or limestone.
540–645 "	Soft limestone or calcareous shale, gas at 626 feet in grey, medium soft limestone or shale.
645–680 "	Hard limestone.
680–720 "	Soft, light grey gypsum (?).
720–740 "	Soft, dark blue shales.
740 "	White limestone (?) with gas.
745–760 "	Darker limestone (?).
760–785 "	Blue-grey limestone.
785–790 "	Light red sandstone (Medina ?).
790–805 "	Dark red sandstone (Medina ?).
805–810 "	Light red sandstone (Medina ?), very hard.
810–820 "	Dark red sandstone (Medina ?).
820–838 "	White, hard sandstone.
838–845 "	Grey shale (?).
845–850 "	Darker grey shale.
850–890 "	White sandstone, hard, with gas at 850. (In white Medina ?).
890–bottom	Soft red shale.

The limestone at 450–475 feet is probably Niagara.

Well at Kenmore. (Drilled by Mr. Mook; record from Miss Flora King.) This well is located on Kenmore avenue, east of Delaware. The drill found here:

Drift,		30 feet.
Mineral water,	at	60 "
Blue rock,	"	65 "
Gypsum,	"	150 "
Shale,	"	300 "
Sulphur gas,	"	350 "
Salt water,	"	400 "
Hard rock and shale,	to	700 "
Medina brown sand,	700 "	725 "
Gas in red sand,	at	786 "

Well No. 1, Clarence. (Record from J. W. Stearns, driller and contractor.)

Drift,			103 feet.
Salina,	from	103–465 feet,	362 "
Niagara limestone,	"	465–665 "	200 "
Shales,	"	665–733 "	68 "
Clinton,	"	733–760 "	27 "
Red Medina,	"	760–862 "	102 "
White Medina,	"	862–881 "	19 "
Red shale to bottom of well, at			888 "

Some sulphur gas was found at 505 feet in the Niagara, and good gas in the white Medina at 864 feet. This well is located on the east side of the Ransom road, near the West Shore railroad tracks.

Clarence Well No. 2 is located beside the brook about thirty rods north of Main street. It is about 880 feet deep. In July, 1895, the gage showed 400 lbs. pressure. The two wells supply thirty-five houses with gas.

The Akron Wells. There are three borings at Akron, known as the Old Well, Well No. 1, and Well No. 2. The Old Well was put down in 1889 or 1890 in the eastern end of the village, near the Bloomingdale road. Well No. 1 is located in the bed of the creek, about half way between Falkirk and the West Shore railroad; and Well No. 2 is about 300 yards west of the West Shore railroad station on the north side of the track.

The following record of Well No. 1 was furnished by Mr. J. W. Stearns:

Drift,		32 feet.
Salina,		400 "
Niagara,	400–590 feet,	190 "
Shale,	590–650 "	60 "
Clinton,	650–685 "	35 "
Red Medina,	685–762 "	77 "
White sand,	762–787 "	25 "
Red shale,	787–805 (bottom),	8 "

All the preceding wells, together with the Almshouse and Bennett wells, in the city of Buffalo, are located upon the rocks of the Salina group.

Natural Gas in Buffalo.

Wells at the Almshouse, Main street, near the City line. Two wells were sunk here to provide fuel and lights for the almshouse, one being drilled by Mr. M. McIntyre, and the other by James Woodring. The first well was 800 feet deep, getting gas in the white Medina near the bottom, with a pressure of 105 lbs. in thirty minutes. Well No. 2 was drilled to the depth of 1,000 feet, but struck gas at about the same level as the first, 800 feet. The two wells are now coupled together and used to furnish heat for cooking throughout the buildings. At first the gas was used under the boilers, running four forty horse power and two forty-five horse power boilers; but later coal was substituted for this purpose and gas reserved for the ranges. The original rock-pressure was 325 lbs., and the wells are said to furnish nearly as much gas as they did at the beginning. Information regarding the above wells was furnished by Professor Franklin W. Barrows and Mr. Winspear, engineer at the almshouse.

Kensington Well. This well was sunk near the railroad tracks at the north end of the Spaulding Machine Shops. No gas was found and no record kept of the rocks through which the drill passed.

A well was sunk for water at the Grattan & Jennings quarry, Amherst street and Delaware, Lackawanna railroad, without finding gypsum. The well was one hundred feet deep.

Wells of the Buffalo Cement Company. Near the Main street crossing of the New York Central Belt-line is a group of twelve wells, eleven of which have been drilled by the Buffalo Cement Co. Of the first three wells Mr. Charles A. Ashburner has given an account,* which I quote:

"Well No. 1 was drilled in 1883, with a diamond drill. * * * This well shows gas in a very limited quantity at a depth of 451 feet, 9 inches, which slightly increased in volume down to 490 feet, 6 inches, when the drilling ceased. The gas rock, as shown by the cores, is a very compact sandstone with numerous pin-point openings.

"Well No. 2 was put down in 1884 to a depth of 1,305 feet, but proved unsatisfactory. No salt was found and but little salt water; and no perceptible increase of gas was obtained beyond that shown in Well No. 1. Mr. L. J. Bennett writes that from the best information based upon his drill-notes, the various rocks penetrated in Well No. 2, were as follows:

Lower Helderberg limestone,	50 feet.
Salina shales,	550 "
Niagara and Clinton limestone and shales,	185 "
Medina sandstone,	520 "
Total,	1,305 feet."

* See "Petroleum and Natural Gas in New York State," by C. A. Ashburner, p. 19.

In the above record the rock called "Lower Helderberg" is probably the water-lime of the upper Salina. This well was located only six feet from Well No. 1.

Dr. Julius Pohlman, of Buffalo, examined the samples from Well No. 2. His record, quoted from Mr. Ashburner's report, is as follows:

"Beginning at a spot where the rocks of the water-lime group, suitable for the manufacture of cement, had been removed, and which is seventy feet above the level of lake Erie, or 643 feet above tide-water, the drill encountered the following strata:

From 1– 25	feet,	Shale and cement rocks in thin streaks.
25– 30	"	Tolerably pure cement rock.
30– 43	"	Shale and cement rock in thin streaks.
43– 47	"	Pure white gypsum.
47– 49	"	Shale.
49– 61	"	White gypsum.
61– 62	"	Shale.
62– 66	"	White gypsum.
66– 73	"	Shale and gypsum, mottled.
73– 131	"	Drab-colored shale with several layers of white gypsum, measuring eighteen feet in all.
131– 133	"	Dark-colored limestone.
133– 137	"	Shale and limestone.
137– 140	"	Dark-colored compact shale.
140– 720	"	Gypsum and shale, mottled, and in streaks.
720– 725	"	Limestone.
725– 760	"	Soft red shale.
760– 785	"	White solid quartzose sandstone, very hard.
785–1305	"	Soft red shale.

"At 1,305 feet the drill was stopped. Permanent water was struck at forty-three feet; gas of fair quality as well as quantity, at 452 feet; salt water, leaving on evaporation about twelve per cent. of salt, was found at 555 feet. A shaft, twenty feet square, was sunk on the premises later, for the purpose of determining the feasibility of mining the gypsum, but the rush of water through the gypsum layer at forty-three to forty-seven feet, was so strong that a pump with a capacity of 2,000 gallons per minute failed to make any impression upon it, and the attempt was abandoned."

Well No. 3, according to Mr. Ashburner, was 517 feet deep, striking gas at about 460 feet. After torpedoing the well the gage showed sixty pounds pressure in fifteen minutes and 142 pounds maximum rock pressure. Six months later it gave 27,600 cubic feet in twenty-four hours, 865 feet from the well, by meter measurement.

The other wells range from 517 to 565 feet in depth, and show essentially the same geologic conditions as the preceding. All the wells were connected together and the gas piped to the cement works, where it was used as fuel under the boilers and to houses along Main street, supplying in the latter about thirty-five fires. Mr. Bennett informs me that the gas was measured for one season and a daily record kept of the amount consumed. The meter showed from 58,000 to 80,000 cubic feet per day, 65,000 cubic feet being, in his opinion, a fair average. The total amount which passed through the meter during the season was 18,321,600 cubic feet.

The core of Well No. 1 is now in the possession of the Buffalo Society of Natural Sciences.

The Jefferson and Best streets group. In the vicinity of Jefferson and Best streets is a group of thirteen wells which were at one time very productive, but are now partly filled with water and give very little gas. The first of these was drilled in 1889 by Gerhard Lang, on his property at the northeast corner of Jefferson and Best streets. This proving successful, he afterwards drilled three more, two of which were good. One of these wells supplied two boilers at his brewery for a year. After that the pressure gradually decreased and at present all four wells are abandoned.

In the same year, Mr. George Rochefort drilled two wells on the southeast corner of the same streets, opposite Lang's property. These were about 1,000 feet deep. Well No. 1 furnished fuel and lights for his brewery, running four boilers and a malt-kiln, and displacing about thirty tons of coal a day. The gas from Well No. 2 was piped to private houses. Mr. Rochefort informs me that the pressure in Well No. 1 was, at the start, 525 pounds, and in Well No. 2, 490 pounds.* At present the pressure is about seventy-five pounds. According to Professor F. W. Barrows, one of these wells was 800 feet deep, and the other 1,100 feet.

Mr. C. Schuler, near the southwest corner of Best and Jefferson streets, has a well which was drilled about the same time as the Rochefort wells. It is about 1,000 feet deep and at one time yielded a fair amount of gas. At present it is full of water and furnishes only gas enough for one house.

Four other wells were drilled on lots fronting on Jefferson, between Best and High streets, known respectively as the Steffan, Weppner, Everson and

* A record obtained by Professor Barrows in 1890, gives pressure at that time as 200 pounds and 150 pounds.

Ruhl wells. Two more were located in the rear of these on an alley running west from Berlin street. The relative location of these is shown by the accompanying map. The Everson well, in the rear of 971 Jefferson street, had, according to the owner, Mr. Edward L. Everson:

Drift,		40	feet.
Salt water,	at	700	"
Gas sand (white Medina with gas),	"	940	"
Well was drilled to	"	1,010	"

At the start the gage showed 300 pounds rock-pressure, which had fallen, at the time of my visit, to fifty pounds. The hole is now partly full of water which has to be removed at frequent intervals with a "Klein" pump. Professor F. W. Barrows says of this well: "It gave a pressure of 280 pounds in twenty-five minutes, and furnished enough gas to supply thirty or more families with fuel and lights. It was left wide open for months, allowing the gas to escape into the air."

Well corner Sherman and North streets. (Drilled by Mr. Mook; record from Professor F. W. Barrows.)

Clay,	16 to	20	feet.
Limestone, Corniferous,	"	122	"
Limestone, water-lime,	"	150	"
Reddish brown water-lime,	at	150	"
Red sand and gas,	"	860	"
Red sand and gas,	"	875	"
Gas,	"	935	"
Gas,	"	960	"
Red shale,	from 960 to	1,200	"

The rock-pressure in this well was 375 pounds, the pressure running up to 150 pounds in twelve hours.

Well at Cook's Distillery, East Side of Spring street, between Broadway and Sycamore. (Drilled by Mr. Mook; record from Professor Barrows.)

Flint,	80 to	125	feet.
Slate and gypsum, in streaks,		200	"
Limestone,	from 300 or 400 to	800	"
Medina sandstone,	100 "	900	"
White sandstone,	between 900 and	1,000	"
Red shale below.			

No comment accompanies the above notes which were evidently given approximately from memory. Mr. Mook thinks the well was sunk to the Trenton at about 3,029 feet.

Well of Julius Binz, Broadway Brewery, corner Broadway and Smith streets. (Record, approximate, from Professor Barrows.)

Flint and lime,	700 feet.	
Red sand,	200 "	
White sand,	100 "	(?)
Soft red shale,	1,000 "	
Hard grey rock,	800 "	

Sulphur gas was found between 600 and 700 feet. White sand with some gas at about 950 feet, and gas in soft red shale at 1,944 feet. No more gas was found in the well which was drilled to 2,760 feet.

The rock-pressure, in 1890, was seventy to eighty pounds in six hours, but the gas obtained would run an eighty horse power boiler only an hour at a time without "rest." The well supplied twenty-two ordinary gas-burners and the surplus was used with coal in the furnaces. The gas in this well ceased flowing on the last day of the year 1893. At night the burners showed the usual pressure, but on the morning of January 1st the gas had stopped entirely and none has been produced since.

Wagner Gas Wells, Wagner Car Shops, Broadway near City line. Two wells were put down here, the first to 1,200 feet and the second to 3,150 feet. According to Professor Barrows, Well No. 1 showed:

Red sand, with sulphur gas	at	790 feet.
Struck gas	"	1,000 "

The rock-pressure was 375 pounds at first.

Well of German-American Brewing Co., corner High and Main streets. (From Mr. Storck, Superintendent.) This well was drilled, in 1891, to a depth of 1,004 feet to obtain fuel for the brewery. A very little gas was found at 800 feet, but not enough to be of use. Water at a temperature of about 50° F., was found in abundance between 350 and 400 feet from the top, and is used to cool the beer. The cold water takes the place of ice and in that way has paid the cost of drilling the well.

Urban Well, on Oak street, 170 feet north of Genesee. (Drilled by Mr. Mook. Record by Professor Barrows.) This well is 2,000 feet deep and had a very little gas at about 1,000 feet. It is now furnishing only enough for one street-lamp.

Well at Water Works. (From Superintendent Knapp.) At 900 feet enough gas was found to warm a house. Well was sunk to 2,020 feet without finding more. No record of rock passed through by the drill was kept.

Buffalo Gas Light Co., corner Jackson and West Genesee streets. This well is located in the rear of the gas works near Fourth street and the Wilkeson slip. It was bored in 1872 to see whether gas existed there, and if so, whether this could be utilized for illuminating purposes. A small quantity of gas was found which was used as fuel under the boilers.

Mr. Boore, the superintendent, informs me that he measured the gas for twenty-four hours, and the meter showed 14,000 cubic feet. After ten or twelve days the flow of gas diminished to a quantity sufficient to furnish only one or two ordinary gas jets and the well was abandoned. The well seems to have been of the type of "great pressure but little gas," as it is said to have blown out the casing and seed-bag. The supply was not increased by torpedoing. Some sulphur gas was found near the bottom of the well, and water charged with some saline matter which was extremely caustic, and irritating not only to the tongue but to the skin. Information from Mr. Boore and Mr. Krumholz. Record of this well is in existence but could not be found at the time of my visit.

Well in South Park. (Record from memory by Mr. G. C. Shaffer, who was present while well was being drilled in July, 1895.)

Soil,	42	feet.
Shale and limestone,	280	"
Flint (?)	120	"
Limestone (?)	550	"
Shale,	60	"
Red Medina,	80	"
Shale,	20	"
Gas-sand,	16	"
Red shale,	600	"
Red sand,	300	"
White shale,	600	"
Brown shale,	200	"
Red shale,	100	"
Into Trenton,	320	"

The measured distance to the top of the Trenton was 2,960 feet. The drill passed through a part of the Marcellus at the top, Mr. Shaffer estimating it at sixty feet. Owing to the presence of the Stafford limestone so near the Corniferous it was not easy to distinguish them apart.

Hamlin Wells, American Glucose Works, near Elk street market. Two wells were put down here to furnish fuel and lights for the Glucose Works. Well No. 1 was bored in 1888 or 1889, near the northeast corner of East Market and Perry Streets, James Woodring doing the drilling. The written record of the well and a set of samples of drillings have been lost. Professor F. W. Barrows had access to the latter in 1890, and has fortunately preserved the following memoranda.

	42	feet,	Drift.
At	42	"	Chocolate-colored limestone.
	60	"	White and grey limestone.
	150	"	Limestone.
	650	"	Grey shale and gypsum (salt water).
	675	"	Sandy, with spots of iron.
	726	"	Like the preceding.
	800	"	Grey slaty lime.
	850	"	Harder grey limestone.
	905	"	Rusty red sand, chestnut color.
	910	"	Same, but lighter color.
	915	"	Same, but lighter color.
	920	"	Same, but lighter color.
	925	"	White sandstone, rusted so as to look red.
	930	"	Dark red or brown, fine grains.
	940	"	Light grey, rusty patches, traces of oil.
	955	"	Like the last, but more rusty. Gas.
	962	"	Same, but finer grains. More gas.
	967	"	Greenish grey; large grains light-grey and others dark-red, all of a shaly appearance.
	1,038	"	Dark brown shale.

The rust mentioned by Professor Barrows in several samples was probably caused by chips from the drill oxidizing in the air. This well, according to Professor Barrows, was 1,050 feet deep. Mr. C. Wesley, of the Glucose Co., thought the well was 1,170 feet deep, but had no written record. The supply of gas from this boring was very small although the rock-pressure was strong. At the time of my visit in November, 1885, it gave about enough gas to supply one or two ordinary gas burners.

Well No. 2 was drilled in May, 1890, on the east side of Chicago street, 600 feet from Scott street. No gas was found here and the well was allowed to fill up.

Well at the Buffalo Chemical Works, Abbott road and Elk street, near Buffalo creek. (From Mr. S. V. Fowler, superintendent, and James Woodring, driller.) In 1880, a well was put down here to a depth of 250 feet where a copious supply of water was found sufficient to fill the pipe and flow above the surface of the ground. The water, however, was heavily charged with sulphuretted hydrogen which unfitted it for use.

Later, wells were sunk for water at the oil refinery, a quarter of a mile up the creek where the Atlas Works now are. The same vein of water was reached and used to cool the condensers. Large pumps were used to furnish the great quantities necessary, drawing upon the supply so that the water ceased to flow at the Chemical Works. The latter well was then deepened to 1,032 feet, striking the Medina white sand. Here a small flow of gas was obtained, sufficient for the laboratories where it has been used ever since. As the Chemical Works were then outside the limits supplied with city gas, the natural product was a great convenience and has paid cost in that way. The pressure in November, 1885, was forty pounds. This well is located very near the southern limit of the Corniferous limestone. Fifty feet of drive-pipe were used, resting directly upon the limestone.

Well at the Snow Steam Pump Works, near Bailey avenue and the Western New York and Pennsylvania railroad. (Record from Mr. M. McIntyre, driller.)

Drift,	52 feet.	
Limestone and flint,	140 "	192 feet.
Limestone and shales, changing in color,	425 "	617 "
Chocolate sand (limestone?),	105 "	722 "
Sulphur gas and a strong flow of salt water about the middle. Water cased off at 700 feet. Shales, dark in color, with small shells,	40 "	762 "
Red sand, varying in color from dark red to a very pale red,	120 "	882 "
Shales and limestones, varying in color,	40 "	922 "

White sand, with gas, similar to the white Medina,	15 feet,	937 feet.
Shales, white and red, soft-drilling,	50 "	987 "
White Medina sand, with gas,	20 "	1,007 "
Red shale to bottom,	18 "	1,025 "

Above record from the original kept at the time of drilling.

A well was also sunk at the Atlas Works, about midway between the last well and the Buffalo Chemical Works. No record of this was obtainable; but Mr. McIntyre informs me that the rocks passed through by the drill were almost identical with those at the Snow Pump factory, so that one record would answer for both.

There is also a well on Grey near High street, of which no record was obtained. The geologic conditions are said to be nearly the same as in the Sherman-North well.

The Schüsler Brewing Co., corner Emslie and Clinton streets, have a well 1,100 feet deep. At first enough gas was obtained to light the brewery, but it has now ceased to flow. The gas horizon here was 200 feet from the surface. Very little gas was found in the Medina.

Other Wells Outside the City of Buffalo.

Well No. 2, at Depew. (J. W. Stearns, driller.)

Drift,	34 feet.
Corniferous, water-lime and Salina shales,	560 "
Niagara,	200 "
Shales,	60 "
Clinton,	30 "
Red Medina,	90 "
White Medina (no gas),	12 "
Red shale to 2,150 feet.	1,164 "
Oswego sand,	75 "
Shale to top of Trenton at 2,855 feet,	630 "
Through Trenton at 3,575 feet,	720 "
Dark grey sandstone to 3,685,	110 "

Some gas was found at about 1,700 feet, and a little salt water in the lowest sandstone. Well No. 1 was bored about 200 yards east of No. 2, and had essentially the same record down to, and through the white Medina. Both wells were started upon the Corniferous limestone, about one and one half miles from the southern limit of the outcrop. Pressure in No. 2 is said to be 620 pounds per square inch. A company is now being formed to pipe the gas through the village of Depew.

Alden Wells. Five wells have been sunk here, four of which are started upon the upper part of the Marcellus shale near its junction with the Hamilton, and the other a little farther south upon the Hamilton shale. A pocket of gas was found in one well sufficiently strong to lift the tools from the well. Mr. J. W. Stearns thinks this was above the Corniferous limestone. The largest supply was found in the Medina. About 100 houses are supplied with fuel from these wells and at present there is no appreciable diminution in the pressure. The following data regarding one well were furnished by Mr. Best, who has charge of gas distribution at Alden:

Soil,	38	feet.
Slate (casing),	220	"
Top of Medina,	1,190	"
Medina,	90	"
Pocket,	20	"

Well drilled to 1,300 feet.

The top of this well is about thirty feet below the level of the railroad station.

Lancaster Wells. A well was sunk a few years ago on the left bank of Cayuga creek, where it begins to widen to form lake Como. Mr. James Payne informs me that the drill stopped in red shale at 1,350 feet. No gas of any consequence was found. Another boring, said to be about 300 feet deep, was made on the Lawson road about a mile south of the Como well. A little gas was reported here, but I have not been able to verify the report. A well was also drilled on the Borden road about eighty rods south of the Buffalo and Lancaster electric railroad. Mr. James Woodring, who bored the well, informs me that the well was 1,200 feet deep. The white Medina was here but four feet thick and no gas was found. These wells are located a little above the Stafford limestone of the Marcellus.

Well at Gardenville. July 1885.*

Marcellus shale,	60	feet.
Limestones (Corniferous and water-lime),	205	"
Salina shales to Niagara,	800	"

* See Report State Geologist, 1885.

A full record of this well was not obtained, the drill having penetrated only about fifty feet into the Niagara at the time of my visit. Some gas was found on the top of the Niagara, enough for one or two stoves, and brine in a few feet of shale a short distance above.

Father Baker's Well, West Seneca. This is located in the village of West Seneca, 175 yards east of the present terminus of the electric railway. Mr. Woodring, who drilled the well, informs me that it was completed in February, 1891. It was cased to 900 feet and was 1,133 feet deep when finished. A thirty-quart shot of nitro-glycerine was exploded in the gas sand, and the pressure immediately ran up to 400 pounds in thirteen minutes, with a maximum rock pressure of 600 pounds. The Rev. Mr. Baker informs me that the pressure is now 375 pounds, while he is using it. The gas supplies the church and school buildings, saving $3,000 a year in fuel, and also furnishes fifty families with heat and light.

The Reed Well, located one hundred yards further east, is also a good well, the owner claiming 600 pounds rock pressure.

Well on Eli B. Northrup's Farm, Spring Brook. (Completed December 17, 1893.)*

Drive pipe,		30	feet.
Casing,		174	"
Flint,	at	390	"
Through hard rock,	"	530	"
Salt water,	"	1,050	"
Top of Niagara,	"	1,055	"
Slate,	"	1,205	"
Sulphur gas,	"	1,243	"
More gas,	"	1,265	"
Clinton,	"	1,280	"
Top of Medina,	"	1,308	"
Top of gas sand,	"	1,388	"
Through gas sand,	"	1,402	"
Bottom of well,	"	1,410	"

Well on Elbert More farm, Spring Brook. (E. H. Argue, driller.)

Soil,	to	17	feet.
Fresh water,		47	"
Casing,		110	"

* Records marked with an asterisk were furnished by the South Buffalo Natural Gas Co

Shale to flint,		435	feet.
Through flint,	at	600	"
Niagara limestone,	"	935	"
Sulphur gas,	"	1,100	"
Sulphur water,	"	1,165	"
Shale (sixty feet),	"	1,245	"
Clinton,	"	1,325	"
Top of Medina (?),	"	1,433	"
Gas sand,	"	1,436	"
Gas sand,	"	1,438	"
Bottom of gas sand (white),	"	1,460	"
Red rock (800 feet),	to	2,260	"
Black shale, 900 feet, to Trenton,		3,100	"

Well in Eighteen-Mile creek, near Idlewood. (Record by Michael McIntyre, driller.) Well started on the Hamilton shales, near the Encrinal limestone.

Fresh water,	at	70	feet.
Cased out,	"	100	"
Corniferous limestone,	"	270	"
Bottom of Corniferous,	"	520	"
Shale and limestone,	to	945	"
Salt water and some gas,	at	1,000	"
Cased off,	"	1,025	"
Shale and limestone,	to	1,150	"
Small showing of gas (in Clinton),	"	1,205	"
Red Medina,	1,205 "	1,320	"
White Medina,	1,320 "	1,345	"

The showing of gas was so small that the well was not torpedoed. Mr. McIntyre is of the opinion that a shot of nitro-glycerine would have made this well a fair producer. At present it furnishes about enough gas for a grate.

Well on William J. Heiser farm, Woodlawn Beach, Hamburg township. (From Mr. Philip Lerue, contractor and driller, Titusville, Pa.)

Soil,	7	feet.
Marcellus shale,	125	"
Lime and flint, very hard,	140	"

Slate and shells to 825 feet,	653 feet.
Here got the "sulphur sand,"	80 "

With quite a flow of gas and some salt water.

From 733 to 1,000 feet, soft rock,	267 "
Red Medina at 1,000 feet,	110 "

Struck gas sand at 1,153. Gas sand seventeen feet thick, with very little gas. Total depth of well, 1,296 feet. Stopped in red shale.

Well on John M. Fick farm, West Seneca township. (W. H. Curtis, driller. Completed, June 2, 1894.*)

Drive pipe,		26	feet.
Casing,		123	"
Flint,	at	318	"
Through flint,	"	509	"
Niagara,	"	890	"
Sulphur gas,	"	1,020	"
Water and gas,	"	1,060	"
Through water and gas,	to	1,132	"
Slate,			
Clinton,	at	1,200	"
Medina sand,	"	1,223	"
Through Medina sand,	"	1,308	"
Gas sand,	"	1,326	"
Through gas sand,	"	1,337	"
Pocket,	to	1,413	"

Well on Carl Saitz farm, West Seneca township. (Completed August, 1894. Good well.)*

To flint,	at	366	feet.
Through flint,	"	528	"
Top of Niagara,	"	915	"
Bottom of Niagara,	"	1,172	"
Top of Clinton,	"	1,242	"
Bottom of Clinton,	"	1,264	"
Gas sand,	"	1,360	"
Through gas sand,	"	1,375	"
Drilled,	to	1,425	"

Well on John J. Clarris farm, West Seneca township. (Drilled by H. W. Curtis; completed December 2, 1893.)*.

Drive pipe,		18	feet.
Casing,		94	"
Flint,	at	190	"
Through flint,	"	365	"
Niagara,	"	740	"
Sulphur gas,	"	841	"
A little water,	"	856	"
More water,	"	880	"
Through Niagara,	"	975	"
Clinton,	"	1,052	"
Medina,	"	1,075	"
Through Medina,	"	1,160	"
Gas sand,	"	1,171	"
Through gas sand,	"	1,185	"
Bottom of well,	"	1,189	"

Well on Anthony Solly farm, West Seneca township. (Drilled by H. W. Curtis; completed September 19, 1894. Well dry.)*

Drive pipe,		18	feet.
Casing,		92	"
Flint,	at	188	"
Through flint,	"	354	"
Niagara,	"	725	"
Sulphur gas,	"	855	"
Water,	"	910	"
Through water,	"	985	"
Clinton,	"	1,045	"
Medina,	"	1,085	"
Through Medina,	"	1,170	"
Gas sand,	"	1,179	"
Through gas sand,	"	1,193	"

Well on J. A. Timmerman farm, West Seneca township. (Stearns & Leopold, drillers; completed April, 1894. "Dry hole.")*

Drive pipe,		17	feet.
Casing,		103	"
Hard rock,	at	360	"

Niagara,	at	980	feet.
Water and gas,	"	1,100	"
Slate,	"	1,180	"
Clinton,	"	1,250	"
Medina sand,	"	1,275	"
Some gas,	"	1,287	"
Slate,	"	1,355	"
Gas sand,	"	1,368	"
Bottom of gas sand,	"	1,376	"
Bottom of well,	"	1,395	"

Well on John Schmalz farm, West Seneca township. (Completed August 17, 1894; "Dry hole.")*

Drive pipe,		50	feet.
Casing,		112	"
Flint,	at	188	"
Through flint,	"	350	"
Niagara,	"	740	"
Water,	"	912	"
Through water,	"	990	"
Clinton,	"	1,073	"
Medina,	"	1,095	"
Gas sand,	"	1,155	"
Through gas sand,	"	1,180	"
Gas sand,	"	1,186	"
Through gas sand,	"	1,200	"

Well on the John Sax farm, West Seneca township. (Drilled by Stearns & Leopold.)*

Drive pipe,		17	feet.
Casing,		103	"
Top of flint,	at	185	"
Through flint,	"	365	"
Top of Niagara,	"	800	"
Salt water and some gas,	"	910	"
Top of slate,	"	995	"
Top of Clinton,	"	1,063	"
Top of Medina,	"	1,090	"

Top of gas sand, ...	at	1,175	feet.
Bottom of gas sand, ...	"	1,186	"
Bottom of well, ...	"	1,194	"

Nagle Well, West Seneca township. (Sunk January, 1895.)*

To top of flint, ...	240	feet.
" bottom of flint, ...	425	"
" top of Niagara, ...	800	"
" bottom of Niagara, ...	1,040	"
" top of Clinton, ...	1,120	"
" bottom of Clinton, ...	1,148	"
" top of Medina, ...	1,148	"
" bottom of Medina, ...	1,228	"
" top of gas sand, ...	1,237	"
" bottom of gas sand, ...	1,247	"
Total depth of well, ...	1,300	"

Well on Herman Metzler farm, West Seneca township. (Completed about September 10, 1894. A good well.)*

To top of flint, ...		280	feet.
" bottom of flint, ...		462	"
" top of Niagara, ...		805	"
" bottom of Niagara, ...		1,085	"
" top of Clinton, ...		1,115	"
" top of red Medina, ...		1,185	"
" bottom of red Medina, ...		1,255	"
Shale to top of gas sand, ...	at	1,267	"
To bottom of gas sand, ...		1,279	"
Depth of well, ...		1,341	"

Well on Anthony Groell farm, West Seneca township. (Drilled September to October, 1893, by Stearns & Leopold; completed October 23, 1893.)*

Drive pipe, ...		19	feet.
Casing, ...		104	"
Flint, ...	at	180	"
Through flint, ...	"	340	"
Top of Niagara, ...	"	795	"
Sulphur gas, ...	"	845	"
Through Niagara, ...	"	995	"

Slate to Clinton,	at	1,070	feet.
Medina,	"	1,105	"
Gas sand,	"	1,188	"
Through gas sand,	"	1,202	"
Bottom of well,	"	1,209	"

Well on George Reichert farm, West Seneca township. (H. W. Curtis, driller; completed January, 1894.)*

Drive pipe,		18	feet.
Casing,		110	"
Flint,	at	225	"
Through flint,	"	390	"
Niagara,	"	785	"
Sulphur gas,	"	930	"
Through sulphur gas,	"	1,060	"
Clinton,	"	1,172	"
Medina,	"	1,192	"
Through Medina,	"	1,207	"
Gas sand,	"	1,220	"
Through gas sand,	"	1,229	"
Bottom of well,	"	1,233	"

Well on Henry Eisenhart farm, West Seneca township. (Completed February, 1895. Production in twenty-four hours, 800,000 feet).*

Thickness of top sand,	80	feet.
Thickness of bottom sand,	12	"
Thickness of pocket,	33	"
Depth of well,	1,348	"

Roth Homestead Well No. 1. Reserve. (Thomas Argue, driller.)* Drilled to 1,221 feet June, 1894.

Well No. 6 on Shoop farm. (Drilled by H. W. Curtis.)*

Drive pipe,		46	feet.
Casing,		870	"
To bottom of Niagara,		970	"
Clinton,	to	1,045	"
Medina,	at	1,070	"
Gas sand,	"	1,156	"
Through gas sand,	"	1,166	"
Bottom of hole,	"	1,170	"

John Roth Homestead farm, Reserve, Well No. 1. (W. H. Curtis, driller.)*

Drive pipe,		56 feet,	Drift,	56	feet.
Casing,		140 "	Shale,	140	"
Niagara limestone,	at	750 "	Cornif. and Salina,	554	"
Through Niagara limestone	"	980 "	Niagara,	230	"
Shales to Clinton,	"	1,052 "	Shales,	72	"
Medina,		1,072 "	Clinton,	20	"
Through Medina,		1,160 "	Medina,	88	"
Gas sand,	to	1,168 "	White Medina,	8	"
Bottom,		1,181 "	Red shale (?),	13	"
				1,181	feet.

Well No. 2 on W. S. Roth farm. (October 1894; Thomas Argue, driller.)*

Top of gas sand,	1,205	feet.
Bottom of gas sand,	1,216	"
Pocket,	71	"
Total depth,	1,287	feet.

Well No. 4 on the Will Roth farm, near Reserve. (H. W. Curtis, driller. Struck gas October 15, 1889.)*

Drive pipe,		58	feet.
Casing,		134	"
Flint,	at	183	"
Flint,	to	362	"
Niagara,	at	755	"
Through Niagara,	"	985	"
Slate, 70 feet to Clinton,	to	1,055	"
Medina,	at	1,079	"
A little gas,	"	1,097	"
Through Medina,	"	1,148	"
Gas sand,	"	1,160	"
Through gas sand,	"	1,173	"
Bottom of hole,	"	1,173	"

Schudt Well, Reserve, West Seneca township. (Drilled in October, 1894, by R. W. Argue. 200,000 cubic feet per day.)*

Top of flint,	at	232	feet.
Bottom of flint,	"	390	"

Top of Clinton,	at	1,100	feet.
Top of Medina,	"	1,130	"
Bottom of Medina,	"	1,210	"
Shale to top of gas sand,	"	1,225	"
Bottom of gas sand,	"	1,233	"
Pocket,		60	"
Total depth,		1,293	"

*Schneider Well, on Lot 175, West Seneca township, near Ebenezer.**

To top of flint,	240	feet.
" bottom of flint,	425	"
" top of Niagara,	800	"
" bottom of Niagara,	1,040	"
" top of Clinton,	1,120	"
" top of Medina,	1,148	"
" bottom of Medina,	1,228	"
" top of gas sand,	1,238	"
" bottom of gas sand,	1,247	"
Total depth,	1,302	"

Goodker Well No. 1. (Drilled November, 1894.)*

Top of gas sand,	at	1,357	feet.
Bottom of gas sand,	"	1,370	"
Pocket,		44	"
Total depth,		1,414	"

Schraub Well. (November, 1894.)*

Top of gas sand,	at	1,149	feet.
Bottom of gas sand,	"	1,160	"
Pocket,		6	"
Total depth,		1,166	"

William Shaefer Well No. 1, West Seneca township. (Drilled April, 1894.)*

To top of sand,	1,226	feet.
" bottom of sand,	1,239	"
Pocket,	33	"
Depth of well,	1,269	"

Well No. 2, Robert Ewald farm, Ebenezer, West Seneca township. (Completed May, 1894; 150,000 cubic feet in twenty-four hours.)*

To top of sand,	1,206	feet.
" bottom of sand,	1,213	"
Pocket,	30	"
Depth of well,	1,243	"

Hart Well, Seneca plank road, East Hamburg township. (Record from Mr. G. C. Shaffer.)

Soil,	20	feet.
Shale,	465	"
Flint,	160	"
Limestone (?),	635	"
Slate,	60	"
Red Medina,	80	"
Gas sand,	16	"

Hart Well No. 5. (Completed July 1894.)*

To top of first sand,	1,384	feet.
To bottom of first sand,	1,400	"
Pocket,	14	"
Depth of well,	1,414	"

Hampton Well, one and one-half miles east of the Hart Well, towards Spring Brook, on the Plank road. (Record from Mr. G. C. Shaffer.)*

Soil and quicksand,	50	feet.
Shale,	485	"
Flint,	190	"
Limestone (?),	635	"
Shale,	60	"
Red Medina,	80	"
Gas sand,	30	"

McCarthy Well No. 4, East Hamburg township. (Completed June, 1894.)*

To top of sand,	1,320	feet.
To bottom of sand,	1,332	"
Pocket,	54	"
Depth of well,	1,380	"

Berg Well, East Hamburg township. (Completed December, 1894. 1,300,000 cubic feet per diem.)*

Top of red sand,	at	1,304	feet.
Bottom of red sand,	"	1,339	"
Shale 34 feet to top of white sand,	"	1,373	"
Bottom of white sand,	"	1,387	"
Pocket,	"	4	"
Total depth,		1,391	"

Shorr Well, East Hamburg township, one-half mile west of Webster's Corners. (A "dry hole.")*

To top of gas sand,	1,453	feet.
To bottom of gas sand,	1,478	"
Depth of well,	1,478	"

Well on Miles P. Briggs farm, Duell's Corners, East Hamburg township. (Completed April 15, 1894; Thomas Argue, driller. "A rank duster.")*

Top of flint,	at	650	feet.
Top of Medina,	"	1,538	"
Through Medina,	"	1,623	"
Top of gas sand,	"	1,623	"
Bottom of gas sand and well,	"	1,673	"

Well on F. Boldt farm, East Hamburg township. (Completed April, 1894; H. W. Curtis, driller.)*

Drive pipe,		13	feet.
Casing,		100	"
Flint,	at	349	"
Through flint,	"	520	"
Niagara,	"	925	"
Water,	"	1,050	"
Through water,	"	1,180	"
Slate to top of Clinton,	"	1,240	"
Red Medina sand,	"	1,262	"
Shale,	"	1,351	"
Gas sand,	"	1,360	"
Through gas sand,	"	1,374	"
Bottom of well,	"	1,376	"

Well on Kleis Farm, near Windom, Hamburg township. (Mr. Mook, driller; sunk in August, 1895. Well gives about 75,000 cubic feet per day.)*

Soil,	28	feet.
Shale,	300	"
Flint,	180	"
Limestones and shale to Niagara (?),	640	"
Niagara (?),	75	"
Clinton,	25	"
Red Medina,	80	"
Shale,	30	"
White sand,	15	"

W. P. Roth, Well No. 1, Lot 298, West Seneca township. (H. W. Curtis, driller; completed October 15, 1892. Gas found at 1,079 feet.)*

Casing,		135	feet.
Flint,	at	182	"
Through flint,	"	362	"
Niagara,	"	755	"
Through Niagara,	"	985	"
Shale 70 feet to Clinton,	"	1,055	"
Red Medina,	"	1,079	"
White Medina,	"	1,160	"
Through white Medina,	"	1,173	"
Bottom, at	"	1,173	"

*Diehl Well, Lot 323, West Seneca township.**

Red Medina,	at	1,167	feet.
Gas sand,	"	1,259	"
Through gas sand,	"	1,271	"
Pocket,	"	39	"

J. H. Bassett Well, Lot 31, East Hamburg township, near Windom. (Completed March 28, 1895.)*

Red Medina,	at	1,265	feet.
White Medina,	"	1,348	"
Through white Medina,	"	1,360	"

John Ertel Well, Lot 463, East Hamburg township. (Completed March 24, 1895.)*

Red Medina,	at	1,308	feet.
White Medina,	"	1,398	"

Through white Medina,	1,410 feet.
Bottom of well,	1,447 "
Pocket,	37 "

Titus Well, Windom. (Drilled August 28 to October 21, 1895.)*

Well,	1,314 feet.
Top sand,	16 "
Pocket,	3 "

Saville Well.

Depth of well,	1,502 feet.
Pocket,	16 "
Top sand,	21 "

Bedford Well. (Drilled October 17 to December 3, 1895. 260,000 cubic feet per day.)*

Well,	1,230 feet.
Pocket,	38 "
Top sand,	10 "

Beaver Well, Ebenezer. (1,208 feet deep; good well.)*

East Aurora village. A well was drilled here between May and October, 1893, to the depth of 1,800 feet. It is located near the railroad tracks about 200 yards south of Main street. A very little gas was found, and also brine which produced, upon evaporation, twenty per cent. of salt. The depth at which they were struck was not ascertained.

About two miles southwest of East Aurora, on Cazenovia creek, a well was sunk in the eighties, of which the following is a partial record: †

Shales (Lower Portage Hamilton and Marcellus),	695 feet.
Corniferous limestone (and water-lime ?),	165 "
From the above limestones to salt,	605 "

Saturated brine was found at 1,465 feet, filling the well and running over the top. The stratum in which the brine occurs was reported to be seventy feet thick. No attempt was made to utilize the brine, and the well is now abandoned. At one time considerable gas is said to have escaped from this boring, but at the time of my visit, in August, 1895, the amount would barely support one ordinary gas jet. Surface gas in quantities sufficient to burn, bubbles up from crevices in the bed of the creek in several places near by, and I suppose that the gas found in the well was from the same source, the black shales of the Portage group.

† See Report State Geologist (N. Y.), 1885.

Half a mile further up the same creek a well was drilled for oil, about the year 1875. No record of this is preserved, but it is reported that gas was found at 900 feet, with sufficient pressure to throw water over the top of the derrick.

Well at Pipe Creek, near West Falls. This well was put down in 1865, to the depth of about 1,000 feet. Mr. A. L. Henshaw, who furnished me these facts, says that the pressure at first was sixty pounds. The well is now full of water from which the gas bubbles up vigorously, furnishing about a cubic foot a minute. Another shallower well was bored a little further up the creek, but struck no gas. Surface gas escapes from fissures in the bed of the creek in several places. One crack furnishes enough for four or five gas-burners.

The Colden Well. (Record by Mr. A. H. Hayes.) This well is located one-fourth mile south of the village, on the west side of the creek. It was put down by a stock company of which Mr. Hayes was an officer. Gas was found at 300 or 400 feet in sufficient quantity, as Mr. Hayes thinks, to supply the village with fuel. From the description of the flow, it appears that the well must have been a good one, but the gas was allowed to go to waste. Here, also, there is much surface gas. A water well fifty feet deep, in the village, furnishes enough gas to keep a street-lamp going all the time.

Another well, on the hill between Colden and Boston, was bored about the time the Colden well was sunk. Mr. A. L. Henshaw visited this while drilling was in progress and saw the gas burning. From his description I should judge the flow was not large.

Wells at Patchen, Boston township. Two wells are located here, one in the village near the creek a short distance south of the bridge, and the other some fifty rods further up the creek. Mr. John H. Wait, who worked upon the well while it was being drilled, furnishes me the following information:

Well No. 1 was sunk on the Wait farm, to the depth of 762 feet, by a company from Oil Creek, Pa., about the year 1860. A strong vein of gas was found at 272 feet, which escaped with such force as to stop drilling for three days. The pressure is described as sufficient to lift two men seated upon the ends of a plank laid across the top of the casing.

Later on another company, from Oil Creek, leased farms in this vicinity and put down well No. 2. At 320 feet they struck gas, but the flow was not so strong as in well No 1. At 940 feet they struck a hard rock (the

Corniferous ?) which proved so difficult to drill that the well was abandoned at 1,000 feet. This well still gives a blaze two or three feet high when ignited. Near the old well is a spring which gives off gas all the time. Six other gas springs are also reported from the town of Boston.

The Old Boston Well. This is located on the Henry Jones farm on the east side of the creek three or four miles south of Boston Corners. Mr. H. N. Drake of Findlay, Ohio, has kindly furnished me the following information regarding it:

"In 1878 or 1879, Mr. Chubbuck and myself took the contract to sink the well to the depth of 2,000 feet. For the first 1,000 feet the rock was black shale containing some gas. At 1,225 feet we struck a very hard rock which we called flint and limestone [Corniferous ?]. At about 1,800 feet we got rock-salt about sixty or eighty feet thick, some of which was clear as crystal and some dark in color. The rest of the rock was a sort of rotten sand. At 2,008 feet we struck a vein of mineral water that colored the tools and cable black as ink and had a very disagreeable odor. The depth of the hole was 2,140 feet. There was no sign of oil from top to bottom."

The record of this well is very interesting for the reason that the presence of rock-salt seems to have been discovered here at about the time it was found in Wyoming county, a fact not heretofore published. The horizon of the Corniferous limestone is distinctly defined, and quite probably the water charged with sulphuretted hydrogen was the vein often found in the Niagara elsewhere in Erie county.

Well at Eden Valley. (From Mr. Daniel Schweickhart.) This well is located about a mile east of the village and about thirty feet higher than the railroad station. The well was sunk by Mr. Schweickhart previous to 1884, to obtain water for his brewery. The record given from memory at the time was as follows: *

Shale,	125	feet.
Blue hard rock,	200	"
Black slate,	300	"
Flint, lime and sand,	400	"
Brine in soft rock,	50	"
	1,075	"

This well has since been deepened and furnishes enough gas for his house and brewery.

* See Report State Geologist for 1885

Angola Well. (About 670 feet A. T.) This well is located upon the farm of Mr. Alvin Eddy, three-quarters of a mile south of Angola on the road to Brant Centre. No record of the well is preserved, but Mr. Eddy gives me the following facts from memory:

Struck rock, ...	at	12 feet.
Limestone (Corniferous?), ...	"	800 "
Through limestone (?), a hard rock here, . .	"	1,300 "
Well drilled	to	1,500 "

Some gas was found near the bottom of the well. At present the hole is full of water and gives very little gas.

Mr. J. R. Newton of Angola has a well 450 feet deep on his premises. It is said to furnish sufficient gas to heat his house.

Well at Fenton, near Brant. (Drilled in 1890 and 1891.) The original record of this well is lost. The following facts are furnished by Mr. Clarence M. Fenton, who had charge of the work of drilling the well.

Soil and quicksand, ...		80 feet.
Hard blue rock, ...	to	1,200 "
Vein of water, ...	at	1,300 "
Red sand with good flow of gas, ...	"	1,900 "
Drilled	to	1,952 "

The well was torpedoed with 100 quarts of nitro-glycerine and filled with packer and two-inch piping. When confined the gas pressure runs up to 1,000 pounds to the square inch. When blown off, the well furnishes only gas enough to fill a three-quarter inch pipe, or about 10,000 feet per day. This is used to run the cappers of the Erie County Preserving Co.'s cannery at Fenton, and supplies also two or three stoves. At present the well is three-fourths full of water heavily charged with salt.

While drilling was in progress a greasy rock was found at 1,200 feet, from which there was a flow of gas sufficient to make a flame two feet above the top of the well. At the same time the cable was smeared with a dirty mixture of tar and vaseline, smelling of petroleum.

Wells at Zoar.

Kelley Well, three-quarters of a mile west of Town line. (Completed January 10, 1888; record from Mr. Michael McIntyre, driller.)

Drive pipe, ...	60 feet.
Casing, ...	240 "
Top of Corniferous limestone, ...	1,500 "

First oil (green) and gas,	1,725 feet.
Second oil (amber), with salt water,	1,760 "
To bottom,	1,825 "

Kerr Well. (Begun August, 1888; record from M. McIntyre.)

Drive pipe (through drift),	379 feet.
Casing,	755 "
Top of Corniferous,	1,725 "
Gas,	1,885 "
Depth of well,	2,150 "

This is the largest producing gas well yet found in the county, and probably in the state. Gas was struck on October 27th. There was, at the time, in the well, the string of tools sixty-five feet long, together with more than 1,800 feet of rope, the whole weighing probably two tons. The escaping gas forced everything out of the well and at least 150 feet into the air. The drill, in descending, struck upon its end and penetrated the soil to the depth of fifteen or twenty feet, bending the stem like a wire. The noise made by the gas escaping through a five-inch hole could be distinctly heard at Springville, nearly six miles away. It was ten days before the pressure decreased enough to permit the resumption of drilling, and Mr. McIntyre estimates that during this time the daily flow could not have been less than twenty-five or thirty million cubic feet. The well is now owned by the Buffalo Natural Gas Fuel Co., and is known as the "Freak." Ordinarily it is held in reserve, the pressure gradually rising to about 600 pounds. When an unusual amount of gas is needed, this gas is turned on to the line, and the well furnishes a million feet a day for a period of two or three weeks. By this time the pressure has fallen to about 300 pounds, and the well is shut off and allowed to "rest." In the course of two or three weeks the pressure rises again to 600 pounds, and the well is re-opened.

The horizon in which this gas occurs is probably the upper part of the water-lime, the rock immediately below the Corniferous limestone.

Along the northern outcrop of this rock in Erie county, there is a layer, locally known as "bull-head," which is filled with cavities from the size of a pea up to several inches in diameter. This rock also contains cavernous seams through which subterranean waters flow and appear at the outcrop in copious springs.

The immense volume of gas from the Kerr well indicates that the gas accumulates in a cavity so large that it cannot readily empty itself when opened.

Richardson Well, near Morton's' Corners; Lot 92, Collins township. (Begun March 5, 1889; M. McIntyre, driller.)

Drift,		80	feet.
Casing,		435	"
Top of Corniferous,	at	1,925	"
Small show of gas,	"	2,195	"
Salt water,	"	2,675	"
Salt water, chocolate-colored sand,	"	2,785	"
Through limestone and shale,	"	2,815	"
Red Medina,	"	2,815	"
Through Medina,	"	2,935	"
Limestone and shale to white Medina,	"	2,955	"
Through white Medina,	"	2,990	"
Red shale,	"	2,990	"
To bottom,		3,303	"

Well on Monroe Kelley farm, Zoar, one-half mile west of Kerr Well. (From Mr. Michael McIntyre.) This well showed the greatest thickness of drift known to me in the state, namely, 515 feet.

White Well, Zoar. (Completed July 2, 1892; record by M. McIntyre; controlled by the Standard.)

Drive pipe,	170	feet.
Casing,	460	"
Top of Corniferous,	1,535	"
First gas,	1,570	"
Second gas,	1,605	"
Depth of well,	1,795	"

White Well, No. 3, is 800 feet east of the Kelley Well. White No. 1 is 600 feet east of No. 3. White No. 2 is 1,400 feet east of Well No. 1. Of these No. 1 is the best well.

White Well, No. 1, Zoar flats. (Record by Mr. M. McIntyre.)

Drive pipe,		140	feet.
Top of Corniferous,	at	1,530	"
First gas,	"	1,630	"
Second gas,	"	1,660	"
Depth of well,		1,795	"

Frye Well, Zoar. (Record by Mr. M. McIntyre; 100,000 cubic feet daily.)

Drive pipe,	165	feet.
Casing,	465	"
Corniferous,	at 1,570	"
First gas,	" 1,575	"
Second gas (best),	" 1,655	"
Third gas,	" 1,755	"
Depth,	2,001	"

White Well, No. 2, Zoar flats. (Record by Mr. M. McIntyre. Top of well 20 feet lower than Well No. 1, which is 1,400 feet away.)

Drift,	165	feet.
Casing,	385	"
Top of Corniferous,	at 1,560	"
A little gas,	" 1,565	"
Much salt water,	" 1,790	"
Abandoned,	" 1,800	"

Parkinson Well, top of hill, Zoar. (Record by Mr. M. McIntyre.) This well furnishes about 25,000 cubic feet of gas daily.

Drive pipe,	325	feet.
Casing,	465	"
Top of Corniferous,	at 1,720	"
Show of gas,	" 1,730	"
Bottom of well,	2,021	"

The last well sunk at Zoar, September–October, 1895, is situated about 2,000 feet south of the Parkinson well. It had—

Drift,	60	feet.
Corniferous,	at 1,445	"
Drilled	to 1,802	"

Well on the south side of Cattaraugus creek, opposite Zoar. (Record from Mr. M. McIntyre; no gas worth piping.)

Drift,	80	feet.
Casing,	420	"
Top of Corniferous,	at 1,700	"
Show of oil and gas,	" 1,865	"
Depth of well,	1,950	"

A part of the gas from the Zoar field is piped into Springville, where it supplies about 120 families. The company controlling it is called the Springville Natural Gas Co., of which the officers are: Dr. Brooks, president; H. Leland, treasurer; F. D. Smith, secretary. There is also a board of directors, of which Mr. M. McIntyre is a member.

The Springville Well. (From Mr. Mook, driller; well contains twenty-five feet of rock salt.)

Blue sandstone and shales,	1,800	feet.
Limestones,	750	"
Salt,	at 2,525	"
Well bored	to 2,550	"

At Gowanda, on the Cattaraugus county side of the creek, a well was sunk, in the eighties, by Mr. Silas Vinton, who gave to me the following record:

*Soil,	6	feet.
Shale,	450	"
Sand, with oil and gas,	4	"
Shale to "second sand," where more oil and gas were found,	450	"
Shale,	390	"
Hard rock (Corniferous and water-lime),	400	"
	1,700	feet.

Mr. Charles S. Howland informs me that this well was deepened in February, 1889. The Corniferous limestone was reached at 1,390 feet. Drilling was continued to 2,251 feet, where salt water and mud were found and the well abandoned. The well, when cleaned of water, gives gas enough to fill a two-inch pipe with a light pressure. This well is located near the creek, about 200 yards east of the station.

Another well was drilled over thirty years ago on the Erie county side of the creek within the village limits. Locally it is known as the "Trunk Well." Gas was found at about 860 feet, and the well was drilled about forty feet deeper. This furnished gas for a house for several years, but is now "filled up with a substance resembling glass and nearly as hard."

* Vide Report State Geologist 1885.

Maps.

The location of gas wells and gas territory is shown upon the general map accompanying this report. Where the scale was too small to show details accurately, enlargements of the more important districts have been given. The map of the South Buffalo field was constructed mainly from data furnished by Messrs. E. M. Cobb, President, and C. T. Sloan, Vice-President of the South Buffalo Natural Gas Co., who have allowed me the free use of their maps and the original records of wells drilled under their direction. In this map, wells known to furnish little or no gas are marked (*). Those which were being drilled at the time the information was being collected are marked (†). Wells marked (‡) are either good producing wells now or were at some time. The names, location by lot number, and the character of the wells are shown on the following table designed to accompany the map.

Name of Well.	Lot.	Township.	
Samuel Wasson,	35	West Seneca.	*
Beck,	92	" "	*
C. Wansperg,	121	" "	‡
Solly,	172	" "	*
Sax,	174	" "	‡
W. Schneider,	175	" "	‡
Ebenezer Station,	189	" "	†
Solly,	234	" "	*
Father Baker,	283	" "	‡
Reed,	284	" "	‡
J. Deppler, No. 3,	296	" "	‡
L. Roth, No. 2,	298	" "	‡
Susan C. Schudt,	332	" "	‡
W. Booth,	346	" "	*
Bedford,	359	" "	‡
P. Aubel,	337	" "	‡
Roth Bros.,	336	" "	‡
George Avery,	340	" "	*
G. Diehl,	323	" "	‡
Robt. Ewald,	329	" "	‡
Johanna Schudt,	330	" "	‡
G. E. Clarris,	364	" "	‡
A. Groell,	368	" "	‡

Name of Well.	Lot.	Township.		
C. Schudt,	373	West Seneca.		‡
Herman Metzler,	372	"	"	‡
J. Nagel,	377	"	"	‡
George Reichert,	382	"	"	‡
H. Grotke,	386	"	"	†
J. Timmerman,	395	"	"	‡
	432	"	"	‡
G. Reichert,	421	"	"	‡
William Schaefer,	453	"	"	‡
H. Eisenhart,	422	"	"	‡
J. Fick,	418	"	"	‡
William C. Grotke,	411	"	"	‡
	293	"	"	*
	294	"	"	‡
	370	"	"	‡
	168	"	"	‡
Blossom,	102	Elma.		*
Elma Village,	58	"		‡
Elma Station,	55	"		‡
Springbrook (Albert Moore),	81	"		‡
B. Root,	91	"		*
G. Schmalz,	86	"		*
	448	East Hamburg.		*
	400	"	"	†
C. Spayer,	407	"	"	†
J. Schwartz,	451	"	"	‡
Carl Berg,	454	"	"	‡
Timothy McCarthy,	455	"	"	‡
Duell's Corners (M. P. Briggs),	——	"	"	*
F. Boldt,	458	"	"	‡
G. Seitz,	460	"	"	‡
	463	"	"	‡
Alfred Moore,	469	"	"	‡
Bassett,	31	"	"	*
W. K. Saville,	14	"	"	†
John Johnson,	17	"	"	*
Henry J. Hart,	18	"	"	‡

Name of Well.	Lot.	Township.	
Matthias Schorr,	21	East Hamburg.	*
B. F. Hampton,	11	" "	*
Adam J. Benzig,	26	" "	*
Franklin F. Holmwood,	64	" "	‡
Kleis,	35	Hamburg.	‡
Titus,	32	"	‡
Heiser,	11	"	‡

Wells Outside of Erie County.

The following well records are interesting in connection with the preceding:

Well No. 1, Philip Zavitz farm, located on Lot 35, third concession from lake Erie, township of Bertie, near the town line of Humberston, Ontario, Can. (Record from Mr. E. Coste.)

Soil,		7 feet.	
Corniferous, to	25 feet,	18 "	
Onondaga shale, gypsum dolomites (Salina pd.), to	415 feet,	390 "	
Guelph and Niagara,	415–655 "	240 "	
Niagara shale,	655–705 "	50 "	
Clinton limestone,	705–735 "	30 "	
Medina sand and red shale,	735–846 "	111 "	
Gas in white Medina,	at 836 " sand,	13 "	thick.

At Point Abino gas was found at 500 and 575 feet below the surface, or 193 feet below the bottom of the Niagara limestone.

Well No. 1, Corfu, Genesee county, N. Y.; north of the village. (From Mr. J. W. Stearns.)

Marcellus shale,	30 feet.
Corniferous,	180 "
Limestone and shale,	458 "
Niagara limestone,	250 "
Niagara shale,	70 "
Clinton,	30 "
*Medina,	110 "
Red shale to bottom of well,	20 "

* Notes say "white Medina."

Well No. 1 on the Bradshaw farm, near Coomer P. O., District 13, Lot 36, town of Newfane, Niagara county, N. Y. (Record from Mr. E. Coste.)

Well begun in red shales of the Medina group.

Trenton,	at 1,435 feet.		
Continued	to 2,115 "		680 feet.
Calciferous sandrock,	to 2,125 "		10 "
Laurentian,	at 2,125 "		
Drilled into Laurentian,			9 "
Depth of well,	2,134 feet.		

Well No 2 (drilled January 4, 1892; started on the red Medina. Record from Mr. E. Coste.)

Drive pipe,			24 feet.
Red Medina, dark Hudson river and Utica shales,	to 1,200 feet.		
Trenton,	1,200–1,910 "		710 "
Calciferous,	1,910–1,930 "		20 "
Hydromica and dark green schists of the Archean, from	1,930–1,980 feet.		50 "

No Potsdam sandstone was recognized. This well had a little gas, from 1,912 to 1,918 feet. Cased to 243 feet, and was dry after that.

Record of Well at Fulton, N. Y. (Mr. J. W. Stearns, driller.)

Drift,		43 feet.
Red sand,	to	690 "
(A little gas at 320 and 370 feet.)		
Oswego grey limestone,	from 690 to	1,070 "
Sand and limestone,	"	1,200 "
Limestone and shale,	"	1,460 "
Black shale,	"	1,640 "
Top of Trenton,	"	1,640 "
Gas,	1,680 "	1,685 "
Gas,	at	1,865 "
Gas,	"	1,875 "
Gas,	"	1,900 "
Drilled	to	1,935 "

A well in the village of Canandaigua, N. Y., has fifty-one feet of rock salt, according to Mr. James Woodring, of Buffalo, who sunk the well.

A well was also put down on the Indian Reservation at Versailles, N. Y., to the depth of 216 feet. No gas was found, but good water was obtained.

Surface Gas.

Small quantities of gas escape from crevices in the rocks in many places within the county. The most abundant supply comes from the Portage rocks in the horizon of the lowest sandstones along a line connecting roughly Wales Centre, East Aurora, North Boston and North Collins, and extending eight or ten miles southeasterly. The lower Portage shales also furnish supplies from rock crevices and water wells, and the Hamilton and Marcellus some from similar sources.

A few of the points at which gas has been noticed are at Eighteen-Mile creek, near the lake; between Wales Centre and East Aurora, where the town-line road crosses a brook; near Holland; in Cazenovia creek, between East Aurora and Griffin's Mills; on Pipe creek, near West Falls; in many places in the town of Boston; in the ravine between Shirley and North Collins and near Lawton's station.

Gas Horizons.

In the wells which have penetrated the Trenton limestone in Erie county, no gas has been found. The Bradshaw well, No. 2, in Niagara county, however, furnished a little in that rock. The Depew well. No. 2, struck a paying streak of gas in the red shale, a little less than 1,700 feet below the top of the Corniferous limestone. Nearly all the gas obtained within the limits of Erie county comes from the "white Medina" sandstone, although some is found in the higher "red Medina," and occasionally in the Clinton. The gas obtained from these sources is comparatively free from sulphur and makes excellent fuel and a fair illuminant.

The upper part of the Niagara group furnishes a variable amount of gas in many of the wells throughout the field. The most characteristic constituent of this gas is sulphuretted hydrogen (H_2S), commonly known as "sulphur gas." Water in contact with the gas dissolves out the H_2S, becoming "sulphur water." Hence sulphur gas and sulphur water may occur either together or separately, and the presence of either in the same formation may determine the gas horizon. In ten wells it was found at depths varying from 25 to 172 feet below the top of the Niagara, two having it at about fifty feet and three at 130 feet. In six wells the average distance was 130 feet, which may be assumed as the horizon where we would be most likely to find it.

Wells No. 1, No. 2 and No. 3, at the Buffalo Cement Works, struck gas at 450 to 460 feet, or about 400 to 410 feet below the Water-lime. Allowing

386 feet for the Salina shales, this gas horizon would be fourteen to twenty-four feet below the top of the Niagara. Getzville well No. 17 struck some gas at 265 feet, which was unquestionably in the Salina shales; but the greater part was found at 474–481 feet. The record indicates Niagara at 361 feet or 292 feet from the surface of bed rock. The gas horizon was 113 feet lower and was undoubtedly in the Niagara.

In connection with this it is interesting to examine the record of the Boston well. Rock-salt was found here 575 feet below the top of the Corniferous or a probable distance of 407 feet below the water-lime. At 783 feet below the top of the Corniferous, or 615 feet below the water-lime, a vein of water was found, evidently sulphur water, which was very offensive and colored the drill and cables black. As the Salina shales are thickest in the trough containing the deposit of rock-salt, it is apparent that the drill in this well had penetrated some distance into the Niagara limestone. The Corniferous limestone and water-lime appear to act as the reservoir for gas in the Zoar field. In three wells quite a show of gas was found within ten feet below the top of the Corniferous, one had gas at forty-five feet, and two others at seventy and eighty-five feet respectively. Three had gas between 100 and 130 feet, and the famous Kerr well found it at 160 feet below the top of the Corniferous. Although a cavity was undoubtedly the reservoir in the last instance, the porous "bull-head" of the water-lime is the most probable receptacle for gas within the formations named.

A pocket of gas with a flow sufficiently strong to throw the tools out of the well was found in one of the wells at Alden. The reservoir was in the Marcellus and was quickly exhausted. Shallow wells in the Portage rocks furnish small quantities of gas in a few instances which are elsewhere noted.

Natural Gas Reservoirs.

The geologic conditions controlling the accumulation of natural gas are not sufficiently understood to furnish reliable data by which a gas well may be located. There are no surface indications of anticlines or other results of deep-seated disturbances which might act to accumulate and hold large quantities of gas. In the Medina sandstone, which is here the principal reservoir, the gas is found where the rock is soft and porous, but is not found where the rock is hard. Whether this difference in hardness is due to flexure of strata or to some inherent quality of the rock itself, is still to be determined. Good wells are found close by poor ones, and several "dry" wells may almost encircle a good one. The most experienced and intelligent men in the gas business frankly say that the drill is the only means of ascertaining whether gas exists in the earth or not. And after a careful study of the conditions existing in Western New York, I am free to express the opinion that the presence of gas in any locality in Erie county can not be predicted as securely as, for instance, a salt-well might be located in Wyoming or Livingston counties. In localities already tested, the chances may be two out of three that a new well will find a paying quantity of gas. In a new district the first well might get it, or it might not be found by sinking five or six. The wells put down during the past year, however, go to show that natural gas is much more widely distributed than was at first supposed, and that it is destined to wider use, both for fuel and lights. The greater part of the best wells are located along the Marcellus outcrop or on the Hamilton shales, just south of it; but it is extremely doubtful whether proximity to the outcrop has anything to do with the production of the gas.

It has been shown that surface gas exists in considerable quantities in the Portage shales. Although the supply from this source may not be sufficient to pipe to a distance, it appears to me that this might be utilized for local consumption. A well from 100 to 500 feet deep, if properly located, might furnish fuel for several houses; and it is by no means impossible that the time will come when a gas well in that region will be considered as necessary as a water well.

A General Geologic Section of Western New York, from Lake Ontario to Cattaraugus Creek.

By using the well-records from Niagara county, in connection with those from Erie county, the approximate thickness of the several formations is shown from the Archean, up to near the top of the Portage group. Since the measurements have been obtained from drillers' records, lithologic characteristics, such as hardness, color and material have in most cases furnished the data by which the formations are distinguished.

The Portage Group, in the Boston well was 938 feet thick; in the Zoar wells 1,346, 1,395, 1,490; and in the Richardson well, 1,541 feet.

The Genesee shale, at Eighteen-Mile creek, was seventeen feet thick, but is thicker eastward. At Windom it is estimated, without actual measurement, to be . . . . 25 feet.

The Hamilton and *Marcellus shales* in the well at Eighteen-Mile creek are, together, 287 feet thick. In the Heiser well at Woodlawn, one and one-half miles north of the edge of the Hamilton, the Marcellus is 125 feet thick, and is probably not less than 140 feet in all, making the Hamilton shales, ... 147 feet.
and the Marcellus shales, ... 140 feet.

The Corniferous limestone, Onondaga limestone and Water-lime, all being hard, are classed together by drillers as "flint." The well at the Snow Steam Pump Works, near the southern edge of the Corniferous, in Buffalo, had 140 feet of this flint. The Sherman-North street well had 150 feet. An examination of twelve other wells gives an average of 168 feet. The wells at the Bennett cement quarries, Buffalo, begun below the Onondaga, had, with the cement and "bull-head" lying above the mouth of the well, sixty-two feet of water-lime. The Fogelsonger well on the same horizon had sixty-two feet of hard water-lime, thus giving of

Corniferous and Onondaga limestone, ... 108 feet.
Water-lime, ... 60 feet.

The Salina shales, from the bottom of the flint to the hard rock known to drillers as Niagara limestone (but possibly including some Salina), averaged in ten wells, ... 386 feet.

Making the Salina and Water-lime together 446 feet thick.

The Niagara includes an upper limestone and a shale below, the latter averaging seventy-two feet in thickness. The whole in ten wells averaged . . . . 319 feet.

The Clinton was from twenty-three to forty feet thick, and averaged in nine wells, ... 27 feet.

The Medina, including (*a*) a hard red sandstone, the "red Medina;" (*b*) a shale of varying thickness, sometimes absent entirely, and (*c*) an almost white siliceous sandstone, known as "white Medina." These collectively ran from 83 to 140 feet in thickness, the white band being from four to thirty feet, but usually ten to fifteen feet thick.
Nineteen wells gave, of the whole, an average of . . . . . . 109 feet.

From bottom of white Medina to the top of the Trenton limestone, the Albert Moore well gave 1,635 feet; the South Park well, 1,800 feet, and the Depew well, ...	1,869 feet.
The Trenton limestone in the Bradshaw well, near lake Ontario, was 680 feet; in Well No. 2, 710 feet, and in the Depew well, ...	720 feet.
The Calciferous, resting on the Laurentian gneiss, was in the Bradshaw well, No. 1, ten feet; in No. 2, twenty feet; in the Depew well, ...	110 feet.
Without reaching the Archean, total thickness of above section,	5,561 feet.

The deep Richardson well at Zoar, which has been quoted above, passed through the white Medina at	2,910 feet.
Adding from the Depew well, the shales below, ...	1,869 "
And the Trenton, ...	720 "
With Calciferous, ...	110 "
We have a total of	5,609 feet.

A difference of only forty-eight feet in the results, as shown by the two computations, shows that the estimates are approximately correct. It will be noted, however, that the Calciferous was not fully penetrated in the Depew well, and that the Richardson well is not situated upon the highest land in that part of the county; so that the total thickness is probably from 100 to 200 feet more than the result given above.

Rock-Salt.

The borings in Erie county have added materially to our knowledge of the extent of the Western New York salt-field. Thick beds of rock-salt are known to occur at Boston Corners and at Springville, while the northern edge of the same deposit was pierced in the old well southwest of East Aurora. At Gowanda and Zoar the drill passed through the Salina shales, finding brine, but no salt, in the rock-salt horizon. The limit, north and west of which rock-salt has not been found in the county, and is not likely to be found, is a line drawn from East Aurora to Patchen, curving westward near Boston Corners and thence southward, crossing Cattaraugus creek about three miles west of Springville. It is, therefore, probable that a well sunk to the Niagara limestone at Wales, South Wales, Elmwood, or at any point within five miles southeast of these places, would pass through a good bed of rock salt.

Water-Power.

Although there are several large streams in the county, they are not well adapted to furnish much water-power. In their lower courses, where the volume of water is large, they either flow across a plain having very little fall, or, as in the case of Eighteen-Mile creek, lie at the bottom of deep gorges, where they are practically inaccessible. In the hill region, where there is plenty of fall, the volume of water is small. Ellicott and Murder creeks furnish good, but not continuous water-power where they break over the limestone terrace, and the two branches of Cazenovia creek are capable of furnishing much more power than is now used. At present it is principally utilized for local grinding, sawing, etc. At Falkirk some of the power is used in one or two of the cement and flour mills and, at Holland, in a large tannery. Beyond these interests, water-power contributes very little toward the manufacture of products designed for outside use.

While in most instances I have given the source of information furnished for this report, I wish especially to acknowledge my obligation to the officers of the South Buffalo Natural Gas Co. and to Mr. Michael McIntyre, for the use of maps and records of wells in the South Buffalo and Zoar fields, and to Mr. J. W. Stearns and Mr. Mook, who have furnished me records of wells drilled under their supervision. Also to Professor Franklin Barrows, who has turned over to me original material regarding natural gas, which he collected several years ago, and which has not heretofore been published.

Note to Page 326.

While the work of deepening the Erie canal was in progress in the spring of 1897, the canal-bottom was exposed all the way from Ferry street to the harbor. From Ferry street to the railroad bridge, well-defined glacial markings were found wherever the bottom was covered by clay or boulders. This portion seems to have been a part of the river bottom when the canal was made. From the railroad bridge to the harbor the canal-bottom was glaciated almost continuously. Excellent areas of grooving and polishing were noticed just above the Porter avenue bridge, and again near the New York Central railroad bridge across the canal near the Terrace.

FIGURE 1

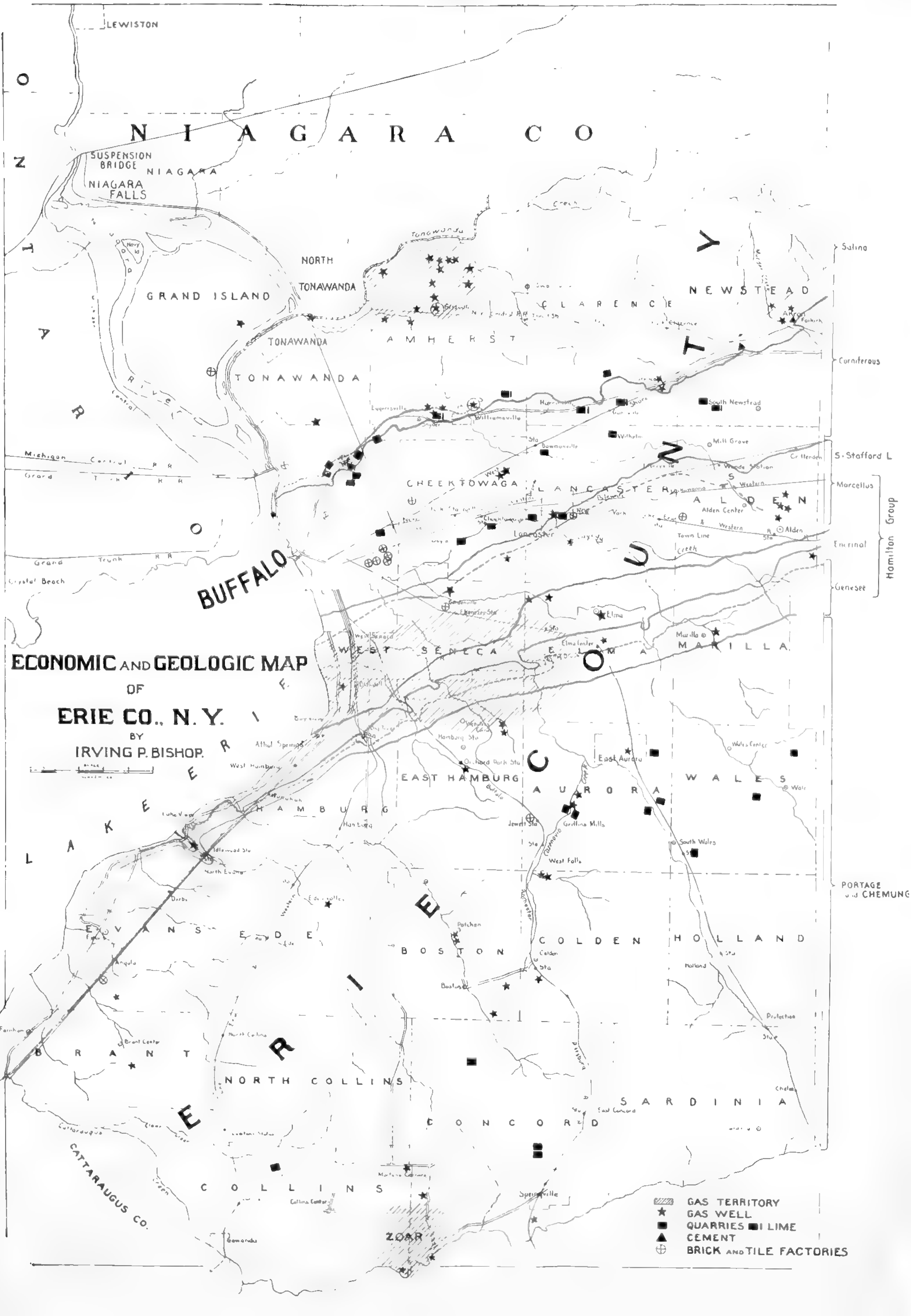
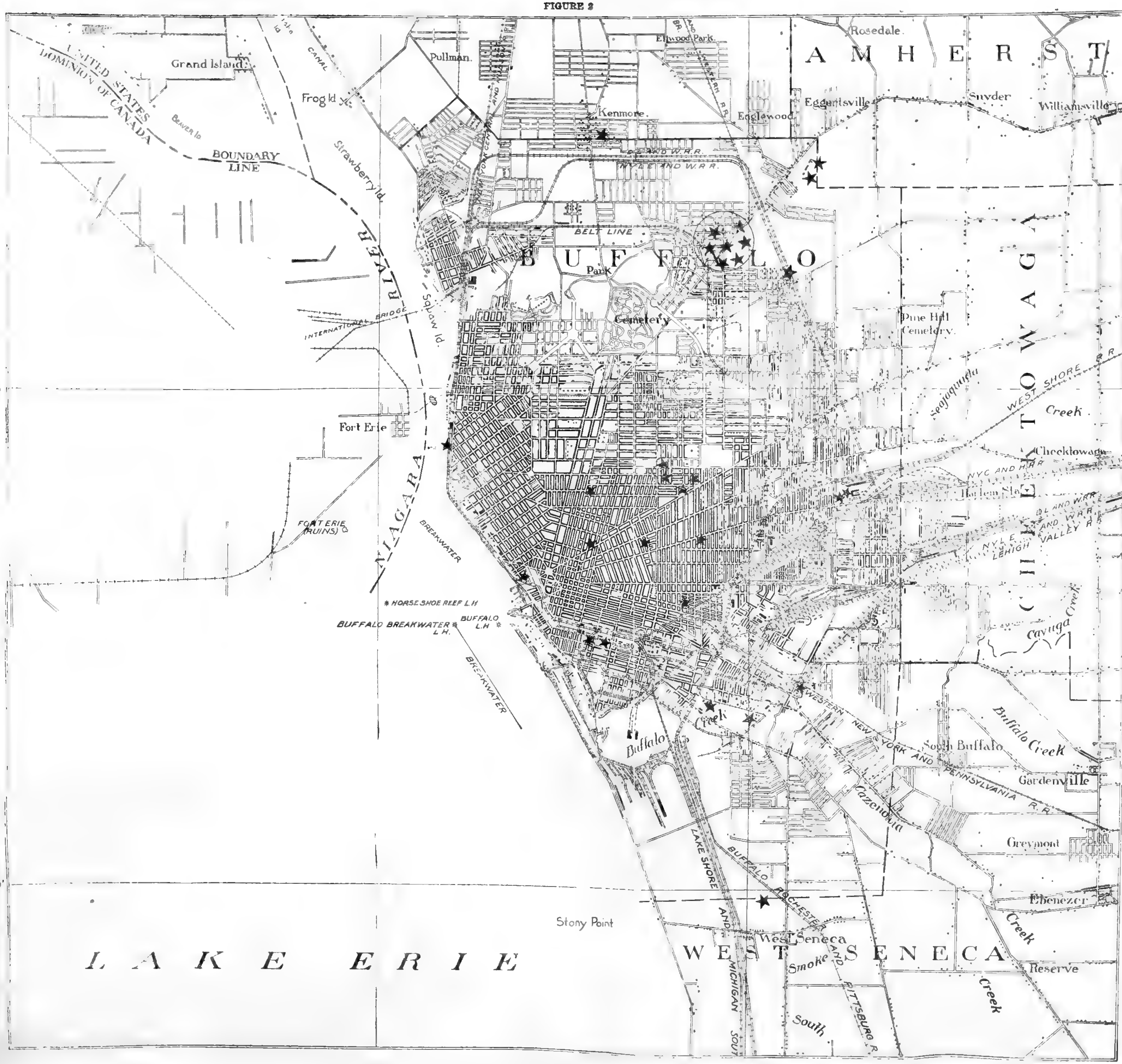

ECONOMIC AND GEOLOGIC MAP
OF
ERIE CO., N.Y.
BY
IRVING P. BISHOP
NIAGARA CO
ERIE COUNTY
LAKE ERIE
LAKE ONTARIO
CATTARAUGUS CO.
LEWISTON
SUSPENSION BRIDGE
NIAGARA
NIAGARA FALLS
GRAND ISLAND
NORTH TONAWANDA
TONAWANDA
BUFFALO
AMHERST
CLARENCE
NEWSTEAD
CHEEKTOWAGA
LANCASTER
ALDEN
WEST SENECA
ELMA
MARILLA
EAST HAMBURG
AURORA
WALES
HAMBURG
EVANS
EDEN
BOSTON
COLDEN
HOLLAND
BRANT
NORTH COLLINS
CONCORD
SARDINIA
COLLINS
ZOAR
Salina
Corniferous
S. Stafford L
Marcellus
Encrinal
Genesee
Hamilton Group
PORTAGE and CHEMUNG
GAS TERRITORY
GAS WELL
QUARRIES LIME
CEMENT
BRICK AND TILE FACTORIES

FIGURE 2



MAP SHOWING LOCATION OF BORINGS FOR NATURAL GAS IN THE CITY OF BUFFALO.

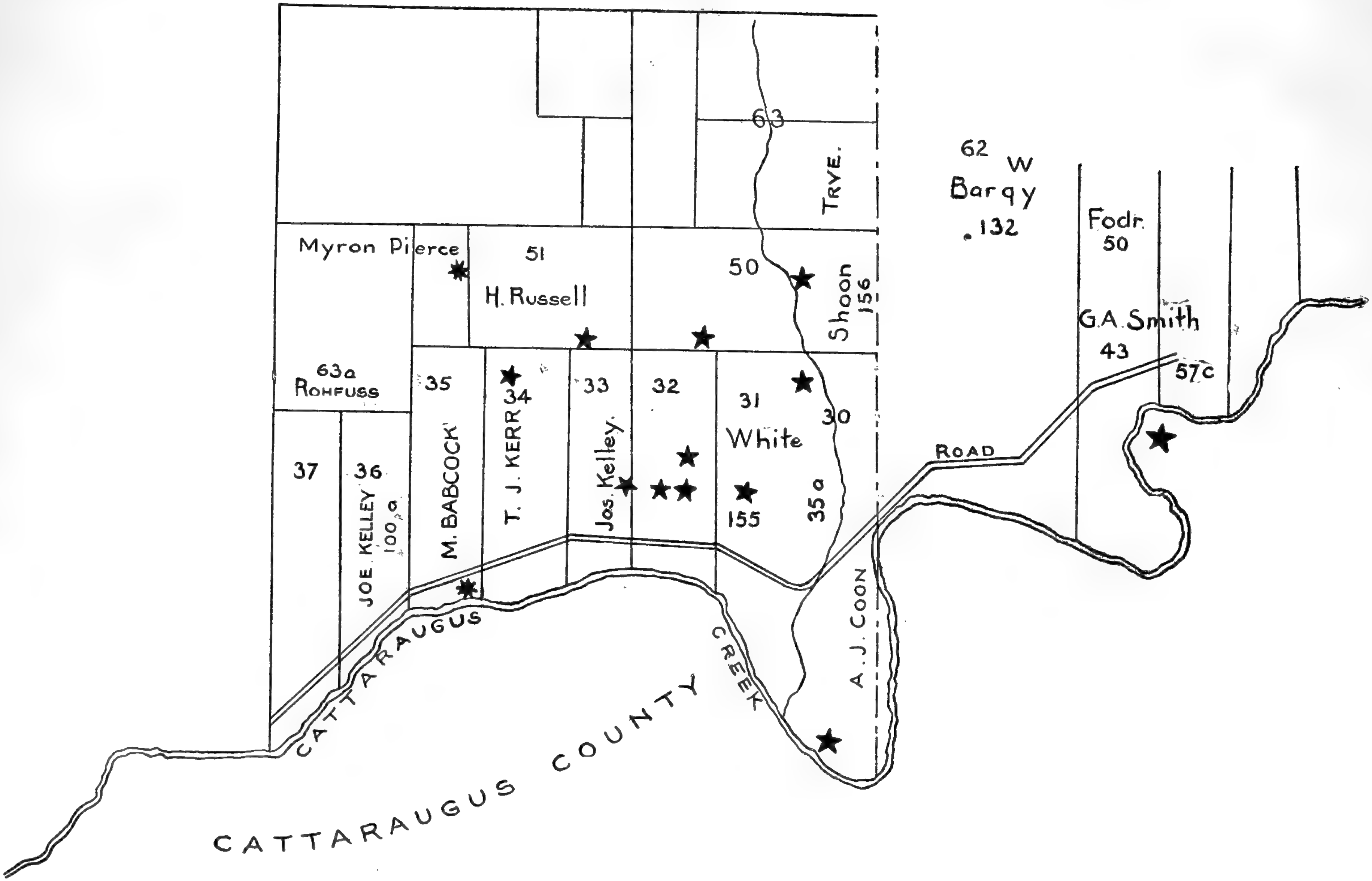
The Almshouse and Buffalo Cement Company's wells are the only ones now productive.

FIGURE 3

GROUP OF GAS WELLS NEAR THE MAIN STREET CROSSING OF THE NEW YORK CENTRAL BELT LINE, BUFFALO.

Productive wells are represented by stars; unproductive wells by double stars.

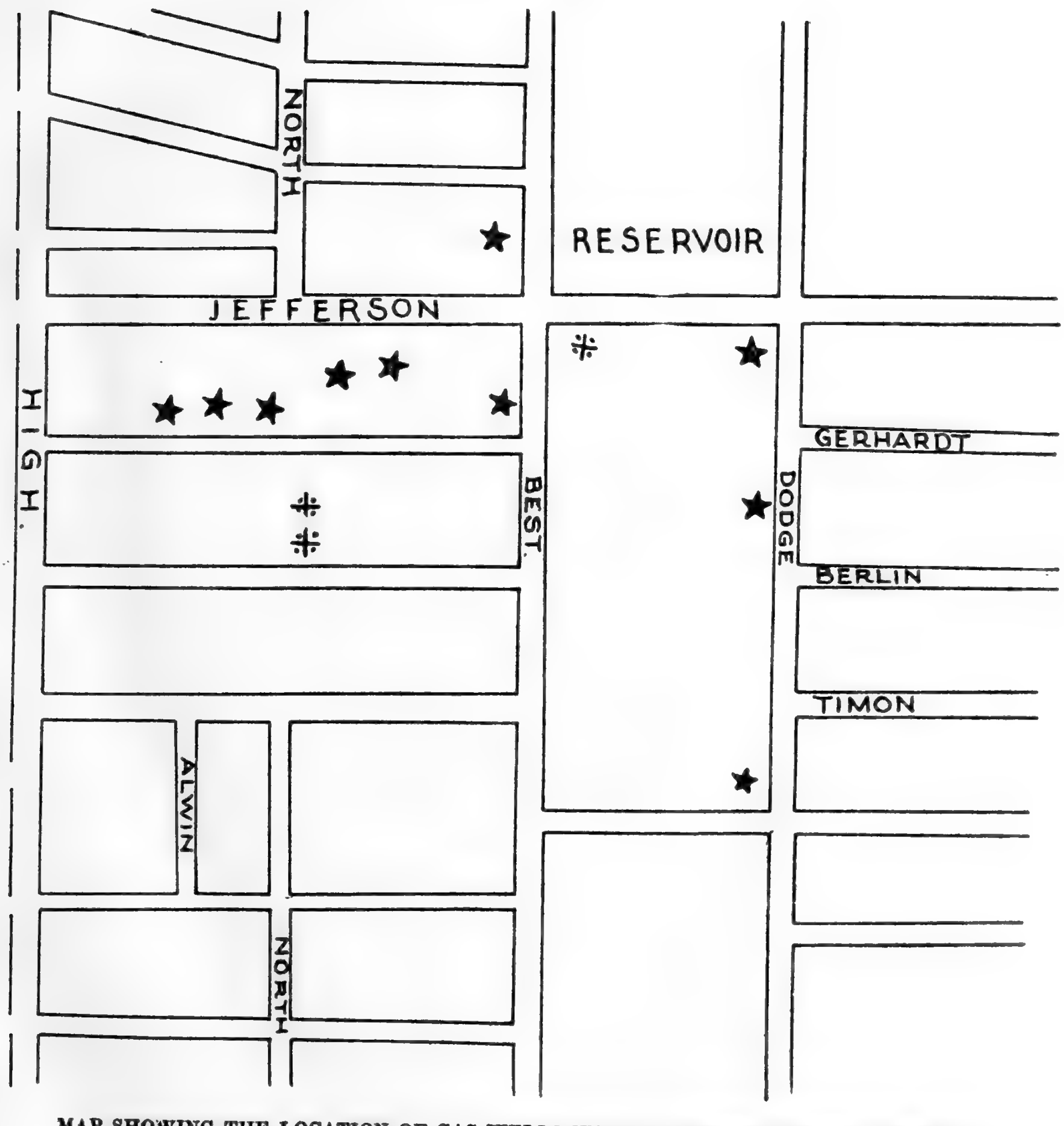
FIGURE 4



MAP SHOWING LOCATION OF GAS WELLS NEAR THE WORKS OF THE BUFFALO CEMENT COMPANY, MAIN STREET AND BELT LINE, BUFFALO.

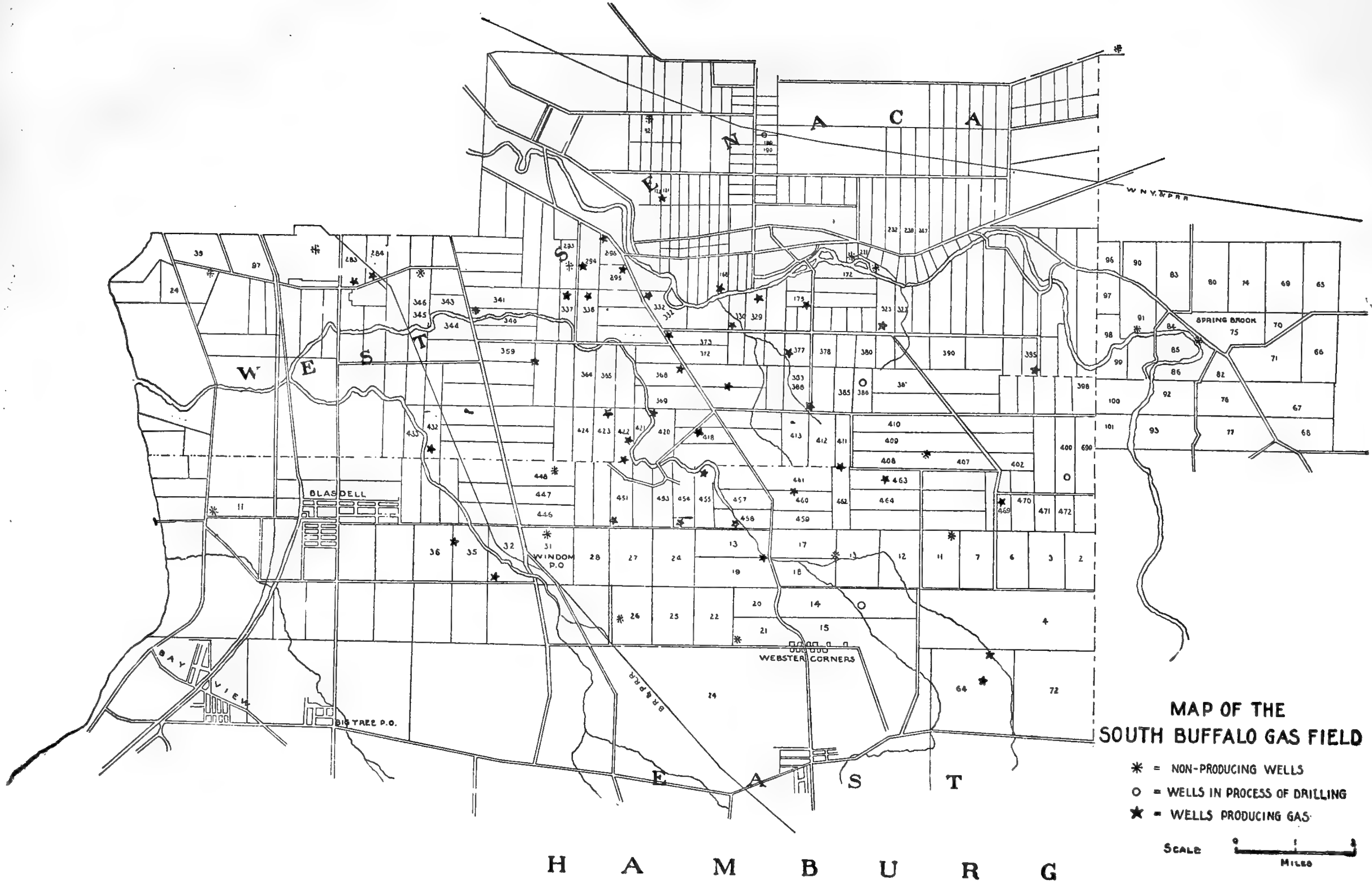
Star = Wells which have produced or are now producing gas. Double star = Non-productive wells.

FIGURE 5



MAP SHOWING THE LOCATION OF GAS WELLS NEAR JEFFERSON STREET, BUFFALO.
Wells at one time productive are represented by stars; unproductive wells by dotted crosses

FIGURE 6


WEST SENACA
EAST
HAMBURG
BLASDELL
WINDOM P.O.
WEBSTER CORNERS
BAY VIEW
BIG TREE P.O.
SPRING BROOK
W. N. Y. & P. R. R.
B. R. & P. R. R.
MAP OF THE
SOUTH BUFFALO GAS FIELD
✳ = NON-PRODUCING WELLS
○ = WELLS IN PROCESS OF DRILLING
★ = WELLS PRODUCING GAS
SCALE 0 1 2
MILES

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

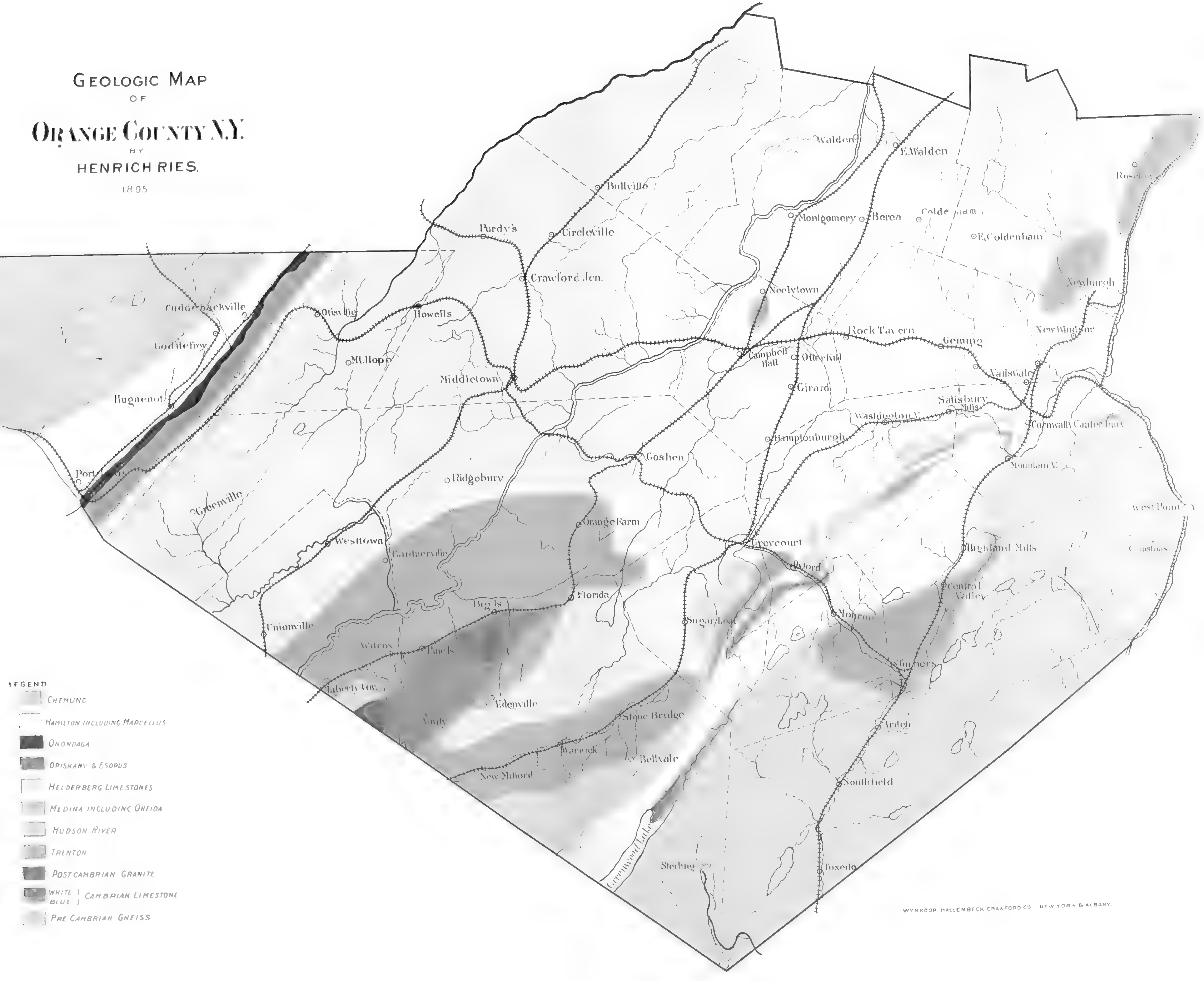
(GEOLOGICAL MAP.)

GEOLOGY OF ORANGE COUNTY.

JAMES HALL,
State Geologist.

HEINRICH RIES, Ph. D.
Assistant.

1895.


GEOLOGIC MAP
OF
ORANGE COUNTY N.Y.
BY
HENRICH RIES.
1895
LEGEND
CHEMUNG
HAMILTON INCLUDING MARCELLUS
ONONDAGA
ORISKANY & ESOPUS
HELDERBERG LIMESTONES
MEDINA INCLUDING ONEIDA
HUDSON RIVER
TRENTON
POSTCAMBRIAN GRANITE
WHITE) CAMBRIAN LIMESTONE
BLUE)
PRE CAMBRIAN GNEISS
Walden
E.Walden
Bullville
Purdy's
Circleville
Montgomery
Berea
E.Coldenham
Crawford Jcn.
Newburgh
Cuddebackville
Otisville
Howells
Neelytown
Godefroy
Mt.Hope
Rock Tavern
Gemug
New Windsor
Campbell Hall
Otter Kill
Middletown
Vails Gate
Huguenot
Girard
Salisbury Mills
Washington V.
Cornwall
Canterbury
Hamptonburgh
Goshen
Mountain V.
Ridgebury
Greenville
West Point
Orange Farm
Westtown
Gardnerville
Greycourt
Highland Mills
Oxford
Central Valley
Florida
Big Is
Monroe
Unionville
Sugar Loaf
Wilcox
Pine Is.
Turners
Edenville
Stone Bridge
Arden
Warwick
Bellvale
New Milford
Southfield
Greenwood Lake
Sterling
Tuxedo
WYNKOOP HALLENBECK CRAWFORD CO. NEW YORK & ALBANY.

Report on the Geology of Orange County.

By Heinrich Ries, Ph. D.

Contents.

The following report is principally based on the results of three months' work in the field during the summer of 1895, and to it is added such additional information on the geology as has been published by others.

Orange county is situated in southeastern New York, and extends from the Hudson river on the east to a short distance beyond the Shawangunk mountain on the west. The county has an area of 838 square miles, with an east and west width of forty-five miles, and a north and south length of thirty-five miles. On the east it is bounded by the Hudson river, on the north by Ulster and Sullivan counties, on the west by Sullivan and Delaware counties, and on the south by Pennsylvania and New Jersey. The county is well known on account of its scenery, mineral localities and dairy products.

Topography. In the eastern portion of Orange county, and bordering on the Hudson river, are the Highlands, a range of parallel hills, nearly all of them over 1,000 feet in altitude, and separated by shallow valleys. The more prominent elevations of this region are: Crow's Nest, 1,418; Butler hill, 1,524; Bear mountain, 1,350 feet A. T.

The Highlands cover about 140 square miles.

West of the Highlands, and separated from them by a fault valley, is the Bellvale–Skunnemunk ridge, extending in a northeasterly direction from the state line, on the northwest side of Greenwood lake, to Cornwall. At Monroe, the ridge is interrupted by a broad, transverse valley, and northeast of Monroe it has a double crest with steep cliffs.

The fertile rolling country to the northwest has a topography of little variety, except to the south, the land gradually rising until it merges into the eastern slope of the Shawangunk mountain. This mountain enters the county from the north, and crosses it in a northeast to southwest direction, passing into the Blue mountain, in New Jersey. It does not present the steep slopes and precipitous cliffs in Orange county that it does in Ulster, but is a rounded ridge whose cultivated eastern slope changes abruptly at the summit to a wooded one of deep descent on the western side overlooking the Neversink valley and the intermediate Helderberg ridge. The crest of Shawangunk mountain varies, within Orange county, from 1,200 to 1,400 feet A. T., being highest at the northern end.

To the west of the Shawangunk mountain, the Hamilton and Chemung formations give rise to an elevated plateau, with few longitudinal valleys, but several transverse ones.

The valleys of Orange county are largely dependent on the geologic structure, and follow the axis of the folds or the lines of faulting, and are in general, therefore, parallel to the strike of the rocks. These valleys also form important lines of drainage.

The Wallkill, which is the largest river of the county, enters it from the south, and, flowing northward through a broad, shallow valley whose width increases to the north, passes into Ulster county, finally emptying its waters into the Hudson at Rondout. Except in the southern portion of the county, all but one of its tributaries come from the west and northwest. In Warwick township, the river is bordered for twelve miles by a swampy tract, the Drowned Lands.

The Neversink river, which crosses the eastern side of Deer Park township, follows the western base of the Helderberg ridge, and empties into the Delaware river at Carpenter's Point. It drains the western slope of Shawangunk mountain and the greater portion of the township to the west of it. The eastern side of the Shawangunk ridge is drained by the Shawangunk kill, whose water-shed borders that of the Wallkill.

The Ramapo river has its origin in Round pond, south of Monroe, and, flowing southeastward through the fault-valley in the Highlands, receives most of the drainage of Monroe and Tuxedo townships. In the northeastern part of the county, the Moodna river and Quassaic creek are important streams.

Orange county abounds in lakes, especially in the Highland area, and a few of them are utilized for water supply. Of these, Little pond, near Newburgh; Little Long pond, near West Point; Mt. Basha lake and Long pond, south of Monroe, and Greenwood lake, are of importance. The last-named lake is the largest in the county, being six miles long and three-quarters of a mile wide, but only half of it lies within the state.

Many of the lakes are disappearing, on account of swamp-growth extending from their inlets, or the cutting down of their outlets, and the beds of former ponds are an important agricultural feature of the county.

The geologic formations occurring in the county range in age from the Pre-Cambrian to the upper Devonian. Nearly two-thirds of the county is underlaid by the Hudson river slates, as will be seen from the accompanying geologic map, and the crystalline rocks of the southeastern portion also cover a considerable area. The other formations occur in irregularly shaped areas of variable size, but there is a tendency in them all to extend in a northeast and southwest direction.

Folding and faulting have produced numerous and local complications, especially along the line of Bellvale and Skunnemunk mountains.

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Dwight, W. B., 1884: Recent investigations and palaeontological discoveries in the Wappinger Limestones of Dutchess and neighboring counties, New York state. *Proc. A. A. A. S.*, XXI., p. 384; *Nat. Leis. Hour* and *Mus. Bull.* No. 18, May, 1884, p. 4.

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Merrill, F. J. H., 1886: Ref. On the age of the Green Pond, Bearfort and Skunnemunk mountain rocks. *N. J. Geol. Surv.*, 1886, p. 113.

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Smock, J. C., 1889: The Building Stones of New York. *Bull. N. Y. State Museum*, Vol. II., No. 10.

Smock, J. C., 1884: Ref., Ann. Rept. N. J. State Geologist, pp. 29, 46 and 51.

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Of the above list of papers the more important are those of Prof. Kemp and Mr. Hollick, Prof. Prosser and Mr. Darton.

The following is a list of the formations occurring in Orange county, together with their character and approximate thickness:

Pre-Cambrian,	Gneisses, granites and limestones,	——
Olenellus, ?	Limestones, usually impure,	20′ +
Cambrian,	Limestones,	200 +
Trenton,	Limestones,	
Hudson river,	Shales, slates and sandstones,	2,000 + ?
Medina (incl. Oneida),	Sandstones and conglomerates,	150′–750′
Lower Helderberg,	Limestones and shaly limestones,	25–500′
Oriskany,	Impure limestones, sandstones, quartzite and conglomerate,	50′–150′
Esopus,	Slates and sandstones,	750′±
Onondaga,	Cherty limestones,	250′
Marcellus,	Arenaceous shales and shaly sandstones,	800′
Hamilton,	Shales, sandstones, flagstones and conglomerates,	1,200–1,800′
Chemung,	Arenaceous shales and sandstones,	2,250′
Pleistocene,	Clays, sand, gravel and boulders,	

PRE-CAMBRIAN. This formation consists of a great mass of gneisses, gneissic rocks, and some limestones. At times the gneissic rocks are massive and resemble a true granite. At other localities they present a schistose facies. These rocks form the Highland region, the northwestern side of Bellvale mountain, and a series of rounded knob-like hills extending from Sugar Loaf village to Newburgh.

The gneiss is usually a mixture of quartz, biotite and feldspar, the latter often plagioclase. Hornblende sometimes predominates, as in the gneiss of Bellvale mountain and Tuxedo township. Pyroxene gneisses also occur. The gneiss forming Sugar Loaf mountain, and the areas to the northeast, is a granulite gneiss with little or no mica or hornblende.

Bodies of iron-ore are not uncommon and are not confined to any particular area or belt, although future detailed study of these rocks may show that they belong to definite horizons. The ore-bodies are generally of small size, and lens or pod-shaped, and the ore is, in most instances, lean. The two important ore-bodies are those of Forest-of-Dean and Sterling.

Limestones occur interbedded with the gneiss, but are rare. One bed is found at Popolopen pond, and another at Fort Montgomery.

The crystalline rocks of this region often appear folded and sometimes faulted; the thin sections do not, however, afford as much evidence of dynamic metamorphism as one might expect. The folds of these Pre-Cambrian rocks frequently pitch to the northeast. Dikes are not infrequently met with.

In view of the limited extent of our present knowledge, these rocks can only be classed as Pre-Cambrian. This is also suggested by Van Hise. (Bulletin United States Geological Survey, No. 86, p. 415.)

CAMBRIAN. The rocks of this age are light-colored, generally massively bedded magnesian limestones. No fossils have been found in them, but their age is based on: (1) the similarity of character of the several areas; (2) on their relations to the overlying formations, and (3) on the occurrence of Cambrian fossils in the limestone of northern New Jersey*, of which they are undoubtedly a continuation. Their greatest development is in the western part of Warwick township, and in Lookout mountain, south of Goshen. The limestones are normally light blue and finely crystalline, but sometimes become coarsely granular, shaly or even brecciated, as east of Goose pond mountain and south of Neelytown. Around Edenville they have been changed by granite intrusions to a coarsely crystalline white limestone.

In Bellvale and Skunnemunk mountains, the limestones underlie unconformably the younger formations, while north of Greenwood lake and east of Pine hill they are faulted against the gneisses, and the same relations hold true at Snake hill southwest of Newburgh. In the northeastern part of the county they are faulted against the Hudson river slates.

The thickness of the Cambrian limestones in Orange county can not be determined with accuracy, but it is probably not less than 500 feet. In Lookout mountain, south of Goshen, they have a thickness of about 200 feet.

TRENTON LIMESTONE. There is a small, highly fossiliferous area of this rock on the River road, about two and three-quarters miles north of Newburgh

* A. F. Foerste.—American Journal of Science, December 1893, p. 435.

PLATE I

OUTCROP OF ORISKANY QUARTZITE WEST OF THE NORTHERN END OF BELLVALE MOUNTAIN; SHOWING THE DEBRIS OF ANGULAR FRAGMENTS AROUND IT.

ferry. In the single exposure known, this rock is a dark blue-grey, shaly limestone, containing abundant crinoid stems and several Trenton species. The rock strikes N. 35° E. and dips 40° E.

HUDSON RIVER SLATES. Two-thirds of Orange county is underlaid by the members of this formation, which cover nearly the entire area of the townships of Mt. Hope, Crawford, Montgomery, Goshen, Wallkill, Wawayanda, Chester, Newburgh and Cornwall.

In the western portion of the county, the formation is represented by interbedded shales, and red, brown or grey sandstones, while in the central part the slates and shales only appear. The sandstone beds again come in towards the northeast. Conglomerates are occasionally seen in the northeastern part of the county. The slates are black, grey or brown, and often very fissile. The sandstone layers are often several feet in thickness.

Fossils are rare, but have been found at several localities, notably Sugar Loaf, Rock Tavern, Greycourt and Goshen. They show a mixed Hudson river-Trenton fauna.

The country underlaid by the Hudson river formation is a fertile one, and the outcrops are comparatively few, forming rounded hills and ridges. These rocks rest unconformably on the Cambrian limestones and gneisses, and underlie the younger rocks in the same manner. Their thickness in this county is probably not less than 2,000 feet.

MEDINA SANDSTONE. The members of this formation are fine-grained quartzites, conglomerates, shales and sandstones. The formation has its greatest development in Deer Park township, where it forms the western half of Shawangunk mountain. There it consists of a quartzose conglomerate 40–50 feet thick, which passes upward into 700 feet of Shawangunk grit. This latter is a hard, evenly bedded quartzite, dipping to the west under the red Medina sandstone, which grades upward into greenish grey shales of the same age. Another area of Medina age forms Pine hill, east of Skunnemunk mountain. Here are 60–70 feet of Oneida conglomerate, dipping to the west over the Cambrian limestones, and passing upward into the Longwood red shales and shaly sandstones, of which there are about seventy feet in Pine hill.

Their upper members are greenish shales and quartzites, which crop out south of Cornwall station. They underlie unconformably the Helderberg limestones.

HELDERBERG LIMESTONES. There is considerable variation in the distribution and thickness of the members of this formation in Orange county.

Small patches occur west of Stone Bridge, northeast of Bellvale, northwest of Monroe and northeast of Highland Mills. The two important areas are the one west of Cornwall station, and the belt along the western side of Shawangunk mountain. In the latter belt are recognized the Tentaculite, Lower Pentamerus, Shaly and Upper Pentamerus members. In the Cornwall area, the Shaly, Pentamerus and Tentaculite are met with. The Scutella limestone is not found in the county. As the characters of these beds are so different at the various localities. they are best described in the paragraphs treating of these regions.

ORISKANY SANDSTONE. The two belts of Oriskany which occur within the county present widely different characters. The western belt forms the western part of the Helderberg ridge, which extends up the Neversink valley from Port Jervis. It consists of fine-grained shaly sandstones and impure limestones, the latter often containing many fossils. The limestones weather to a soft red rock, from which the fossils may often be dug with a knife. The beds dip to the westward under the Esopus slates and Pleistocene deposits of the Neversink valley, but the bedding is almost everywhere obscured, and there is present a pronounced cleavage, which causes the rock to split into very thin layers. The cleavage generally dips steeply to the east. There are also often present cherty bands containing fossils. The Oriskany forms narrow ridges, and the thickness of the formation is about 125 feet.

The second Oriskany area is along the western side of Bellvale and Skunnemunk mountains, where it affords a fine-grained red or gray quartzite, which changes locally to a conglomerate. It is underlaid by the Helderberg limestone in places, and in turn dips conformably under the Monroe shales. About one hundred feet are exposed. The grey limestone is everywhere traversed by innumerable cracks, which produce an extensive and characteristic pile of debris around each outcrop. The red quartzite does not contain these slit-like cavities, which are probably joint cracks. The conglomerate appears in association with the gneiss knobs northwest of Skunnemunk.

ESOPUS SLATE. This formation consists of black or bluish grey shaly sandstones, grits and black slates. It occurs only in the eastern part of Deer Park township, on the western side of the Helderberg ridge, where it rests on the Oriskany sandstone. The formation gives rise to small narrow ridges, which may possibly represent step-faults. The probable thickness is about 700 feet, if there are no faults as above mentioned. All the members have a strong easterly dipping cleavage, which makes a sharp angle with the usually

PLATE II

Esopus slate in railroad cut, one and one-half miles northeast of Port Jervis. The cleavage is well shown.

obscure bedding. No fossils have been found in these rocks in Deer Park township.

Excellent exposures of the black Esopus slate are to be seen in the railroad cut of the New York, Lake Erie & Western railroad, about a mile and one-half northeast of Port Jervis. The formation crosses the Neversink river above Port Jervis and disappears under the drift of the valley.

ONONDAGA (CORNIFEROUS) LIMESTONE. The beds of this age are represented by a dark grey limestone in layers one to ten inches thick, and containing numerous black chert nodules of an irregularly elliptical shape, whose longer diameter is sometimes a foot. The limestone forms Carpenter's Point, near Port Jervis, in the southeastern part of Deer Park township, and also outcrops in a small area farther up the valley, near Port Orange.

Weathering dissolves the lime carbonate, and often leaves the masses of chert projecting several inches above the surface. The nodules sometimes contain fossils (I. C. White, Pennsylvania Geological Survey, G. 6). The Corniferous limestone dips gently to the west. The thickness can not be determined from the exposures at Carpenter's Point, but White estimates it at 250 feet.

HAMILTON GROUP. This is an important formation in Orange county. The lower member, the Marcellus shale, consists of a series of dark colored, bluish black or brown, arenaceous shales, which crop out along the western side of the Neversink valley. They are fossiliferous at several localities, notably at Port Jervis and Rose Point, eight miles northeast of it. They have a low western dip and a steep easterly dipping cleavage. Their thickness, which is in part buried by the drift of Neversink valley, has been estimated by White* and also by Prosser at 800 feet, which seems very probable.

The upper member, or Hamilton proper, overlies the Marcellus, but is not separated from it by any sharp line of demarkation. It forms a series of arenaceous shales and shaly sandstones in its lower beds, while the upper ones are thinly laminated sandstones. The lower members contain abundant fossils. The total thickness in Deer Park township is about 1,800 feet.

The second area of Hamilton rocks forms the greater portion of Bellvale and Skunnemunk mountains, and has been divided by Darton† into three members, viz.: the Monroe shales, Bellvale flags and Skunnemunk conglomerate.‡

* Report G 6, Pennsylvania Geological Survey.

† The Devonian of Eastern New York and Pennsylvania. Bulletin United States Geological Survey, No. 120.

‡ Bulletin Geological Society of America, V., p. 367.

Monroe shales. These are dark grey or black slaty shales and slates, which are usually fossiliferous. They extend around the base of Skunnemunk mountain, and along the eastern base of Bellvale mountain.

Their thickness in the former ridge is probably not over 200 feet, but their greatest development is in Pea hill, near Cornwall.

Bellvale flags. These overlie the Monroe shales, and are represented by a series of thin-bedded sandstones with occasional shaly partings and concretionary layers. They pass into the underlying Monroe shales, and upward into the conglomerate. Normally, the Bellvale flags are moderately fine-grained sandstones of grey color. In their upper layers, near the transition into the conglomerate, they become massive, quartzose and coarse. The sandstones are also traversed by numerous thin veins of milky quartz. The flags extend from the New Jersey state line to the north end of Skunnemunk mountain, where they terminate somewhat abruptly. The thickness of the Bellvale flags is about 1,000 feet.

Skunnemunk conglomerate. In its typical development this rock is composed of an aggregate of quartz and some shale pebbles in a matrix of reddish quartz and argillaceous material. The pebbles are generally one to two inches in diameter, but sometimes attain a size of several inches. Local layers of red slate occur interbedded with the conglomerate in the upper portions and are well seen in the road over the mountain from Greenwood lake to Warwick. The conglomerate passes downward through a pebbly quartzite and red quartzitic sandstone into the Bellvale flags. It can not be said that these intermediate beds of passage belong to one member more than the other. The conglomerate caps Bellvale and Skunnemunk mountains and gives rise to high cliffs and steep ledges. Professor Smock has estimated, and probably correctly, the thickness of the Skunnemunk conglomerate as 300 feet, but in Bellvale mountain, to the south, it is much thicker, not far from 800 feet. Mr. Darton considers that the Skunnemunk conglomerate may possibly represent the Oneonta formation, as the deposition of the latter in central New York was characterized by an abrupt change in the nature of the sedimentation, or it may represent the coarse Chemung beds of the southern Catskills or, thirdly, may be a purely local feature.

CHEMUNG GROUP. This formation is only present in the western portion of Deer Park township. The beds are mostly unfossiliferous sandstones, with some interbedded shales. The divisions occurring within the limits of the county are the Delaware flags, New Milford red shales, Starucca sandstone and Chemung sandstones, of Prosser.

PLATE III

Looking east across Neversink valley, showing the flat, gravelly bottom. At the farther side of the valley is the Helderberg ridge and, in the higher background, the Shawangunk mountain.

Pleistocene. These deposits are represented by the usual accumulations of gravel, sand and boulders. In the larger valleys, as those of the Neversink, Shawangunk, and Wallkill rivers, the gravel and sand accumulations are of great extent and depth. Those of the Neversink valley are in places known to be over one hundred feet thick. Large boulders are restricted to Newburgh, Cornwall and Tuxedo townships, in which they are quite abundant. The alluvial deposits are represented by terraces along the Hudson river and other streams and by numerous pleistocene lake beds which cover some 40,000 acres. The pleistocene deposits are mentioned in detail hereafter.

Geology of the Warwick Cambrian Limestones and the Granites.

In the south-central part of Orange county is a belt of blue and white limestone which begins about two miles southwest of Goshen, in Goshen township and, extending through the western part of Warwick township with increasing width, passes on continuously for twenty miles into New Jersey. To the east of the Drowned Lands, and opposite Black Walnut Island, the belt is about two and one-half miles wide, and continues this width to Amity, where it narrows to two miles. A branch of the blue limestone extends from this point to the northeast, and will be described hereafter. The limestones also extend under the Drowned Lands, and the blue limestone is found again on the west side, where it passes under the Hudson river slate. The white limestone occurs only in the main central belt, and is there closely associated with the blue. The area occupied by each can best be apprehended by an examination of the map. In Orange county no fossils have been found in the limestone, but the contained remains found in New Jersey prove it to be of Cambrian age. The white limestone surrounds two areas of granite and gneissic rocks, and borders on a third, Pochuck mountain. It is also penetrated by many granite dikes and masses containing contact minerals.

Several opinions have been advanced regarding the age of the blue and the white limestones. Keating and Vanuxem (*Jour. Phila. Acad. Sci.*, 1822, p. 277); C. U. Shepard (*A. J. S.* i–XXI., p. 323) 5; Cook (1868, *Geol. N. J.*, p. 310); and Britton (*N. J. Geol. Surv.*, 1886, p. 77–83), considered that the white crystalline limestone was of Archean age, deposited on the gneisses and granites, and metamorphosed. The blue limestone was considered Cambrian.

On the other hand, Nuttall (*A. J. S.* IV., p. 247), Rogers (*N. J. Geol. Surv.*, 1840, p. 47–67), Nason (*N. J. Geol. Surv.*, 1890, p. 25–50), and Mather consider that the blue and the white limestones are one and the same formation, originally blue, but changed to white in those portions bordering on the gneissic and granitic rocks. A third possible view is mentioned by Kemp and Hollick, viz.: that the white limestone is Archean, but metamorphosed along granitic intrusions, and thus charged with minerals, while the blue is of later age. In this main belt no actual contact was found between the blue and the white limestones, although outcrops were found within 200 feet of each other on the road running due north from Edenville and northwest in a general way, along the line of Professor Kemp's section 3. The two are considerably mixed together on the northeast slopes of Mount Eve. The writer, however, found exposures east of the road and one and one-quarter miles west-southwest of Pine Island station, which showed the passage of the blue into the white. In the main belt the blue limestone becomes graphitic and more crystalline towards the white. On the east side of Round hill, the blue limestone is found quite close to the granite and assumes a highly siliceous character, if not actually becoming a quartzite.

Two great knobs of granite, Mount Adam and Mount Eve, penetrate the limestone. The rock is a hornblende-granite, gneissic in places, and coarsely crystalline, especially at the quarries, the anhedra forming the granite being one-quarter to one-half inch diameter. More or less biotite is present, and augite is common near the margins. The granite is a basic variety, and plagioclase equals or exceeds the orthoclase. Quartz is often common, and contains dusty inclusions. The orthoclase is generally microcline or microperthite. The hornblende is black, and is transparent only in the thinnest sections. It is then yellowish green parallel to a, black parallel to b, deep green parallel to c. Brown biotite is usually rare, but it is quite common on Round hill. Allanite, a rare mineral, is abundant in the granite, and, together with pegmatite veins, has spoiled much of the stone for quarrying. Small zircons and titanite are not infrequent. The granite becomes quite gneissic at the north end of Mount Eve, preserving the same mineralogic composition, but the sections show evidences of dynamic metamorphism in the crushed crystals of quartz, feldspar, etc. Sometimes the granite assumes a structure resembling quartz-porphyry. Graphic granite was also found on a knob east of Mount Eve.

The white limestone is coarsely crystalline, with scattered scales of graphite and, less often, phlogopite. Chondrodite is also present and increases near the contact of the limestone with the granite.

Contacts. The granite and the white limestone are found in actual contact in several places, and only a few feet apart in others. Towards the

PLATE IV

Outlet of Wallkill river at north end of Drowned Lands. In the background is the dam of drift which obstructed the river.

contact, the granite becomes an aggregate of light green monoclinic pyroxene and scapolite, or a granite-like zone of the two is present. Titanite is a constant associate.

Near the contact, great quantities of silicates appear in the limestone either in bunches or scattered through it. They are brownish green hornblende, dark brown biotite or phlogopite, green pyroxene, titanite, pyrite, calcite and some scapolite. Chondrodite is sometimes present in great

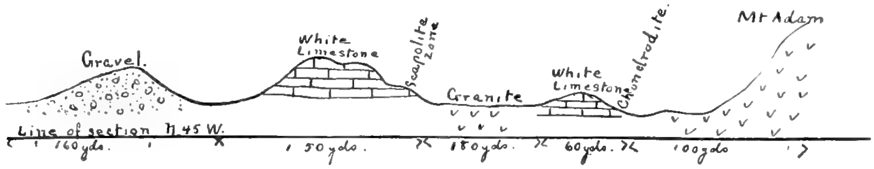


FIGURE 1. Section from southwest side of Mount Adam, northwest towards the Drowned Lands.

quantities. A good contact is to be seen on the prolongation of Mount Eve on the farm of Mr. Onderdonk and on that of Mr. J. Hedges. On the southwest side of Mount Adam is an excellent section across the granite, limestone and contact zones. (Fig. 1.)* Next to Mount Adam is a very swampy strip, following which there is a ledge of limestone with much red chondrodite. Beyond this comes the granite with the scapolite zone. Unusually fine scapolite crystals were found here, with interlaced prismatic pyroxene individuals. Titanite was present in less quantity. The scapolite zone is followed by coarse white limestone, and this, in turn, dips under the gravel bordering the Drowned Lands.

About two miles west of Amity is Pochuck mountain, the greater portion of which lies within New Jersey. The eastern part of the

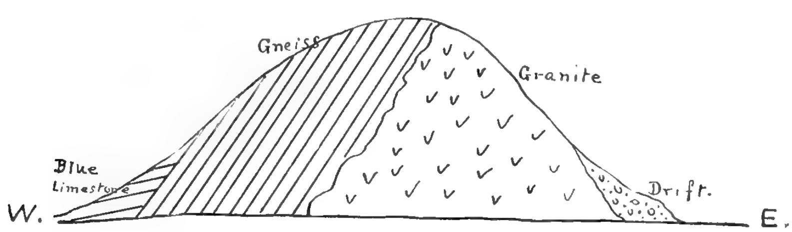


FIGURE 2. Section across the north end of Pochuck Mountain.

mountain is composed of a coarse-grained granite, which is quarried for building purposes. The eastern half of the mountain is a biotite gneiss (508), which strikes N. 20° E.; dips 30° W. Dikes of the granite penetrate

* This section is copied from Prof. Kemp and Mr. Hollick's paper, previously mentioned.

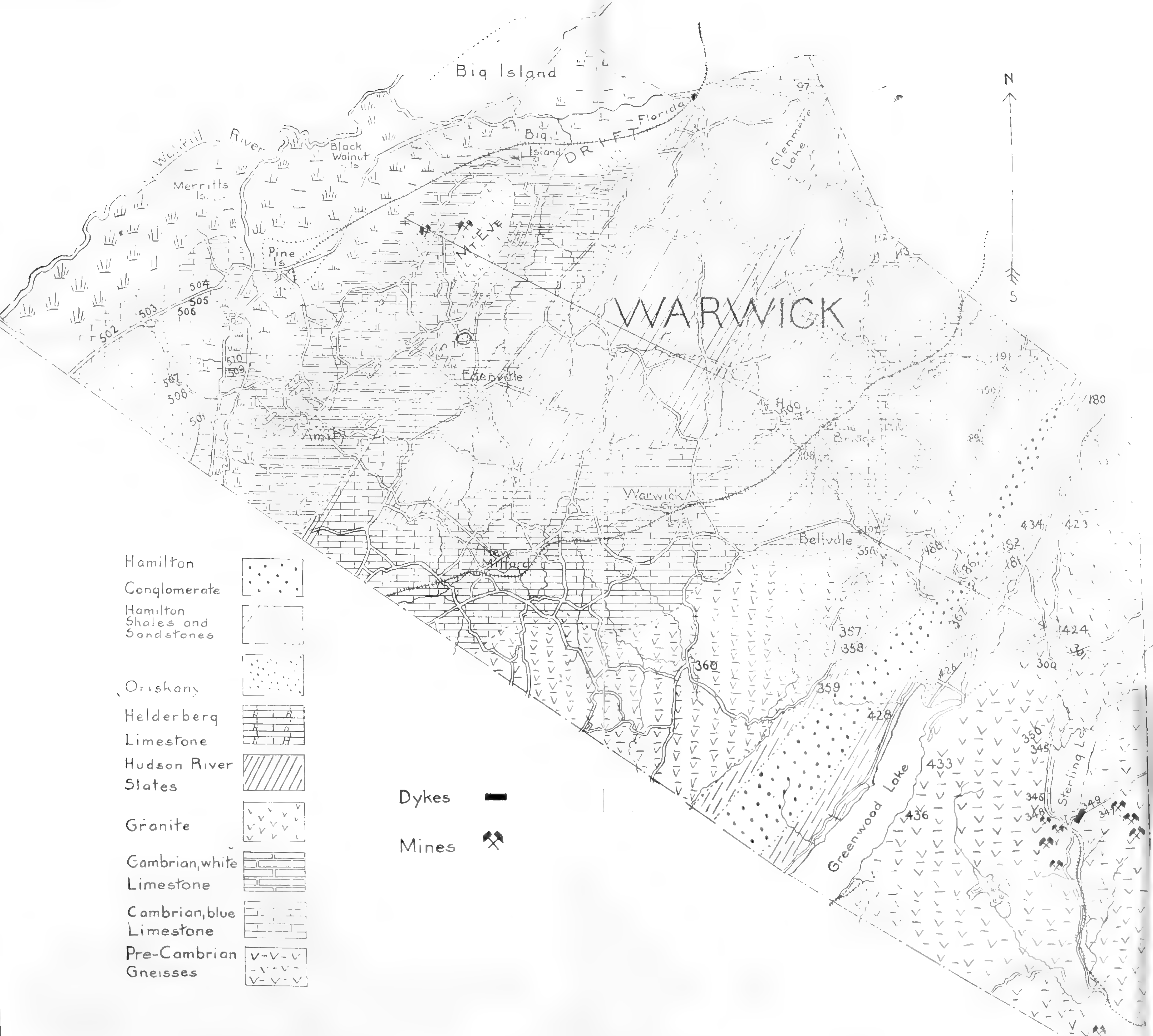
the gneiss, pyroxene being developed as a contact mineral between the two. Small knobs of granite also crop out near the road (505) on the west side of the Drowned Lands, and about one mile north of Pochuck mountain. There is also a hill of gneiss just north of the cross-roads on the east side of the road, and about one and one half miles west by south of Pine Island station. A short distance northwest of this are several outcrops (504), showing the transition of the blue limestone into the white. Up the short, steep slope on the west side of the road, is a blue, fine-grained, hard limestone (504a), with a low western dip.

The blue limestone, with contact minerals, also crops out in the road. Not more than six feet from it is a small mass of white limestone, with graphite scales. Next to this is a dark strip of rock, made up of contact minerals. In the field opposite these outcrops, and about 150 feet distant (504e) is a mass of blue limestone with cavities and calcite streaks. At the north end of the same outcrop is white, coarsely crystalline limestone, while the space between shows every gradation between the blue and the white. A large outcrop of the white occurs on an adjoining knoll to the north. Another outcrop of the blue and the white is in a corn-field about one-third of a mile to the southeast (506).

The prolongation of the white limestone belt so far south from Mounts Adam and Eve, without the appearance at the surface of any large igneous masses, suggests that the Adam and Eve area and the Pochuck mountain area are probably connected, and may be portions of the same intrusion.

Relations of the Limestones and Hudson River Slates. Two facts greatly hinder a correct understanding of the relations of the limestones and the associated Hudson river slates. The area underlaid by these formations in Warwick township is a rich farming country, and outcrops are few, and, again, the limestones in the main belt are often massive, and good strikes and dips are not easily obtainable. On the western side of the Drowned Lands, the limestone boundary extends from Unionville, northeast through Gardinerville and, about two miles east of this place, swings around to the northeast. Near Liberty Corners the blue limestone (502) strikes N. 70° W., and has a dip of 15° W. The layers are four to eight inches thick, with shaly partings. Northeast of Gardinerville the limestone strikes N. 30° E.; dip, 30° N. W. It is somewhat cherty and variable in color.

At Gardinerville, the slate is exposed under the dam in the bed of the stream. The dip is west. Northeast of Orange farm (89) the limestone is well exposed in a quarry on the west side of the main road from Goshen to



GEOLOGIC MAP OF WARWICK TOWNSHIP.

The sections shown in Plate X, Figures 1 and 3, are drawn along the straight lines terminated by arrows. Scale 1 in. = 1 mi.

Warwick. Here it is a very hard, massive rock with an abundance of cherty layers and broken by irregular vertical joints. The dip is very low to the northwest. Half a mile southeast of Mapes Corners is Mount Lookout. This is made up entirely of Cambrian limestone and affords one of the best exposures in the county. The upper beds are somewhat coarse and sandy, while the lower ones are fine-grained and less siliceous. They all dip slightly to the northwest. Most of the limestone is very hard and some of the layers half-way up the hill have siliceous laminae which stand out prominently on the weathered surfaces. Quartz crystals are not uncommon in the cavities of the rock. There are evidences of fossils in some of the coarser layers from the summit of the hill, but no good specimens were found.

Southeast of the hill and opposite a farmhouse on the main road is a ledge of very cherty, moderately coarse limestone. The thickness of the beds in Lookout mountain is fully 200 feet. This hill is in the main belt of limestone, whose most eastern limit is west of the upper end of Glenmere lake. There the slate and the limestone are separated by a narrow ravine, the lime

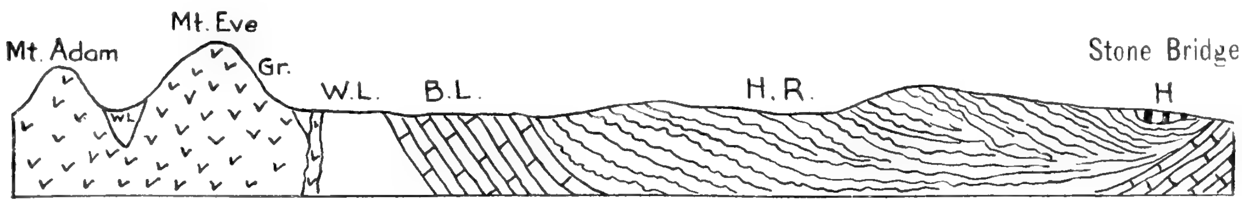


FIGURE 3. Section from Mount Adam to Stone Bridge.
Gr., Granite; W. L., White limestone; B. L., Blue limestone; H. R., Hudson river slates; H., Helderberg limestone.

stone forming a ledge on its western side. At this point (97) the two are about seventy-five feet apart, but a few hundred feet farther south on the west side of the road, they are within six feet of each other. The limestone here dips to the east and is overlaid unconformably by the slate, though an actual contact is lacking.

The Hudson river slates extend southward across Warwick township in a wedge-shaped area which is about five miles wide at its upper border and thins out at a point about one and one-half miles northwest of New Milford. They rarely afford good exposures, but an excellent one is seen on the road from Warwick to Edenville.

One mile west of Stone Bridge, is a small area of Helderberg limestone (500) resting unconformably on the blue cherty Cambrian limestone. The Helderberg is a purplish shale containing remains of *Bryozoa*, *Leperditiæ*, mollusks and trilobite fragments. The species determinable were a *Dalmanites, Leperditia alta, Meristella lævis, Nucleospira ventricosa* and *Cœlospira concava*.* To the east of the Hudson river slate area is the right branch of the Cambrian limestone belt which spreads eastward to Bellvale mountain and northward to Sugar Loaf mountain and underlies the broad, flat Warwick valley.

From the strikes and dips obtainable, the indications are that the Cambrian limestone underlies the slates with a constant, though varying degree of unconformity and which are themselves brought up by low folds; the Mounts Adam and Eve area being along the axis of a low anticline. The section adapted partly from Professor Kemp's paper, is given in figure 3.

Geology of the Region along Bellvale Mountain.

Bellvale mountain enters Orange county from New Jersey along the west side of Greenwood lake, and extends to a point about four miles north of the latter, with an elevation of 1,200 to 1,300 feet A. T., beyond which it extends as a discontinuous rounded ridge with greatly diminished elevation, merging into the southwestern continuation of Skunnemunk mountain, northwest of Monroe. The latter extends, as a high doubly crested cliff-topped ridge, nearly to Cornwall.

The general structure of Bellvale mountain is that of a compressed synclinal of Devonian rocks, a portion of whose western limb has been cut off by a fault, and the missing member replaced by gneiss.

The geologic age of this belt has been, for many years, a disputed point among geologists. Horton, in his report on the geology of Orange county, refers to Bellvale mountain, and states that the southeast side, top, and about one-third of the slope on the northwest side are composed of greywacke and greywacke slate, standing nearly vertical.

On the geologic map of New York, 1844, the area of Skunnemunk mountain is put down as Hudson river slate. On the New Jersey geologic map of 1868, Professor G. H. Cook referred these rocks to the Potsdam.

In 1871, D. S. Martin found the first fossils of this belt in a so-called coal mine on Skunnemunk mountain. (The Coal of Orange county, N. Y., *Proc. N. Y. Lyc. Nat. His.*, I., p. 259.) Professor Martin states that the coal mine of Monroe lies upon the western side near the summit of the mountain. The rock is a dark grey siliceous or argillaceous sandstone, carrying carbonaceous

* J. F. Kemp and A. Hollick. On the Granite at Mounts Adam and Eve, Warwick, Orange county, N. Y., and its Contact Phenomena. Annals of New York Academy of Sciences, VII, p. 638.

PLATE VI

Unconformity between Cambrian limestone and the overlying Helderberg Shaly limestone, west of Stone Bridge, Warwick Township.

matter. The fossils found, fixed the age of these rocks as Devonian, probably Hamilton. The plant-remains proved to be *Lepidodendron* (probably *L. gaspianum*), *Calamites*, *Psilophyton* and, according to Professor Newberry, *Dadoxylon*.

The region was still colored as Potsdam on the geologic map of New Jersey, of 1874, while the area called Hudson river is put down as Silurian slates. In a paper by Dr. T. S. Hunt, the Green pond mountain conglomerate was mapped as greywacke or Upper Taconic (*Trans. Roy. Soc. Can.*, I., ser. IV., page 254). The geologic map of New Jersey, published in the Annual Report of the New Jersey Geological Survey, made no change for the Green Pond-Bearfort region.

In the New Jersey Geological Survey Report for 1884, Smock gives a section from Woodcock hill, northwest of Skunnemunk, southeast and east across Skunnemunk mountain (p. 46), showing the synclinal structure of the mountain. The subsequent work of other geologists shows the main details of this section to be correct. Professor Smock calls attention to the fact that the relations of this Devonian series of rocks are much easier of interpretation in this locality than elsewhere. He also gives a detailed map of the region around Bull hill, northwest of Monroe, and notes the occurrence of plant remains in the Devonian sandstone quarries.

Dr. Merrill studied this series of rocks in northern New Jersey, and the results of his work are given in the report of the New Jersey Geological Survey, 1886, p. 113.

In 1892, Professor Prosser gave a resumé of previous contributions referring to this region, and discussed in detail the plant-remains of Skunnemunk mountain. N. H. Darton has contributed a valuable paper on the geology of this region (Geologic Relations from Green Pond Mountain, N. J., to Skunnemunk Mountain, N Y.) The results of the writer's work in Orange county during the past summer, agree in most respects with those of Mr. Darton.

In Bellvale mountain the synclinal is formed, in great part, of the Skunnemunk conglomerate. Excellent exposures of it are seen (184, 186) on the road from Greenwood lake to Warwick, on the summit of the ridge. Interbedded with the conglomerate are less pebbly beds and streaks of red slate. The quartz pebbles are often ground and distorted on slickensides. The conglomerate passes through a red quartzite into the flaggy sandstones which are seen lower down on the east side of the mountain. These are everywhere traversed by veins of milk-white quartz (367).

Toward the base of the mountain they become more heavily bedded, and are succeeded by shales. The conglomerate extends along the crest of the mountain for several miles north of Greenwood lake, and forms bold cliffs and ledges at the top of the steep wooded slopes. It disappears southwest of Long pond, where the mountain breaks up into rounded hills, and does not reappear again, except at one point, until Skunnnemunk mountain is reached. This one point is about three-quarters of a mile northwest of Round pond, south of Monroe.

The quartz-seamed sandstones come up on the other side of the synclinal, on the northwest side of Bellvale mountain (366), where they are faulted against the Pre-cambrian gneisses. The sandstones and conglomerate everywhere present abundant slickensided surfaces.

About 800 feet of conglomerate are represented in the sections across the mountain at the north end of Greenwood lake.

The Bellvale flags are represented along Greenwood lake by grey flaggy sandstones, often cut by veins of milky quartz. About two miles north of the state line, the Monroe shales appear as black slaty shales, resembling somewhat the Hudson river slates, with which they were for a time confounded. Hamilton fossils are not uncommon. They are abundant in the slates along the road, where the latter follows a cliff above the lake, about one-quarter mile north of the Lakeside hotel.

The fossils are much distorted, but the following were recognizable:

Tropidoleptus carinatus.

Spirifer mucronatus.

Liorhynchus, sp.

Rhynchonella, sp.

The Esopus slate, though very abundant farther down the lake, does not appear north of the state line.

The synclinal fold of Bellvale mountain is often so compressed that the dips are eighty or ninety degrees.* The Monroe shales are exposed along the west side of Long pond, two and one-half miles south of Monroe, and about 500 feet north of the school-house. They here contained a number of impressions closely resembling *Spirophyton.*

North of Greenwood lake, on a small knoll (426), is an outcrop of quartzite with sand grains and occasional pebbles. It dips to the westward under the Bellvale flags. Darton has considered it to be Oriskany, and while it is very probably this, proof is lacking.

* Some of these apparent dips may be cleavage planes.

PLATE VII

Outcrops of white limestone, east of Mount Eve; showing the character of the country underlaid by the limestone.

CAMBRIAN. The Cambrian limestone underlies the drift-filled valley northeast of Greenwood lake, as far north as Long pond. There are small outcrops of it along the base of Bellvale mountain (434), west of Moses Smith's house, and also in a ravine to the northeast (423). The gneiss crops out about 200 feet from it, up the hill-side. The rock is light bluish grey, cherty and massive, and contains numerous slit-like cavities. Scattered over the surface at this locality are many angular fragments of Oriskany quartzite and conglomerate, which appear not to have been transported any great distance. The limestone probably rests unconformably on the gneiss of the eastern side of the valley.

To the northwest of Bellvale mountain, the Cambrian limestone, which spreads out over the Warwick valley, as previously noted, rests unconformably on the gneiss. A good outcrop of this limestone is in the corner of a field just northwest of Bellvale (107). It shows a thin-bedded character, and has shaly layers. The strike is N. 50° E., and the dip 30° W. Mr. Darton* notes a very small outcrop of Helderberg limestone on the northwest slope of Bellvale mountain, and about one-half mile north of the road across the mountain. The rock is said to be a dark grey, moderately pure limestone. Only one shell was found in it, and that resembled *Strophonella punctulifera*, Conrad.

PRE-CAMBRIAN GNEISS. The gneiss, which is faulted up against the Devonian rocks on the northwest side of Bellvale mountain, enters the county as a belt four miles wide, and narrows rapidly towards Bellvale, whence it extends northward, as a narrow strip, to Sugar Loaf. It has a steep dip. Near the fault line, the gneiss is massive and hornblendic (188, 364, 365). The strike east of Bellvale (188) is N. 30 to 35° E.; dip, 80° S. E., and north of Bellvale (188) the strike is N. 25° E.; dip, 30° S. E. At times the hornblende predominates to such an extent as to make the rock black. Toward the west the basic gneiss is succeeded by a more acid phase, containing much orthoclase and mica.

The gneiss retains the acid character over most of the area south of Warwick and Bellvale. About two and one-half miles due south of Warwick, several openings have been made for iron-ore in the hornblendic gneiss. North of the latitude of Lawton, the gneiss area broadens again to form Sugar Loaf and Goose pond mountains. The gneiss forming these hills is a moderately fine-grained mixture of quartz and feldspar with little or no mica and rarely hornblende. The dip is prevailingly steep to the east. Graphite

* Bulletin Geological Society of America, V., p. 380.

is often present, especially along the western border of the area in Sugar Loaf and Goose pond mountains. This graphitic facies is very constant about one and one-half miles south-southeast of Chester (167). The gneiss here is a granular aggregate of quartz and feldspar with numerous graphite scales, and with a strike of N. 25° E. Mica is rarely present. Farther up the mountain the graphite is lacking. The Hudson river slate occurs in the same field, but was not found in contact with the gneiss. A fine-grained hornblendic schist occupies an intermediate position between the slate and the gneiss (167d).

The stratigraphic relations of the gneiss to the surrounding formations are highly interesting. The western face of the area is very precipitous at many points, especially at the southwest end.

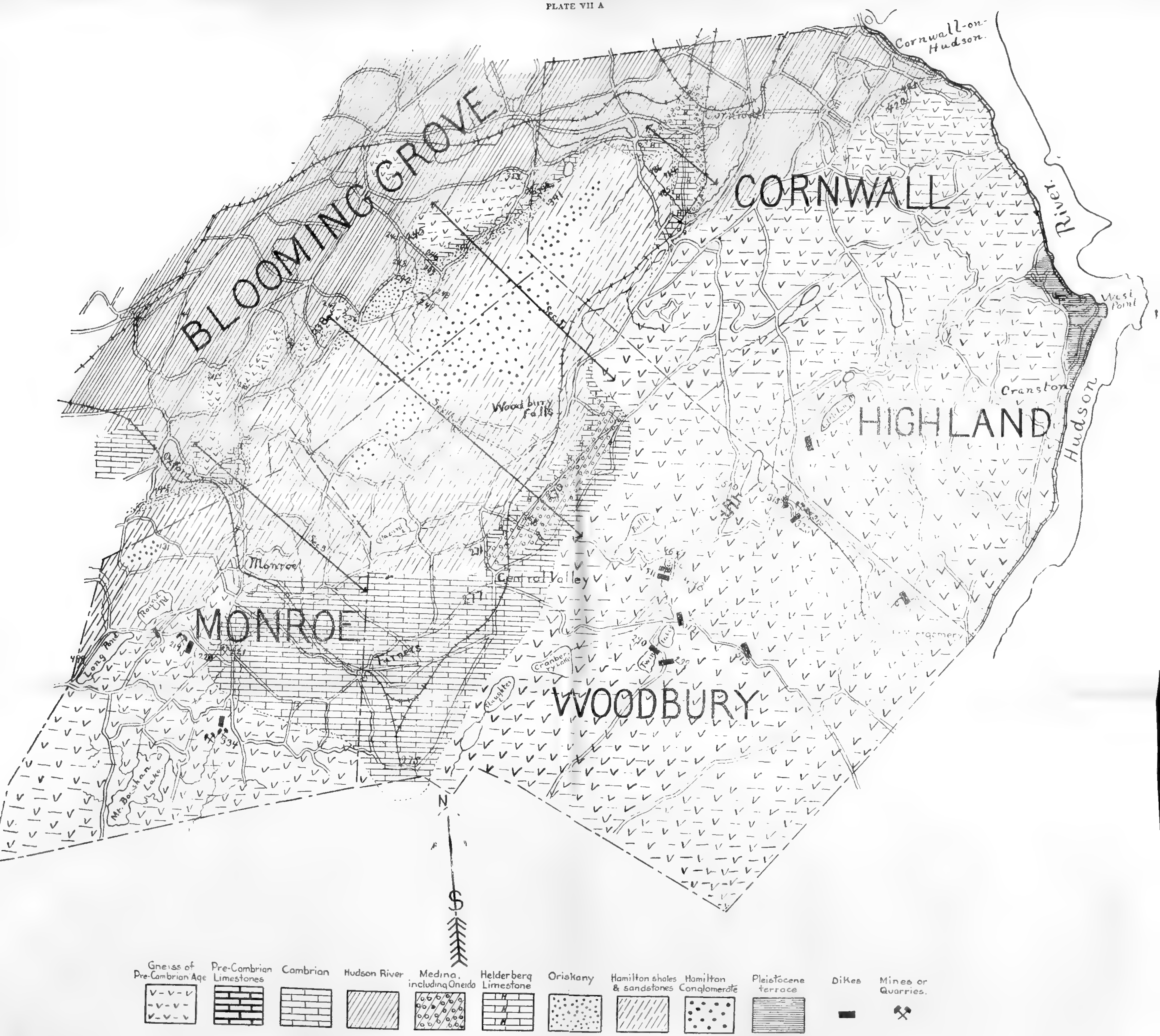
One and one-quarter miles east of Lawton, the Cambrian limestone crops out east of the road (193). The rock is finely crystalline, very hard, and in layers one to two feet thick. Weathering brings out a sub-bedding. The strike is N. 10° E., and dip 20° E. or towards the gneiss. About 300 feet to the east the gneiss rises steeply along a fault line. To the north of this, the slate overlaps the limestone and is faulted up against the gneiss. This fault line probably dies out to the north. On the western side of Sugar Loaf and Goose pond mountains is a flat-bottomed valley which narrows out to the south.

The Cambrian limestone, of which there are several outcrops in this depression, rests unconformably on the gneiss and is, in turn, overlaid by the Hudson river slates, which form a narrow strip along the western side of the valley. The limestone either thins out to the south or is faulted out. To the north and east it underlies the lowlands and also extends northeastward to Oxford, appearing northwest of the station.

There are good exposures of the limestone in the valley of Seely's brook, two miles southwest of Oxford. The rock is not so hard as that east of Lawton, and varies considerably in the coarseness of its grain. A sub-bedding is common and several of the outcrops show a brecciated structure. The strike is N. 45° E., and the dip 30° E.

The Hudson river shales appear along the road running southwest from Oxford along the valley of Seely's brook (203). They are black or brownish black shales which, in their upper portion, contain thin quartzose layers. At one locality along the road (203) fossils are not uncommon. The most abundant are *Orthis testudinaria* and crinoid stems, also fragmentary bryozoans. The slate is considerably broken and the quartzose layers which dip 30° E. of S. are traversed by numerous slit-like cracks, which are approxi-

Figure 4. Outcrop of Monroe shales at the south end of Bagg's clove.



GEOLOGIC MAP OF MONROE, WOODBURY, HIGHLANDS, CORNWALL AND A PART OF BLOOMING GROVE TOWNSHIPS.

The numbers on the map refer to field notes and are in part repeated in the text of the report. The straight lines terminated by arrows show the location of sections on Plate XIV. Scale 1 in. = 1 mi.

mately parallel and form an angle of 60 to 70° with the dip. Overlying the Hudson river shales with a slight unconformity, is the Oriskany quartzite which forms numerous ledges along the western face of this ridge. It is a hard, fine-grained grey or brown quartzite, traversed by numerous cracks which break the rock into angular fragments and surround each outcrop with a characteristic pile of debris.

The rock is sometimes massive, at other times well bedded, giving a strike of N. 25° E. and dipping 40° S. E. At such points it contains slaty or shaly layers, which, however, seem to be rather the result of shearing action than sedimentation. On the eastern side of this ridge the quartzite is hard, fine-grained, massive, and of a light red color, traversed by numerous milk-white streaks of quartz. There are about 100 feet of the quartzite in this ridge.

On the western side of the ridge, the relations of the quartzites to the Hudson river shales are probably, as previously mentioned by Darton, those of an overthrust, since the Helderberg limestone, which underlies the quartzite at several localities in this belt, is missing, and the outcrops of the quartzite and shales are so close together that there is no room for the limestones.

To the west, the Oriskany passes conformably under the Monroe shales, the two being separated by only a narrow valley.

The Monroe shales are well exposed along the road from the valley of Seely's brook to Monroe, and along the "dug road," crossing the hill west of Long pond, which is south of Monroe. They are not infrequently fossiliferous, and at times resemble in appearance the Hudson river shales.

Geologic Relations of the Area along Skunnemunk Mountain.

From Monroe northeastward, the great synclinal fold of Devonian rocks extends as a high ridge nearly to Cornwall, where it ends somewhat abruptly. The southwestern end of the mountain is a gentle syncline, while the northeast end is similar, except that on the eastern side of the mountain the strata curve over and downward, forming an overthrown anticline.

The crest of the mountain is formed of the Skunnemunk conglomerate, the characters of which have been already noted. It begins near the Seven Springs Mountain house, on the ledges a little to the northeast of it, and extends along the two crests of the mountain, giving rise to steep cliffs and rocky slopes. A considerable depression lies between the two crests, and its northern end is occupied by Barton swamp. The conglomerate is about 300 feet thick, as previously noted by Smock, and later corroborated by Darton. It passes into the underlying Bellvale flags, the intermediate beds being a grey quartzitic sandstone; the transition beds are, however, of less thickness than in Bellvale mountain. The lower beds of the conglomerate are to be seen behind the Seven Springs Mountain house, where they are interbedded with grey laminated sandstones.

The Bellvale flags extend the entire length of the mountain, cropping out at numerous points on both slopes. They are thin-bedded, flaggy sandstones, which, in their lower members, have numerous shaly and concretionary layers.

Aside from the outcrops on both sides of the mountain, the sandstones are exposed along the road leading from the main road west of Skunnemunk, up to the Seven Springs Mountain house (236). About one-quarter mile west of the Mountain house are the Davidson quarries at the cross-roads. Several openings have here been made, and a poor quality of flagging obtained. Some plant-remains occur in the quarry, northeast of the cross-road, and shaly layers appear in the southern lower part of the quarry face. The quarry is about 750 feet A. T. Professor Prosser records the finding of the following specimens of plants: *Psilophyton princeps, Calamites,* and aerial rootlets (?) of the latter.

A short distance to the northeast of Davidson's quarry, is Davidson's coal-mine. This point is about one and one-half miles north of Monroe. The greyish flagstones of the quarry contain an abundance of carbonaceous matter, which led the inhabitants to believe that there was coal present. Remains of *Psilophyton* are numerous in the quarry. The species thus far recorded from here are, as already observed: *Psilophyton princeps, Lepidodendron gaspianum, Calamites transitionis* and, according to Newberry, *Dadoxylon;* Dawson, however, thinks the last to be *Calamites radiatus.*

About one and one-half miles northwest of Monroe, on the southwest base of the mountain, and 300 feet lower than the Davidson quarries, are several small quarries on the land of O. H. Cooley. The rock is a thin-bedded sandstone, with shaly layers, which have been polished to a high degree by shearing. Concretions occur in the shaly layers and also in the coarse sandstone ledge to the northeast of Cooley's largest opening. The shales contain abundant remains of plants, commonest among which is *Psilophyton.* Several of the others were submitted to Prof. Knowlton, but they were too fragmentary for identification. Prosser notes the finding of *Celluloxylon primævum,* as identified by Knowlton. The specimen found by Prosser represented the end of a stem protruding from the sandstones of

Cooley's quarry. At the time of the writer's visit in September, 1895, Mr. Cooley had uncovered the specimen to a length of twenty-nine feet. The "fossil tree" has a diameter of fourteen inches at the upper end and eight inches at the lower end. To this point it dips about thirty degrees along the bedding; the stem then makes a sharp turn, and can be seen extending downward several feet more at an angle of about seventy degrees. The dip of the sandstones is about thirty-five degrees to the east.

Most of the rocks on the steep eastern side of Skunnemunk mountain are grey sandstones, which, in the second railroad cut north of Woodbury falls, contain plant remains, chiefly *Psilophyton.*

The hills to the southeast of Skunnemunk mountain, between it and Hazard pond, or Cromwell lake as it is more commonly called, are probably underlaid by the Bellvale flags, but outcrops are very scarce, owing to the heavy mantle of drift. Several outcrops of sandstone were seen about three-quarters of a mile due north of Hazard pond, and to the north of this are some arenaceous shales, in which imperfect specimens of *Chonetes* were found.

The Monroe shales underlie Skunnemunk mountain throughout its whole extent, but are best developed along its western and northwestern base. They are grey to black, fissile to slaty shales, and are not uncommonly fossiliferous. They crop out along the road south of Baggs clove (242) and on the eastern side of Skunnemunk mountain, are to be seen at the base of the mill dam at Woodbury falls, where the dip is nearly vertical. Their greatest development is in Péa hill, near Cornwall. There they crop out in great abundance, especially on the southwest side of the hill, where it rises steeply from Moodna creek (486).

The shale also appears on the eastern side of Pea hill, near the observation tower on the summit. On the south slope in the middle of a field about half-way up the hill, is an inconspicuous outcrop of a very hard, fine-grained red and grey sandstone (484), containing great quantities of fossils. The rock is strongly cemented together with iron. The red sandstone predominates. The following much distorted fossils were observed: *Spirifer*, sp.? *Tentaculites*, sp.? *Meristella*, sp.? *Orthis*, sp.? *Theca*, sp.? *Chonetes*, sp.? *Rhynchonella*, sp.?

Along Moodna river, near the south end of Pea hill, is a cliff of hard sandstone traversed by numerous joints (485). Only one fossil was found in it, viz.: *Pentamerella arata.* Extending up the centre of the cliff is a strip of fine-grained, black, nodular rock, which is so hard as to break with difficulty. The nodules have a shell which resembles the sandstones into which the nodular rock shades. A section of this nodular rock shows it to be a portion of the sandstone which is firmly cemented with iron.

The structure of Pea hill is probably that of a synclinal fold. The Monroe shales are underlaid by the Oriskany quartzite which, in Pea hill, is a coarse pebbly quartzite, massively bedded and very hard. There are good exposures of it along the road at the northeast side of Pea hill, where these fossils were found:

Anoplia nucleata,
Stropheodonta, sp.?
Leptæna rhomboidalis,
Leptocœlia flabellites.

The Hudson river slates no doubt form the bottom of this synclinal fold, but outcrops are lacking in the immediate vicinity.

The general structure of Skunnemunk mountain is that of a much more open synclinal than Bellvale mountain to the southwest. But at the northern end, the flags and sandstones of the eastern limb turn over and downwards on to the limestones of the Helderberg and Cambrian, as already shown by Darton.

The Relations along the Northwest Side of Skunnemunk Mountain.

The Oriskany quartzite, which forms the ridge along the west side of Seely's brook, southwest of Oxford, turns to the east, cropping out in the field below the road, half a mile south of Oxford station (144). At this locality, it is both coarse-grained and finely granular. The next outcrops are in a field about one mile due east of Oxford and west of the high-road. There are three small outcrops, which are hard reddish quartzite with white seams of quartz. Farther east, on Bull hill, are two small areas of the same formation of a more conglomeratic nature, and which rest on the Hudson river slates. They strike N. 40° W., and dip 55° N. E. This locality east of Bull hill is of considerable importance as affording an explanation of the stratigraphic relations of the rocks in this region. The quartzite area (439) is underlaid by a thin-bedded, shaly, dark grey limestone striking N. 60° E., dipping 35° S. E. In the limestones are numerous fragmentary remains of bryozoans, crinoid stems and corals, all of them too poorly preserved for identification. On examination of the specimens Professor Hall pronounced them to be lower Tentaculite limestone. Some years ago, N. H. Darton submitted some specimens from the same locality to Professors Hall and

Figure 5. Unconformity between Oriskany quartzite and Helderberg limestone, northwest of Monroe.

Whitfield, who identified them as upper Silurian, and recognized the species *Spirifer cyclopterus*, *Spirifer macropleurus* and *Orthis oblata*.

An actual contact of the limestone and quartzite is not visible, but the former passes unconformably under the latter. The relations of these two are probably those of an overthrust or overlap, as explained by Darton.*

The Helderberg limestone overlies the Cambrian limestone unconformably. The latter outcrops along a cross-road (440) just east of Bull hill, and a few hundred feet to the northeast of the Helderberg exposures. It is in thin shaly layers, which are seamed by numerous hair-like calcite veins. The rock is also full of cavities containing powdery limonite. In places the limestone is porous and nearly as light as wood, owing to the leaching out of the lime. It also, at times, presents a brecciated structure. The strike is N. 80° E., and the dip 30° S. The Cambrian limestone appears again at the eastern base of Bull hill, near the southeast end, in the railroad cut at the south end of the ridge, on its western slope, and on the northwestern side. It presents variable dips and strikes, and overlies the gneiss of Bull hill unconformably, at least on the eastern and southern side of the ridge, but on the western slope the limestone is overlapped by the Hudson river slates, which rest unconformably on the western slope of the gneiss. The relations of the rocks of the small area are shown in figure 6.

The Oriskany quartzite seen east of Bull hill, probably extends to the north, but is obscured by the heavy covering of drift to a point about one-half mile south of Round hill, where there is a small area resting on the gneiss. It next appears in the eastern slope and summit of a ridge between Round hill and Woodcock hill, again exhibiting the conglomerate facies, with an occasional layer of coarse sandy quartzite. The strike on the crest of the ridge (242) is N. 60° E., dip 30 to 40° S. The Hudson river slates form the western half of this ridge, extending to and along the southern base of Woodcock hill, where the stream has cut a deep gorge through them (245). A short distance southeast of this point, and along the road crossing the south end of Woodcock hill (246), the Cambrian limestone appears. It is light blue, finely crystalline, and contains many calcite veins. It strikes N. 50° W., and dips 30° N. E.

The quartzite is again seen at the edge of a small wood, south of the same road (247). It is here a coarse conglomerate, with a strike of N. 40° E., and a dip of 50° S. E. The limestone is seen just west of it, and underlies it with a slight unconformity, dipping 60° S. E. The limestone also appears at

* Bulletin Geological Society of America, V, p. 367.

the base of the slope in a wood lot west of the previous exposure and south of the road, but the dip at this point is low to the west. Northeast of the

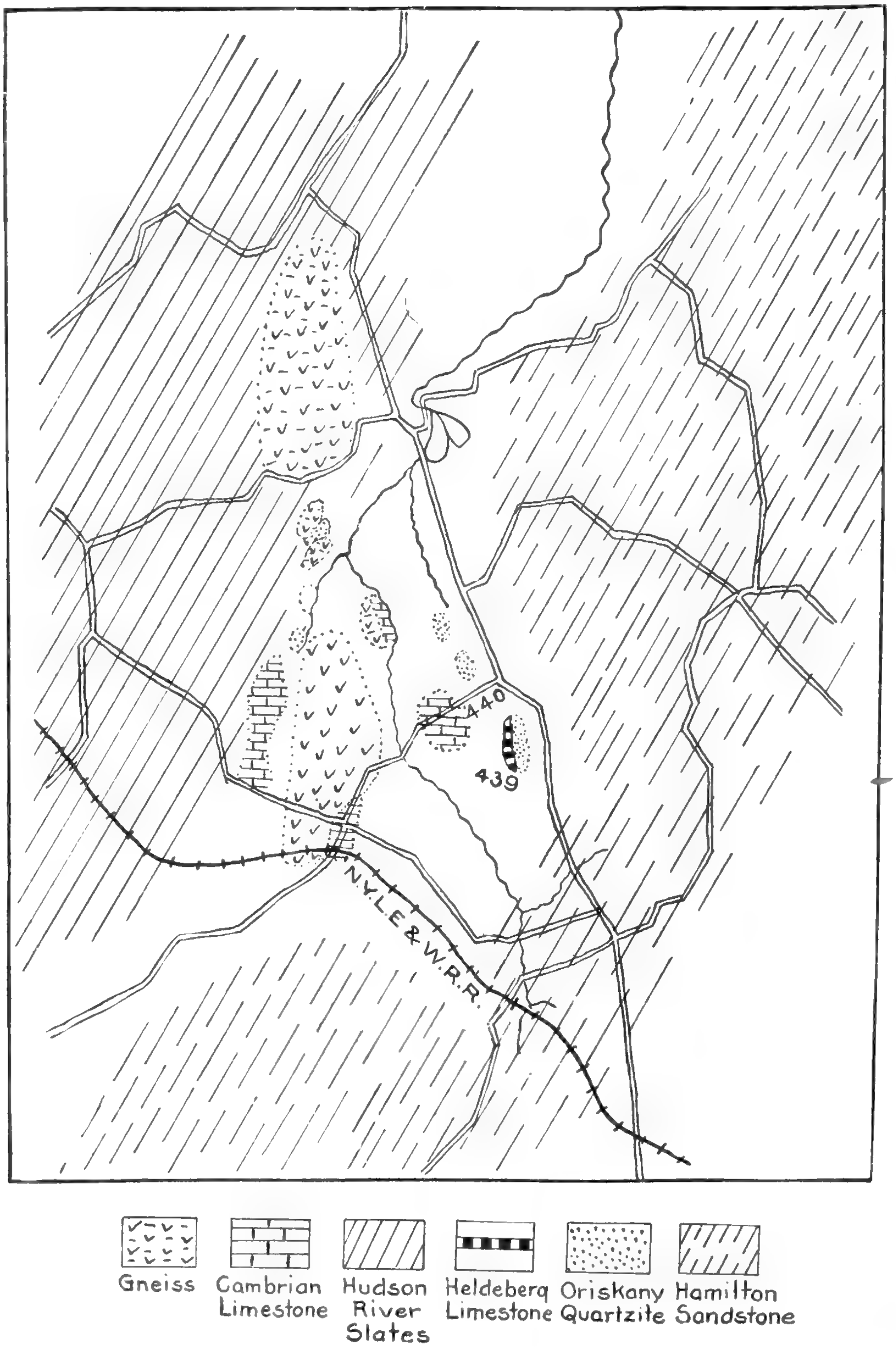


FIGURE 6. Geologic map of the area around Bull Hill.

road, at the upper end of a small field, and at the edge of the woods, the Hudson river slates crop out at the foot of the slope (260), dipping under the quartzite and conglomerate, and forming the ridge between it and the

PLATE VIII

QUARRY IN LIMESTONE NEAR SUMMIT OF SOUTHWESTERN FACE OF LOOKOUT MOUNTAIN.

school house to the southeast. To the west of the shale, in the woods, are large outcrops of massive cherty limestone. It is not well bedded, but an anticlinal structure is clearly apparent.

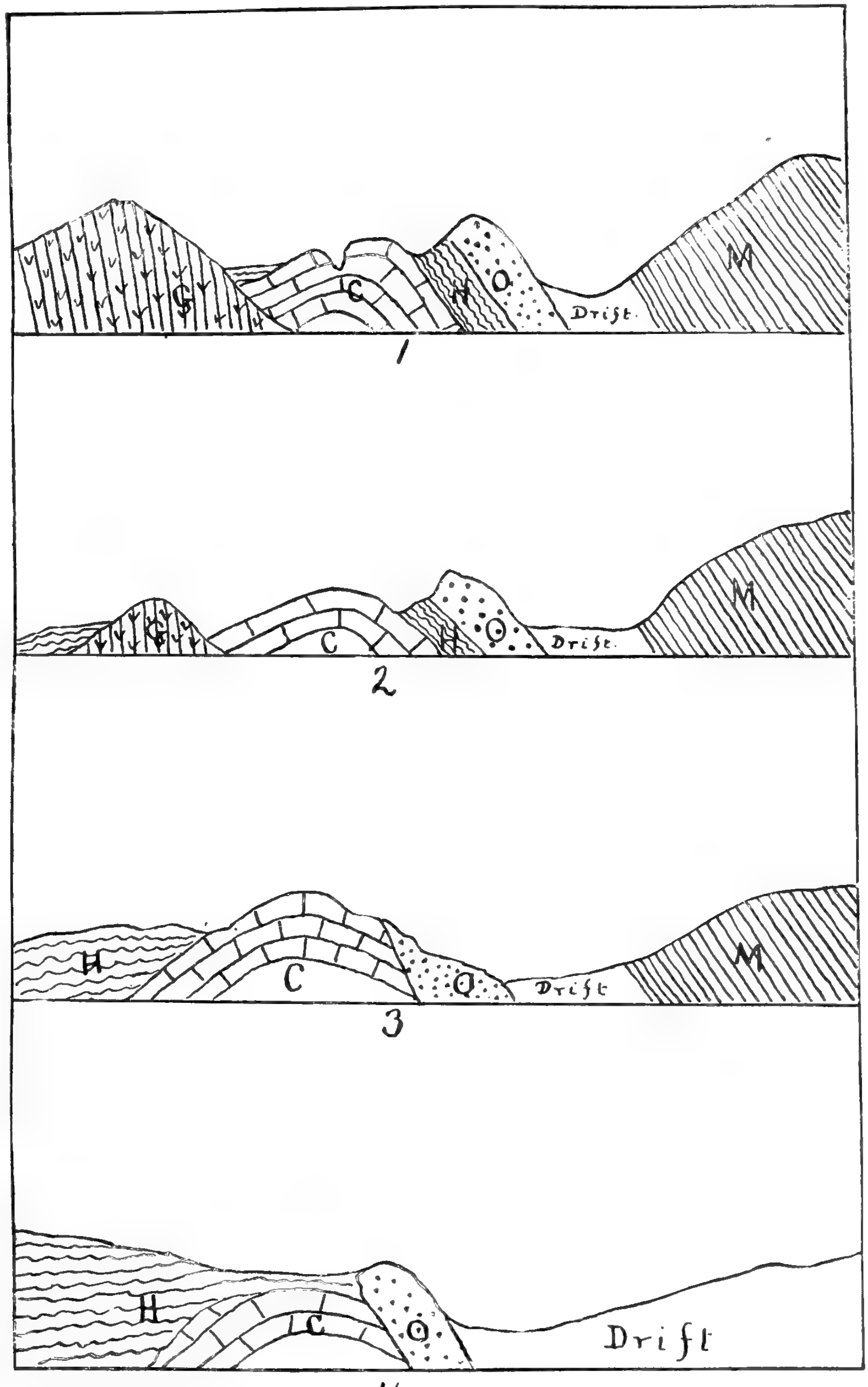


FIGURE 7. Sections along the line of overthrust at the southern end of Woodcock Hill.

The limestone, slate and quartzite continue northeastward in the valley east of Woodcock hill, with somewhat the same relations.

An examination of the distribution of the limestone, shale and quartzite east and southeast of Woodcock hill, shows the presence of an overthrust, which increases to the south, the quartzite covering the limestone. These relations have been previously determined by Darton, and as the writer came to the same conclusions, the sectional drawing from Darton's paper is reproduced here (Fig. 7). East of the north end of Woodcock hill, a spur of the gneiss, together with the limestone and shale, appears east of the road in Baggs clove. The gneiss is seen just east of the road (340), and the limestone and slate in the woods (341 and 342). The Monroe shales appear at the base of Skunnemunk mountain to the east. The Oriskany quartzite was not seen east of the road at this point, but is exposed in the fields a short distance south. The gneiss, limestone and quartzite disappear to the north, either by thinning out or faulting under the Hudson river shales. The thin strip of Hudson river shale, between the gneiss and limestone east of Woodcock hill is pinched out of place. There is apparently a fault line between the limestone and the gneiss.

There is a row of gneissoid hills or knobs northwest of the Skunnemunk ridge, which extends from Oxford in a northeast direction, parallel to Skunnemunk mountain, and as far as Cornwall. The relations of these to the rocks southeast and east of them have been already mentioned.

To the west and northwest they are surrounded by Hudson river slates, which rest unconformably on their slopes. The names of these gneissic hills are Bull hill, Ranier hill, Round hill and Woodcock hill. There is an additional small area near Washingtonville. These hills were no doubt islands in the seas of Hudson river time.

There is a great similarity in the gneiss forming these knobs, the normal facies being a granular mixture of quartz and feldspar, with little or no mica. Nearly all of the outcrops show evidence of dynamic action in the invariable presence of sheared surfaces. The sections often bear additional evidence of this fact.

The gneiss of Bull hill is in two areas, a northern, and a southern one which extends just across the Erie railroad track. The northern area presents a very steep northwest face. On the summit near the north end, a large opening has been made for iron-ore. The strike of the gneiss is N. 30° E. and the dip 40° S. E. The magnetite follows the dip, and, according to the old inhabitants of that vicinity, has been worked to a depth of 150 feet.

PLATE IX

General view looking northeast across Long Pond.

The foreground and the hill on the left are of Hamilton rocks as is also the middle background. The wooded hill at the right is of Precambrian gneiss. Skunnemunk mountain in the distance.

A drift was run in at the foot of the east slope of the hill for drainage purposes. Both the hanging and foot-wall of the ore-body are of hornblendic gneiss, outside of which is the normal gneiss. The ore is very lean, and has a considerable admixture of quartz. No faults or dykes were observed. A sectional drawing of the ore-bed is here given.

A section of the hornblendic wall-rock shows it to be a mixture of green hornblende and some plagioclase. Much of the latter is kaolinized. The hornblende individuals are much bent and broken.

The sections of the normal gneiss show a mixture of quartz and plagioclase feldspar, with little or no mica. The cleavage and other cracks of the feldspar are beautifully coated with limonite. Magnetite occurs sparingly in grains. Fine microperthitic intergrowths were not uncommon.

At the eastern base of Bull hill, near the south end, the gneiss presents the appearance of being broken by a step-fault, the rock forming a gentle

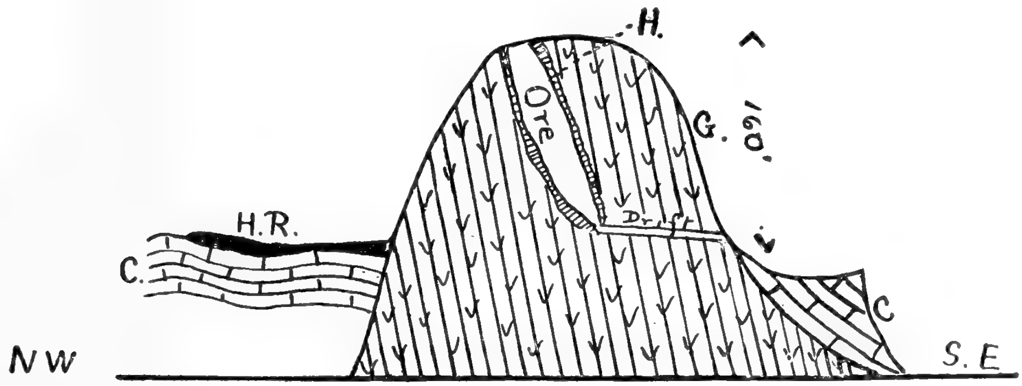


FIGURE 8. Section of Bull Hill, northwest of Monroe; showing iron mine and drift intersecting the ore-body.
G., Pre-Cambrian gneiss; H., Hornblendic wall-rock; H. R., Hudson river slates; C., Cambrian limestone.

slope on the west side of the wood-road, and a perpendicular one on the east side, which slopes gently to the east on its other side.

The Hudson river slates pass between Bull hill and the next gneiss knob to the northeast.

The road north of Rainier hill passes between two knobs of gneiss. The latter outcrops on both sides of the road (238). It is massive, and gives no good dips, but the strike is about northeast and southwest. The slate, no doubt, formerly extended through this cut, but it has been removed by erosion, and is not met with up to a point about 300 feet east of the brook west of the hill. To the north and south of the road, the slates extend some distance up the flanks of the hills. The road swings around to the north and intersects another, which turns east along the north side of Round hill. This road traverses the hill until it rises steeply about three-quarters of a mile west of the cross-roads. At this point (241), the gneiss is again met, cropping out along the roadside. It is very massive, and farther up the hill becomes very hornblendic. The rock is deeply stained with iron. The strike here is N. 40° E., and the dip 70° S. E. An opening for magnetite has been made at the summit of the hill. The slate appears with a western dip within twenty feet of the gneiss, and evidently rests on it unconformably. It shows numerous local crumplings. The gneiss extends along the south side of the road, as far as the school-house at the cross-roads; while the slate forms the slope to the north of the road. Toward the school-house the gneiss becomes more granitic and coarse-grained. Layers of graphitic schist and pegmatite veins are very numerous at this point. Woodcock hill to the northeast is quartzose gneiss, with much graphite in the exposures at the north end of the hill. The strike at the north end is N. 80° E., the dip 70° E. The constant eastern dip in this range of gneiss hills is noticeable. A spur of the gneiss crosses the road to the east, and is seen in the woods within a few feet of the limestone (340). To the north the gneiss disappears under the slate.

Geology of the Region East and Southeast of Skunnemunk Mountain.

The Cambrian limestones which are seen in the valley north of Greenwood lake are covered by drift as far as the valley of the Ramapo, east of Monroe. The limestone extends from a point about two miles south of Monroe, eastward to Turners, and a short distance beyond that point in a southeasterly direction. The most western exposure is in the road-bed a few hundred feet east of the Clove mine, and near a large barn. At this point it is thick-bedded and intersected by numerous joints. A little farther to the east at the cross-road (220), the limestone is argillaceous and shaly, with a barely perceptible dip to the northwest. The outcrops show a similar shaly character at the other end of this cross-road (445) with a low northeast dip. In the limestone quarry to the north, the rock is massively bedded and hard. The limestone here is light bluish grey, in layers six inches to two feet thick, and fine-grained. It has a low dip of twenty degrees to the northwest. The rock is much weathered along the numerous vertical joints, and contains many small cavities lined with crystals of quartz and calcite. About twenty-five feet are exposed.

FIGURE 9. ROUND HILL; A GNEISSOID KNOB NORTHWEST OF SKUNNEMUNK MOUNTAIN.

As the Highlands east of Turners are approached, the dip continues to be northwest, but becomes steeper. Southeast of Turners, and just east of the Erie railroad, the dip is N. W. 45°, while in the quarry north of Arden, where the limestone is seen in contact with the gneiss along a fault line, the dip is nearly vertical, but in the upper portions of the quarry the layers turn over slightly, the dip being to the west. The limestone in the quarry is dark blue, finely crystalline and in layers of variable thickness. The strike of the limestone is N. 45° E. The contact between the gneiss and limestone in the upper part of the quarry is easily seen.

When the furnaces at Greenwood and Southfield were running, the quarry was important as a source of flux.

The northwestern boundary of the Turners limestone area extends from one mile east of Monroe to the southern end of Pine hill, in Woodbury township. The eastern edge skirts the gneiss ridge as a line of knolls, usually covered with a veneer of gravelly drift. Much of this limestone area has a heavy drift covering, and includes the large, swampy meadow tract between Turners and Central Valley.

South of Central Valley (277), the limestone strikes N. 50° E., and dips 70° N. W. Northeast of Central Valley, the limestone area narrows very much and extends up the shallow valley between Pine hill and the Highland ridge. In this valley it underlies the Oneida conglomerate. At the north end of Pine hill it dies out suddenly by thinning or faulting, but reappears in a short strip from Woodbury falls to Mountainville.

Pine hill is a narrow ridge lying east of Skunnemunk mountain. It has a steep eastern face and a gentle western slope. The members of the Medina formation, both with a western dip, give rise to the elevation. The eastern half and face are composed of the Oneida conglomerate, which is a coarse quartzite in its upper portions, but exhibits the usual aspect of the formation in its lower beds. The quartzite grades upward into the Longwood red shales, which form the western slope of the hill. The transition is well shown in the northwestern slope of Pine hill.

The Longwood shales in Pine hill are of a bright red color; they vary from a shale to a shaly sandstone, and are about seventy-five feet thick. At the north end of the hill the shale strikes N. 60° E., and dips 80° N. W., but this is somewhat steeper than the usual dip. The conglomerate strikes N. 60° E. and dips 50° N. W. The cleavage is a prominent feature of the shale, and dips to the southeast. It is well shown in the road-metal quarries at the southwest side of the hill.

The shales and conglomerate terminate at both ends of Pine hill by faulting or thinning out.

The Longwood shales are overlaid by a thin covering of Helderberg limestone, with small amounts of limonite along the contact. The outcrops of the Helderberg are a short distance northeast of Highland mills. They are siliceous in character, and the following fossils have been recorded by Darton: *Orthis oblata, Leptæna rhomboidalis, Spirifer macropleurus.* The Helderberg limestone dips unconformably under the Monroe shales, due to a probable overthrust; but no actual contacts are observable on account of the drift. Another exposure of possible Helderberg limestone occurs one mile south of the Highland mills station (271).

The Area West of Cornwall.

West of Cornwall station is a small ridge holding several members of the Medina and Helderberg formations. The relations of this area were briefly referred to by Professor W. B. Dwight* some years ago, and subsequently in greater detail by Darton.† Figure 10, giving map and sections of this area, is adapted from Darton's paper.

The eastern side of the hill, a few rods from the Erie railroad, is formed of coarse-grained red siliceous conglomerate (Oneida), with red sandstones and shales of Medina age. The conglomerate is massive and the bedding irregular.

At the northern end of the hill, in a cut of the New York, Ontario and Western railroad, there is exposed a section of the Helderberg limestone, which lies west of and over the Medina beds, forming the eastern face of the hill.

The members exposed in the cut are:

Medina sandstones, shales and conglomerate, ...	25 feet.
Tentaculite limestone, ...	10 "
Pentamerus and shaly limestone, ...	40 "

The beds strike northeast with a dip of nearly 90°, and there is no sharp distinction between them. Veins of quartz and limonite are common along the bedding planes.

There are several exposures south of the road crossing the ridge and at points where limonite has been mined, but as they were covered with debris at the time of the writer's visit, Darton's account of them is quoted:

* W. B. Dwight, *Trans. Vassar Bros. Inst.*

† N. H. Darton, *A. J. S.* 3, XXXI., p. 209.

PLATE X

Fig. 1

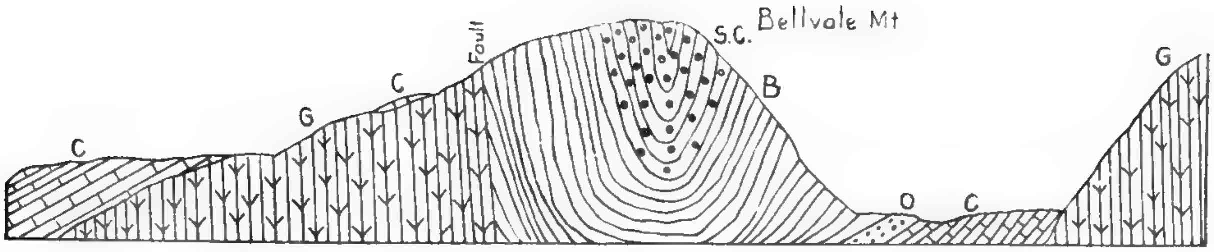


Fig 2

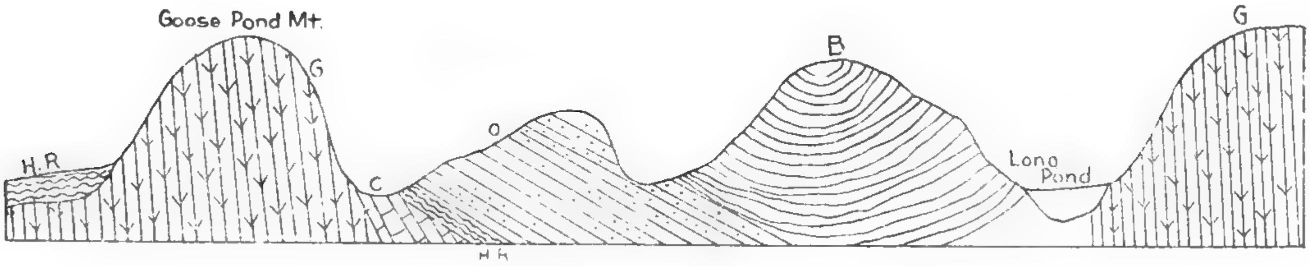


Fig 3

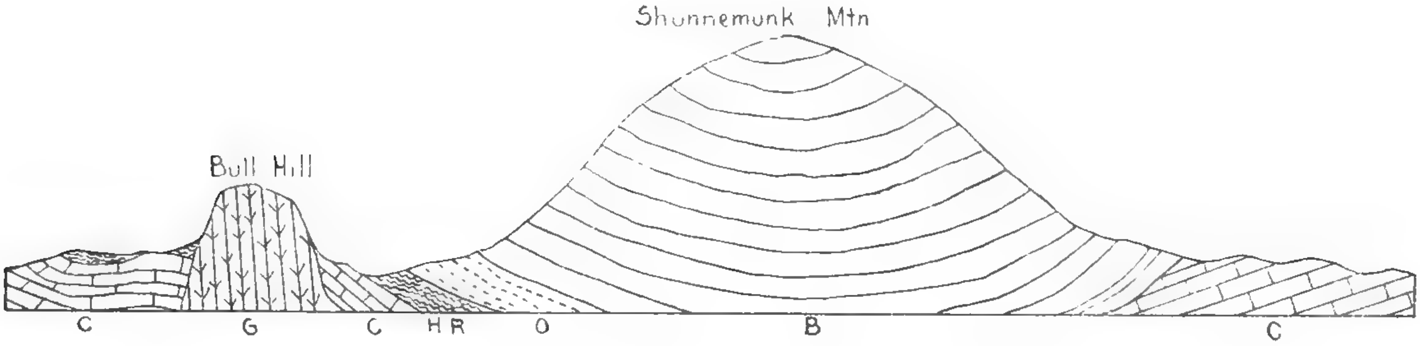


Fig. 4.

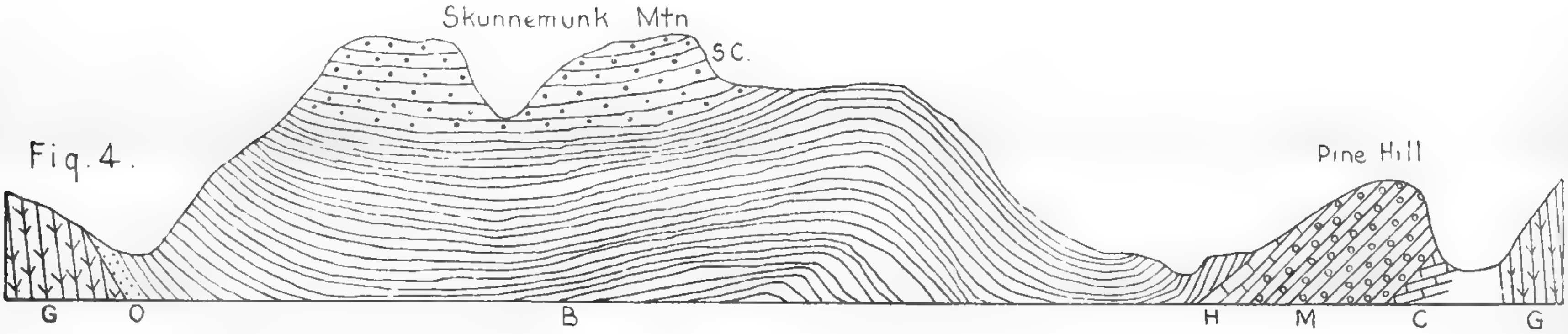


Fig. 5

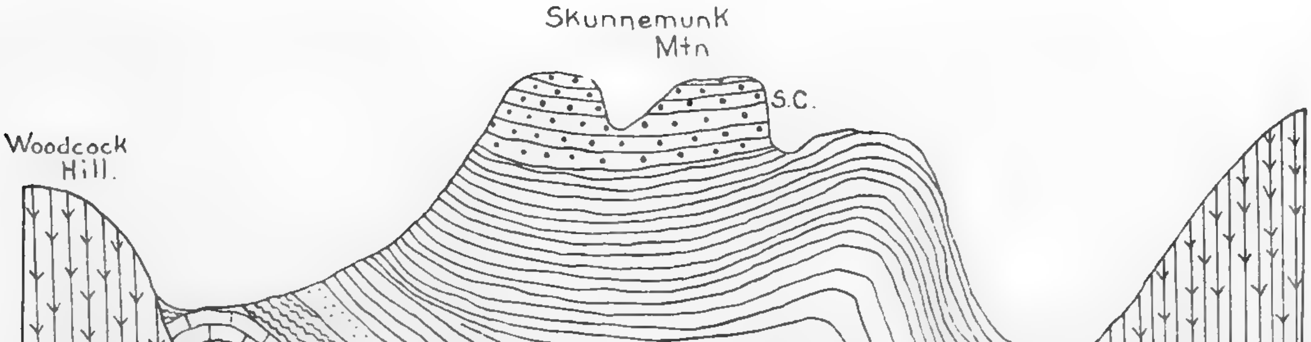
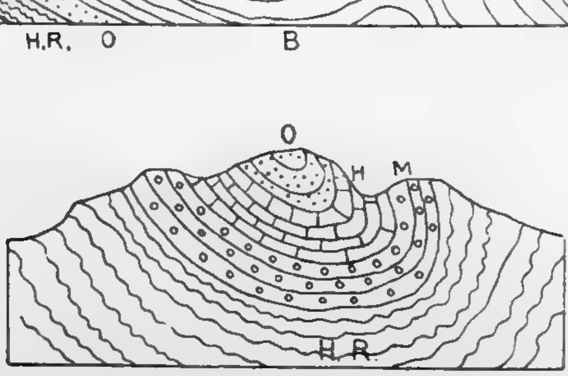
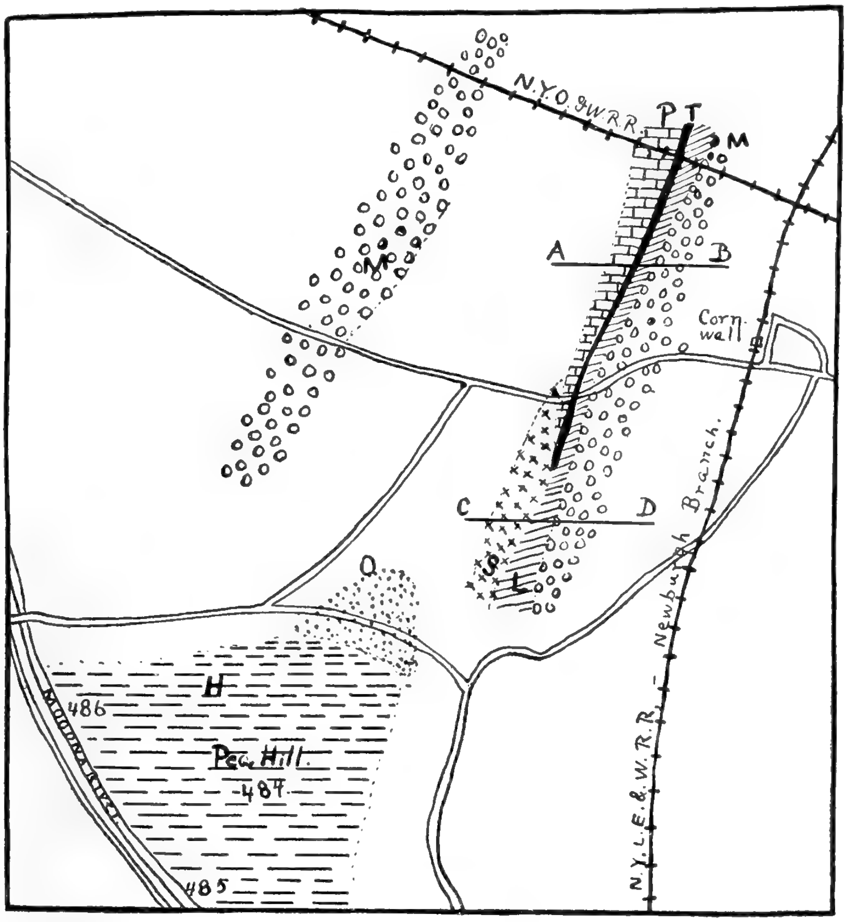


Fig. 6



G. Precambrian gneiss; C. Cambrian limestone; H. R. Hudson river slates; M. Medina; H. Helderberg; O. Oriskany; B Bellvale flags, including Monroe shales; S. C. Skunnemunk conglomerate.

"In a small quarry, about one hundred feet south of the cross-road, the water-lime rocks are exposed for a thickness of about three feet, and the sandstone outcrops a few feet to the east. The dip is N. 65° W. 85°, and the



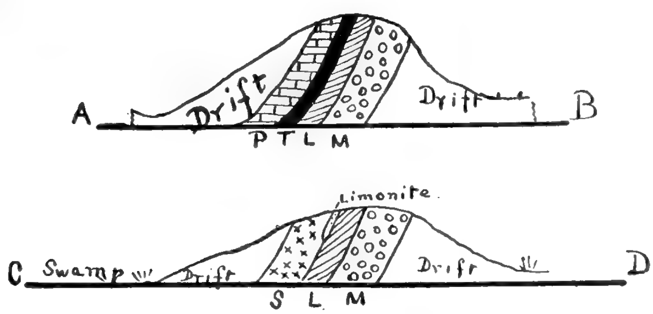


FIGURE 10. Map and sections of Region west of Cornwall.
M., Oneida conglomerate; L., Longwood shales; T., Tentaculite limestone; P., Pentamerus limestone; S., Shaly limestone; O., Oriskany quartzite; H., Monroe shales.

thickness is twelve feet. The Pentamerus and Water-lime disappear by thinning out or faulting, and the Shaly limestone lies directly on the Longwood shales, while along the contact are beds of limonite. The Shaly limestone contains an abundance of fossils, which are easily obtainable in the limonite pits south of the cross-road."

The Helderberg rocks probably extend around the Oriskany of Pea hill to the southwest, but there are no outcrops, owing to the heavy covering of drift.

The Longwood shales at Cornwall are light-colored, thin-bedded quartzites in their upper members, and red and green shales in their lower ones. To the east they are underlaid by the Oneida conglomerate. This conglomerate forms another ridge further west. Northeast of Mountainville, the Longwood shales crop out along the road to Orr mills.

Geology of Deer Park Township.

Shawangunk mountain extends across the eastern edge of the township, and separates it from Greenville and Mount Hope townships to the east. Its rounded crest has an elevation of 1,200 to 1,400 feet, being highest at the northern end of the township. The lowest point in the ridge is west of Otisville, where the Erie railroad passes through. The cultivated eastern face of Shawangunk mountain is underlaid by Hudson river slates and sandstones, while the steep, wooded western face is formed of sandstones and conglomerates of Medina age.

The Hudson river formation consists of westwardly dipping shales and red and grey sandstone beds of variable thickness. No fossils were found in them at this locality. These beds underlie the Shawangunk grit with a slight but constant unconformity. The boundary between the two along the crest of the mountain is generally marked by a swamp, along whose western side the Oneida conglomerate rises as a low cliff. The sheared surfaces give evidence of movement along the contact of the slates and conglomerate. There are, also, along the contact, numerous small fissure-veins bearing lead and zinc intermixed with quartz. The quartz crystals often show a fine zonal structure, due to their intermittent growth. A breccia occurs in the vein at Guymard, six miles northeast of Port Jervis. The fissure vein at this locality is the largest found in the county. It is three to four feet wide and several hundred feet long, and has been extensively exploited in former years. It is no longer worked. The vein occurs in Shawangunk grit, but probably extends down into the conglomerate. The ore consists of galena and sphalerite disseminated through quartz. The quartz crystals often occur in radiating clusters. Another opening for lead

GEOLOGIC MAP OF CHESTER TOWNSHIP. SCALE 1 IN. = 1 MI

and zinc has been made at the summit of the ridge above Guymard, also at the summit west of W. C. Tymeson's house, three-quarters of a mile north of Otisville.

The unconformity between the Oneida conglomerate and Hudson river slates is finely seen in the railroad cut, half a mile west of Otisville, and also on the north side of the road from Finchville over the mountain to Guymard. This unconformity indicates an uplift at the close of the Hudson river period, and erosion of the surface of the Hudson river deposits. Considerable folding also took place. The Oneida conglomerate and Medina sandstones were deposited during a period of increasing submergence.

In the lower portion of the Medina formation there are about forty feet of coarse quartz conglomerate, with interbedded layers of shale. This passes upward into the Shawangunk grit, which is extensively opened in the quarry west of Otisville. The rock dips 30° W., and strikes N. 40° E. It is a fine-grained, bluish grey, gritty quartzite, in layers four to twelve inches thick, and of very constant character. In the topography it creates steep wooded slopes covered with a stunted growth of trees. The grit has a thickness of about 750 feet. It passes upward into sandstones and shales of Medina age. The sandstones are seen on the western slope of the ridge along the road from Finchville to Shin hollow, and a short distance before reaching the railroad track. They are thin-bedded red sandstones and shaly sandstones in layers from one inch to a foot thick. At times they are micaceous and sometimes have small grains of pyrite, as above Guymard. The strike above Shin hollow is N. 40° E., and the dip, 60° W. (Elevation, 910 feet A. T.) Along the road across the mountain east of Greenville, the strike is the same, but the dip is 34° W. The red sandstones pass upward into greenish grey shales, which are exposed in the railroad cut south of Shin hollow. They are very fissile, and the surface of the thicker and harder layers is covered with reticulated cracks.

West of Shawangunk mountain is a depression, followed by the Helderberg ridge holding the Helderberg limestones and the Oriskany and Esopus formations. The Helderberg ridge, with its subordinate crests and ridges, is parallel to the Shawangunk mountain, from Port Jervis to the northern limits of the county, and beyond. The structure of the ridge is that of a monoclinal, with a system of gentle transverse flexures, each hill representing a low anticlinal, while the roads which cross the range lie in the synclinals.

All the rocks in this ridge have a prominent cleavage, which becomes more marked with the ascent in the series, and the bedding is often totally obliterated. Owing to the heavy covering of forest growth, outcrops are comparatively scarce. The best sections to be obtained are at the southern end, east of Carpenter's Point, and at the northern end, east of Cuddebackville, and chiefly on the property of Cornelius C. Cuddeback.

The lower members of the Helderberg limestones are separated from the upper beds of the Medina, which they overlie with a possible slight unconformity, by a narrow, shallow valley. The Coralline limestone may lie in this valley, but if it does, the drift covers it entirely and, furthermore, it must be but a few feet thick in places, as at Shin hollow, where the Medina and Helderberg are found quite close together.

About three miles southwest of Otisville, on the land of Mr. Cuddeback previously mentioned, are several small parallel ridges, with steep eastern slopes, which illustrate fairly well the Helderberg sections at this locality.

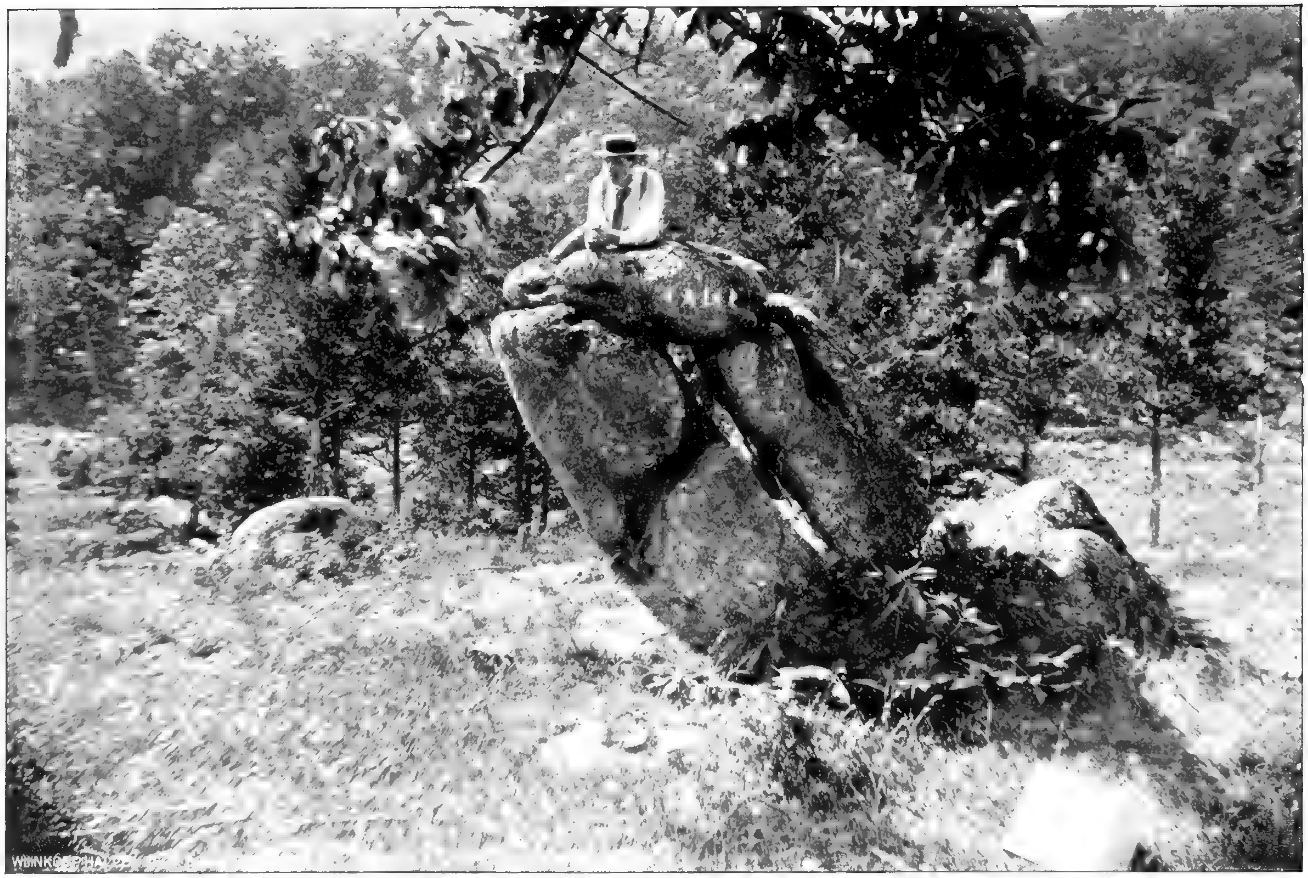
The first ridge is a few feet west of the road, and the south end of it is right behind Mr. Cuddeback's house. At this point, and near the summit of its short, steep eastern slope, are small ledges of the Tentaculite limestone (62a). It is a hard, fine-grained, dark bluish rock, with a sub-bedding that shows prominently on the weathered surface. The beds strike N. 30° E., and dip 35° N. W. There is an irregular cleavage, which dips steeply to the southeast, and along which the rock parts very easily, while it breaks with difficulty parallel to the bedding.

The total thickness of the Tentaculite limestone exposed in this ledge is about twelve feet. Certain layers contain abundant remains of *Leperditiæ* and *Meristina*, and the lower layers of the ledge also furnished a few specimens of *Favosites minima.*

Ledges near the summit of the same ridge, but about 600 feet farther north, consist of layers of impure and sometimes shaly limestone (62b), which contain an abundance of fossils, indicating a mixture of Tentaculite and Lower Pentamerus faunas. The species found were: *Leptæna rhomboidalis*, *Stropheodonta varistriata*, *Rhynchonella*, sp., *Actinopteria*, sp., *Cypricardinia lamellosa*, *Zaphrentis*, sp., *Leptostrophia*, sp., *Pholidops*, sp., *Spirifer Vanuxemi*, *Dalmanites*, *Beyrichia*, including one large form about three-quarters of an inch long.

At the south end of the ridge and just west of 62a, is a second and somewhat lower crest, formed of a hard, bluish grey, fine-grained limestone, with conchoidal fracture and irregular cleavage (62c). It contains no fossils and dips westward under a coarsely granular limestone, which forms a small knoll (63), surmounted by a walnut tree. It seems to be a portion of the

PLATE XII



LIMESTONE BOULDER ON WEST SLOPE OF MOUNT ADAM, SHOWING THE PECULIAR SHAPE DUE TO WEATHERING.

Tentaculite, for the lower layers of the knoll contain Tentaculite fossils. The limestone beds of the knoll dip 35° N. W., and strike N. 40° E.; their total thickness is about six feet, and they probably represent the transition from Tentaculite to Lower Pentamerus. *Stropheodonta varistriata* is present in considerable abundance.

These beds are overlaid by eight feet of Pentamerus limestone, which forms a second knoll, and contains a number of imperfect fossils, besides an abundance of *Pentamerus galeatus*, *Favosites* and *Stromatopora* cf. *concentrica.*

These Pentamerus beds dip northwestward at the usual angle, forming a short ridge about fifty feet to the northwest. The lower beds of this ridge are the Pentamerus limestone, which passes into the Catskill shaly limestone, forming the upper half of the section exposed in this ridge.

The Catskill shaly beds strike N. 40° E. and dip 35° N. W.; they have a pronounced cleavage, and are sometimes quite arenaceous. The usual number of distorted fossils is present, with *Spirifer macropleurus* in great abundance. The other species from the shaly layers which were identified with certainty, were: *Spirifer cyclopterus*, *Orthothetes*, sp., *Leptæna rhomboidalis*, *Spirifer perlamellosus*, *Rhynchonella*, sp., *Cœlospira*, sp., *Pholidops*, sp.

The lower, more massive layers, exposed in the eastern face of the ridge, and representing the transition from the Pentamerus to the Shaly limestone (66a), afforded *Orthis oblata*, *Rhynchonella*, sp., *Fenestella*, sp., *Stropheodonta punctulifera*, *Eatonia singularis*, *Stropheodonta Becki*, *Cœlospira dichotoma*, *Spirifer cyclopterus*, *Stropheodonta varistriata*, var. *arata*, *Pentamerus galeatus*, *Favosites*, sp., *Astylospongia inornata*, *Orthis*, sp., *Dalmanites*, sp., and Ostracode remains.

The total thickness of the Pentamerus limestone in this ridge and the two knolls (63) previously mentioned, is about fifty feet.

The Catskill shaly limestone beds exposed in the short ridge aggregate about fifteen feet in thickness.

There is a depression about 300 feet in width between ridge 66 and the next one to the west (67), which is formed by the cherty limestones and arenaceous shales of the Oriskany. This ridge skirts the Neversink river. The upper shaly layers apparently do not contain any remains, but the lower cherty ones are very fossiliferous, and extend nearly to the summit on the eastern slope of the ridge. *Leptocœlia flabellites* and *Spirifer arrectus* are present in great abundance, while the other species found were: *Platyostoma ventricosum*, *Platyostoma depressum*, *Beyrichia alta*, *Platyceras*, sp., *Rhyncho-*

nella, sp., *Tentaculites*, sp. The total thickness of the Oriskany exposed in this ridge is about one hundred feet.

There are several ledges of Catskill shaly and Lower Pentamerus limestones in Mr. Cuddeback's lane, south of ridge 66, but their character is the same as in the outcrops previously described.

The accompanying sketch gives the section from east to west across Mr. Cuddeback's land.

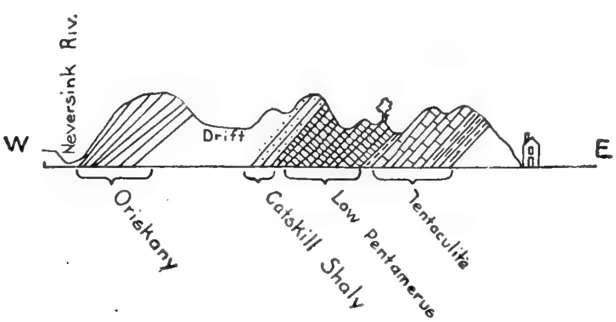


FIGURE 11. Section across the Helderberg ridge, two miles southwest of Otisville.

The approximate thickness of the different members, as exposed in this section, is:

Oriskany shaly and cherty limestones, ...	75	feet +
Catskill shaly limestone, ...	15	" +
Lower Pentamerus limestone, ...	65	"
Tentaculite limestone, ...	45	" +

The next good series of Helderberg exposures is four miles southwest of Otisville, and one mile slightly northeast from Rose Point. The greyish blue Helderberg limestone forms a series of low ledges at the southern end of a large ridge. These ledges are in a field west of the road, opposite a large pond. About fifty feet of cherty limestone of Lower Pentamerus age, are here exposed. Fossils are abundant, and nearly all of them are silicified. These layers are also probably near the transition from the Lower Pentamerus to the Catskill shaly limestones.

The following species were determined: *Spirifer macropleurus* (common in the upper layers), *Orthis planoconvexa*, *Trematospira formosa*, *Orthis biloba* (common), *Cyrtina Dalmani*, *Leptæna rhomboidalis*, *Dalmanites micrurus*, *Spirifer arrectus*, *Pentamerus galeatus*, *Spirifer perlamellosus*, *Stropheodonta*, sp., Bryozoans on *Loxonema*, *Lichenalia*, sp., *Rhynchonella*, sp., *Zaphrentis*, *Favosites*, *Orthothetes*, sp., *Lingula*, sp., *Aulopora*, sp., *Cladopora*, sp.

PLATE XIII

View of Mount Eve from the south. The white limestone is well shown in the foreground.

The same beds are much better exposed in an old lime quarry in the woods (76) a few hundred feet to the north.

The Pentamerus limestone is there well exposed with a thickness of about thirty feet. The beds strike N. 40° E., and dip 45° W. Fossils are abundant in the upper half of the section, the recognizable ones being: *Pentamerus galeatus, Spirifer perlamellosus, Spirifer cyclopterus, Leptæna rhomboidalis, Anastrophia Verneuili, Astylospongia inornata, Rhynchonella equivalvis, Atrypa reticularis, Zaphrentis*, sp., *Favosites*, sp.

Stromatopora concentrica is very abundant near the base of the section, the lower layers of which may represent the upper part of the Tentaculite limestone.

About half-way between 39 and 76, and a few feet farther to the east, is a small quarry by an old lime kiln (13). The beds exposed here are much sheared, dark grey Tentaculite limestone, containing abundant remains of *Meristina, Leperditia, Spirifer Vanuxemi* and *Stropheodonta varistriata.*

From this exposure to the Shawangunk grit exposures at the base of the mountain to the east, is not less than 600 feet; there are, however, no outcrops. Just what formations underlie this interval is uncertain. The red Medina sandstones probably underlie a portion of it, and they crop out in the same valley about two miles farther south. The Coralline limestone may also be here, but if so, is concealed by the drift.

On the slope of the field bordering the river, and about fifty feet east of outcrop 39, there are several outcrops of grey and blue-grey, shaly and arenaceous limestones of Oriskany age. Their total thickness is probably not over fifty to seventy-five feet. A prominent easterly dipping cleavage exists, but the dip could not be determined (40). Fossils are not uncommon, and are abundant in the calcareous layers, especially in the outcrops near the foot of the slope. The list of species collected is as follows: *Avicula*, sp., *Rensselaeria*, sp., *Chonostrophia complanata, Leptocœlia flabellites, Tentaculites elongatus, Platyostoma depressum, Strophostylus?, Discina grandis?, Spirifer arrectus, Merista lata, Pterinea*, sp., *Tentaculites*, sp., *Stictopora*, sp., *Edriocrinus sacculus, Leptocœlia dichotoma, Lingula*, sp., *Eatonia peculiaris.*

The Oriskany forms a series of ledges on the west slope of the hill, on which the limestone ledges 39 and 76 occur. The most southern outcrop on the ridge is just west of 39, where there are small ledges (40) of arenaceous and shaly limestones. Fossils are not uncommon in the more calcareous layers, and the following species were found at this point: *Spirifer arrectus*, Bryozoa, *Stictopora*, sp., *Edriocrinus sacculus, Leptocœlia dichotoma, Platyo-*

stoma depressum, *Lingula*, sp., *Eatonia peculiaris*, *Meristella*, sp., *Discina*, sp., *Tentaculites*, sp. Thickness here fifty to seventy-five feet.

From this point the Oriskany extends northward along the base and western slopes of the Helderberg ridges. It consists of shales and impure shaly limestones, which at times are very arenaceous. The usual strike is N. 30° E., and there is a pronounced cleavage.

From locality 40, the Oriskany extends southwestward to Port Jervis, forming the western face of the Helderberg ridge. The formation preserves the same characters that it exhibits east of Cuddebackville, but there is an apparent increase in thickness, and east of Carpenter's Point the Oriskany must be 100 to 125 feet thick.

The Esopus slate (=*Cauda-galli grit*) is first seen east of Huguenot, along the Neversink river. It increases rapidly to the southeastward, being no less

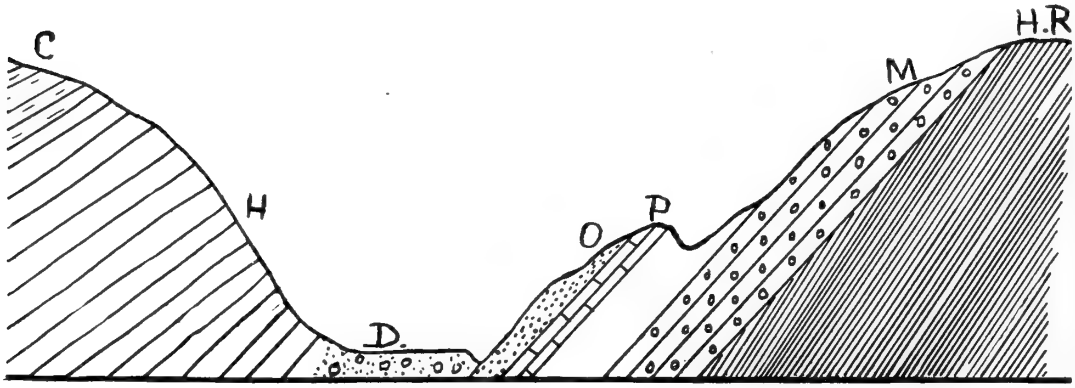


FIGURE 12. Section across the Neversink valley at Cuddebackville.
H. R., Hudson river shales; M., Medina; P., Helderberg limestone; O., Oriskany; D., Drift; H., Hamilton; C., Chemung.

than 700 feet thick east of Port Jervis. The formation consists of black, fine-grained slates, passing upward into grey grits. The members have a marked easterly dipping cleavage, and the true bedding is rarely visible. The black slaty members are finely exposed in the railroad cut of the Erie railroad, one and one-half miles northeast of Port Jervis, while the grits appear along the Neversink river, especially southeast of Huguenot.

The Esopus formation gives rise to narrow, rough ridges, which at times suggest the presence of possible step-faults, but this fact is not certain. To the north, the Esopus slate passes under the alluvium of Neversink valley, north of Huguenot.

The Helderberg formations reach their greatest development in the region just north and south of the boundary line between New York and

PLATE XIV

DIKE OF GRANITE (MARKED BY HAMMER) PENETRATING WHITE LIMESTONE CHARGED WITH CONTACT MINERALS.

New Jersey, and their thickness is considerable. The following section is shown in Bennett's quarry (Barrett, 1878):

Tentaculite limestone,	30 feet.
Favosite limestone,	4 to 6 "
Lower Pentamerus limestone,	50 "
Delthyris shaly limestone,	175 "
Upper Pentamerus limestone,	250 "
Oriskany sandstone,	100 "
Esopus slate,	500 to 800 "

This entire section is not exposed in the face of the quarry, but is included in the ridges to the west, between the quarry and the railroad. The fossils are abundant in nearly all the layers, and a full list has been given by Barrett. The upper portion of the Upper Pentamerus is noteworthy on account of being crowded with trilobite remains. The relation of these beds to the Oriskany has been suggested by Barrett and demonstrated by Beecher.* They form the crest of the ridge known as the Trilobite ridge, in whose southeastern face the quarry lies.†

Between Bennett's quarry and that east of Cuddebackville, there are few outcrops of the Helderberg limestone. There is a good exposure of the shaly limestone at a point just south of the intersection of the roads from Shin hollow and Huguenot (77). It strikes N. 40° E., and dips 60° W. (540 feet A. T.) Fossils are not uncommon, especially *Spirifer macropleurus*, *Eatonia medialis*, *Leptostrophia Becki*, *Orthostrophia*, *Cœlospira imbricata*, *Orthothetes Woolworthana*, *O. punctulifera*, *O. radiata*.

No exposures of the Clinton or Niagara were found, though they occur in Nearpass's quarry, south of the state line.

The Oriskany sandstones and impure limestones and the Esopus slates and grits dip westward under the gravelly dip of the Neversink valley, and the middle and upper Devonian formations rise from the valley on its western and northwestern edge.

The Onondaga limestone unconformably overlies the Esopus slate at Carpenter's Point (83). It forms Carpenter's Point and crops out along the road opposite the cemetery entrance. It is a grey limestone, in layers a few inches thick, and contains numerous elliptical flint nodules, from one inch to a foot long. The weathering of the limestone give it a rough surface, caused by the irregular projecting chert nodules. These nodules sometimes

* *Amer. Jour. Sci.*, Vol. 45, p. 410, 1892.

† Mr. Gilbert van Ingen has given the writer considerable information concerning the region east of Port Jervis.

contain fossils* The Corniferous limestone sometimes has a dip of 20° to the west. It extends northwestward up the Neversink valley, but is buried by drift. A small outcrop occurs north of Port Orange, in the rear of C. Norris's house, with a strike of N. 50° E. and a dip of 70° W. Some of the layers at this locality are quite shaly. The thickness of the Corniferous limestone at Port Jervis is given by White* and Prosser † as 200 feet, and this seems a very reasonable estimate.

The Marcellus begins as a ledge of hard grey slate at the bend of the Delaware river, with a cleavage dipping steeply to the southeast, and extends up the Neversink valley, the lower members being buried under the drift, the upper ones dipping under the Hamilton shales. At the north end of Port Jervis, the Marcellus is exposed at the base of a steep hill, and here consists of bluish black, fine-grained shales, which dip under the Hamilton rocks that are exposed farther up the hill. The dark arenaceous Marcellus shales also outcrop at the base of the ridge along the western side of the Neversink valley. Those at the base of the hill along the railroad, at Rose Point are, according to Prosser,‡ probably near the boundary between the Marcellus and the Hamilton.

The total thickness of the Marcellus shales in the Neversink valley is about 800 feet. The Hamilton rocks which overlie them have a thickness of about 1,400 feet in Deer Park township. They consist of arenaceous shales and shaly sandstones, passing upward through a calcareous zone into argillaceous shales containing fossils.

C. S. Prosser has noted a number of Hamilton localities within the township and a list of the fossils found at each. They are, beginning at the south, as follows:

Arenaceous shales and sandstones of lower Hamilton age forming ledges of a high hill just north of Port Jervis (1,477 A1 of C. S. P.).

One mile and one-half north of Port Jervis are coarse-grained ledges of arenaceous shales and sandstones on the east side of the road (1,477 A2 of C. S. P.). They contain *Spirifer granulifer* in great abundance.

A short distance farther up the road, are coarse, fossiliferous, arenaceous shales, forming ledges on the hillside above the road (1,477 A3 of C. S. P.). This zone, which was called Genesee by I. C. White, contains numerous fossils.

On the east side of the road, a quarter of a mile south of Sparrowbush, occurs another ledge consisting of coarse arenaceous shales, which carry

* Pennsylvania Geological Survey Report, G. 6.

† Bulletin United States Geological Survey, No. 120.

‡ *Ibid.*, p. 45.

PLATE XV

View looking south toward Goose-pond mountain, shown on the right. The hill on the left is Oriskany quartzite, and the valley between is occupied by Cambrian limestone and Hudson river slate; the slope in the foreground is of Hudson river slate.

abundant remains in certain layers. The rock dips N. 25° W. 10°, and shows cleavage planes dipping at a high angle to the southeast (1,477 A8 of C. S. P.).

Farther up the Neversink valley, a short distance north of Rose Point, along the west side of the railroad, are coarse blue arenaceous shales, with sandstones one foot or more in thickness. The dip is 45° W. and the strike N. 30° E. Fossils are common (1,478 A1 of C. S. P.).

Prosser's most northerly station of Hamilton rocks in the township is northwest of Cuddebackville and one mile northeast of Rose Point, where the black argillaceous and arenaceous shales crop out at the base of the hill. The ledges farther up the hill contain abundant Hamilton fossils (1,478 B1 of C. S. P.).

Following the road westward from Huguenot over the hills to Honesville, the following beds were observed.

A short distance west of Huguenot (66) were black indurated shales and sandstones of Hamilton age, in layers about one inch thick. They strike N. 40° E. and dip 30° W.

About one mile farther (67), at 700 feet A. T., coarse sandstones, striking N. 50° E. and dipping 30° W. were met. They are thinly bedded and contain numerous plant stems, as well as fair specimens of *Lepidodendron gaspianum.* A mile and one half west of Huguenot, at a bend in the road (69), and 710 feet A. T., with the strike and dip the same as before, are calcareous sandstones with an abundance of fossils in certain layers.

The remains are closely packed together. Those determinable were: *Spirifer mucronatus* (very common), *Spirifer granulifer, Spirifer fimbriatus* (showing the dermal spines), *Spirifer audaculus, Leptodesma Rogersi, Chonetes,* a small form of *C. coronata* or *syrtalis, Chonetes scitula, Nuculites triqueter* (small form), *Spirifer mesastrialis, Leptodesma,* sp., *Microdon,* sp., *Tropidoleptus,* sp., *Phacops rana, Goniophora,* sp., *Athyris* sp., *Tropidoleptus carinatus, Leda diversa, Nuculites oblongatus, Grammysia* sp., *Lingula,* sp., *Leiorhynchus,* sp., plant stems. The plant stems occur in the same layers with the shells, and concretions are not uncommon. I regard this outcrop as of Hamilton age.

At the summit of the ridge (70), 1,265 feet A. T., the bluish grey sandstones appear and, a little farther on, interbedded red shales which strike nearly north and south, and dip 20° W. These red shales crop out along the road through the woods to the west at several points. This region is an elevated flat-topped ridge covered with a thick growth of scrub-oak.

After passing the cross-roads at a small post-office, three miles north of Sparrowbush, and turning down the valley to the south, there are abundant exposures of the grey Chemung sandstones. They are well seen in Robert Coulter's quarry, north of Sparrowbush, where they strike N. 40° E. and dip 10 to 20° W. The quarry face is thirty feet high. The rock is a grey flaggy sandstone, heavily bedded in the lower portions of the quarry. It is traversed by numerous joints, whose faces are often lined with quartz crystals.

The Chemung formation of Deer Park township consists for the most part of greyish sandstones, which are sometimes thinly bedded. In the southern portion of the township the boundary is much farther to the west, and on account of the scarcity of fossils there is some difficulty in fixing the exact eastern limits.

Prosser gives several Chemung localities in his bulletin on the Devonian of Eastern New York and Pennsylvania. They are:

A mile east, up the road from Rose Point and below Mr. McCarron's house, are thin flaggy sandstones of a greenish grey color, which contain Chemung fossils (1,478 A2). Prosser lists several species, and the following were found by the writer: *Tropidoleptus carinatus*, *Chonetes*, sp., *Tentaculites*, sp.

Near the top of the hill, and north of the road, is Meyer's quarry (47). The rock is a bluish grey flagstone, with shaly partings. Fern stems occur in some of the layers, which dip 13° N. W.

From McCarron's house up to the school-house, along the same road, are many outcrops of thin-bedded bluish grey sandstones, with occasional shaly partings. They strike N. 30° E. and dip 30° W. (46).

About 500 feet north of the school-house is Jackson's quarry. The rock is bluish grey Chemung sandstone, with joints running N. 30° E. and N. 30° W. The layers strike N. 60° E. and dip 25° N. W. About fifteen feet are exposed in the quarry. The lower beds are thicker and contain fragmentary plant-remains.

Two miles west of north of Brookville and three miles northeast of Cuddebackville, is the Ferris quarry, 1,220 feet A. T. The rock is a coarse grey sandstone, with partings of greenish to olive argillaceous shale. It dips 18 to 20° and 40° W. of N. Prosser considers this to be the same horizon as the Starucca sandstone.

Below is the section along the Delaware river, from Pond Eddy to Port Jervis, as measured by White and modified by Prosser:

PLATE XVI

Hudson river slate west of Warwick, on the road to Edenville.

Chemung with Portage, . .	Delaware Flags, ...	400	feet.
	New Milford red shale, ...	100	"
	Starucca sandstone, ...	600	"
	Chemung sandstone, ...	1,150	"
	Genesee slate, white, ...	200	"
Hamilton, . .	Hamilton, ...	1,400	"
	Marcellus, ...	800	"
Upper Helderberg, . . .	Corniferous (Onondaga), . . .	200	"
	Esopus, ...	250 ?	"
		5,100	feet.

HUDSON RIVER SHALES AND SANDSTONES. The rocks of this formation cover such a large portion of Orange county, probably two-thirds of its area, that they deserve special mention.

In the western portion of the county, in Mount Hope and Greenville townships, the shales and sandstones form the eastern slope of Shawangunk mountain, previously mentioned. The beds here exposed are alternating shales and sandstones, the former having a pronounced cleavage which is not

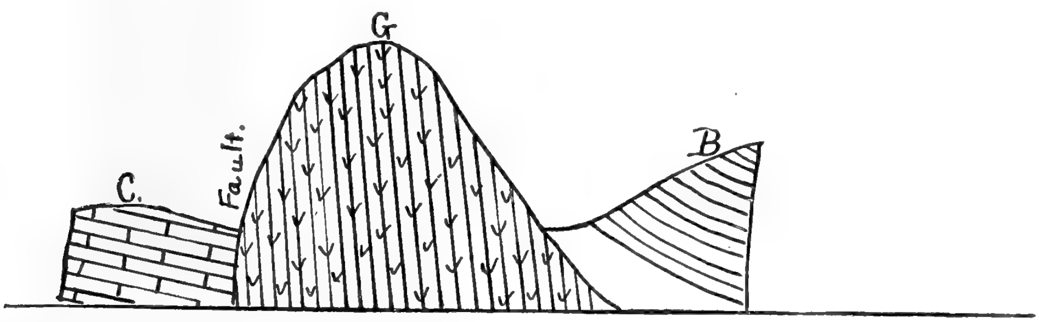


FIGURE 12*a*. **Section across the south end of Sugar Loaf mountain, showing probable fault between Cambrian limestone, C., and Pre-cambrian gneiss, G. The latter passes unconformably under the Bellvale flags.**

shared by the latter. In the railroad cut, west of Otisville, the shales dip 40° W. Northeast of Otisville, along the road by Scudder's house, the sandstone members are prominent and strike N. 60°. The region north of Otisville has a heavy covering of stratified drift, but where outcrops occur the dip is west, while on the southeast side of Shawangunk hill the dip is to the southeast, indicating a probable anticlinal arch with its axis along the river.

The reddish sandstone and quartzitic members predominate in the region around Howell's station. In the cut just west of the station, the sandstones show a low anticline, and the next cut to the west, exhibits a monoclinal fold.

Such local foldings are by no means uncommon. The southeast dip, in the region southeast of Shawangunk hill, changes to a low western one in Minisink and Wawayanda townships, where the slates overlie the Cambrian limestones. The sandstone beds have disappeared, and the formation is represented by hard, black slates, with a pronounced cleavage. South of Denton, the slates give rise to many steep ridges.

From the Wallkill river southeast to Belgrave mountain, there is only a narrow, wedge-shaped area of slate, which begins west of Sugar Loaf mountain, and extends south as far as Warwick. It rests unconformably on the Cambrian limestones, and, while the bedding is often obscured by the marked cleavage, it seems, in general, to be dipping to the west. Glenmere lake lies just within this slate area.

North of Goshen the sandstone members again appear, and are occasionally fossiliferous. A mile and one-half northeast of Goshen, and just after crossing the railroad, the slaty members are prominent, striking N. 60° E., with a dip of 20° W. The dip is very variable, however, and about 500 feet farther north it changes to 70° W. The layers here become more siliceous.

A little beyond locality 461, at 472, the sandstone layers have a low western dip, and contain abundant remains of *Orthis testudinaria* and crinoid stems.

Southwest of Neelytown (464), the slate dips 40° N. W., while northeast of it (478), the dip is northeast. In general, the slate dips away from the limestone area at Neelytown.

At the north end of the iron bridge across the Wallkill river, at Montgomery, and in the river bed, are abundant ledges of slate, with occasional sandstone layers. They here strike east and west and dip 35° N. To the southwest of Montgomery, however, the strike is generally northeast, with a western dip.

An examination of these and the other strikes and dips plotted on the map of this region, indicates that there must be numerous and probably gentle flexures.

The Wallkill river at Walden flows over a ledge of slate and sandstone twenty-six feet high, and then through a gorge sixty feet deep, affording fine exposures of the westwardly dipping shales and sandstones.

Southeast and east of Goshen, the Hudson river slates extend to the range of gneissic knobs northwest of Skunnemunk mountain, where they rest unconformably on the gneiss. Their relations have been mentioned in another part of this report.

PLATE XVIII

LIMESTONE QUARRY AT ARDEN.

From Walden, the slates and sandstones reach eastward to New Windsor and Newburgh townships, to the Hudson river. Along the northern border of the county, the sandstone beds are especially abundant, and conglomerate layers also appear.

The thickness of the Hudson river formation is difficult to determine on account of the many folds and the heavy drift covering in that part of the county where the formation is found. It is probably not less than 1,800 or 2,000 feet. Where it comes in contact with other formations the relations are invariably those of unconformity, faulting or overthrust. These various relations are noted in detail elsewhere, and need not be repeated here.

Organic remains. The exact age of these slates has been a matter of considerable discussion, owing to the apparent scarcity of fossils. Mather* mentions a locality near Sugar Loaf village, west of the station, and at Bulmer's quarry, and states that a few specimens of "testacea" were found (p. 369). He also mentions another locality near Walden.

In 1885, Darton collected the following species from Bulmer's quarry:

Orthis pectinella.
Orthis testudinaria.
Orthis plicatella.
Leptæna sericea.
Camarella hemiplicata.
Strophomena alternata.
Streptorhynchus planumbona or *S. filitexta.*
Trinucleus concentricus.

Those at Walden are found at the junction of beds of sandstone and slate below the bridge. The species found were:

Leptæna sericea.
Orthis testudinaria.
Orthis pectinella.
Conularia Trentonensis (?).

Darton also mentions a new locality in the shales of the railroad cut at Rock Tavern, where the rocks are bent into an overturned synclinal. The fossils occur in the lower members, and are not included in the crumple. The species found were:

Leptæna sericea.
Orthis testudinaria.

* Geology of New York, Part I., 1843, p. 369.

More recently Professor Prosser has recorded a fossiliferous locality in the blue-black shales at a cut of the Lehigh and Hudson railroad, one-quarter of a mile southwest of Greycourt station.

The species found by the writer at the Sugar Loaf locality were:

Orthis testudinaria.
Orthis pectinella.
Leptæna sericea.
Strophomena alternata.
Crinoid stems.

A number of specimens of *Orthis testudinaria* were found in the shales about two miles southwest of Oxford (203), and in the Hudson river sandstones a mile and one-half northeast of Goshen (472).

Mr. J. N. Weed, of Newburgh, informs me that fossils are abundant in the sandstones of the point at the south end of Orange lake, and in nearly all the outcrops of the same members north of Middle Hope.

The fossils found at all these localities indicate a Trenton-Hudson fauna, as previously stated by C. D. Walcott (*B. G. S. A.*, I., 1890, p. 344).

THE NEELYTOWN LIMESTONE. Neelytown is in Hamptonburgh township, four miles south of Montgomery, and in the woods south of Neelytown station is a small area of light blue, granular limestone, which is sometimes brecciated in its upper layers. The limestone first crops out in the cross-road, a few hundred feet east of Neelytown station (477). A short distance to the south, on the west side of the road, in a field, is a small limestone quarry (475). The rock is massive and irregularly bedded, with a brecciated structure, and very indistinct traces of fossils in its upper layers. Chert nodules are very abundant. The strike is east and west, the dip north. There are a number of small outcrops of limestone in the picnic-grove to the southwest, and at the end of the lane leading into it is a low cliff of the limestone, with the layers dipping gently to the northeast. In texture, the limestone resembles closely the upper layers of Lookout mountain, south of Goshen, and is provisionally mapped as of the same age. There is no good evidence that the limestone was brought up by a fault, and it is probably the crest of a low anticlinal fold, from which the overlying slates have been eroded.

A careful search was made for other outcrops of limestone between Neelytown and Walden, but none were found which were clearly in place. Three small outcrops containing Helderberg fossils were found. The first was southwest of Neelytown (465), another east of Montgomery (474), and

PLATE XIX

Quarry in Longwood red shales, east of Highland Mills

a third just east of Walden (480). They are probably deeply buried erratics. The strike and dip of the Hudson river formation surrounding the Neelytown limestone is given on the map.

Geology of Newburgh and New Windsor Townships.

The relations around the northeastern end of Skunnemunk mountain and Pea hill have already been alluded to. In Newburgh and New Windsor townships the areal geology is briefly thus: A belt of Cambrian limestone in the northeastern corner of Newburgh township, with another belt of the same limestone with some Chazy limestone, west of Newburgh. To the northwest and southeast of this area are two small gneiss knobs. The rest of the territory is of Hudson river shale. The Hudson river shales and sandstones, which cover the western and central portions of Newburgh township, are faulted against the Cambrian limestone in the northeastern corner of the township. This fault line crosses the Hudson from Dutchess county, and, entering Ulster county south of Marlborough, passes southward, entering Orange county one mile west of the Hudson river. The limestone has a low western dip, and presents numerous outcrops which form small, rough ridges. Owing to the massive character of the rock, the strike and dip are not always distinct. The line of fault is indicated by a narrow valley, which extends southwest as far as Middle Hope where the stream occupying the valley turns abruptly westward. The western boundary of the limestone extends down to Balmville, and then curves around to the river. The slates appear to the south of the limestone, but the drift conceals their exact relations.

There is a small area of Trenton along the river road, between Newburgh and Roseton, about two and three-quarters miles north of the Newburgh ferry, and at the point where the road comes in sight of the river. The Trenton limestone forms a ledge about 300 feet long and twenty to thirty feet high, on the west side of the road (379). The dark crystalline limestone has a strike of N. 35° E. and dips 40° E. The ledge is about 135 feet above the river. The limestone contains a mass of small encrinal columns and small *Chætetes.* The crinoid present in especial abundance is *Cleiocrinus magnificus*, a species which had only been previously found in Canada until its discovery by Professor W. B. Dwight at this locality.* There are also several other species of Trenton age, viz.: *Platystrophia lynx*, *Plectambonites*, etc.

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* *A. J. S.* (3), XIX., p. 50.

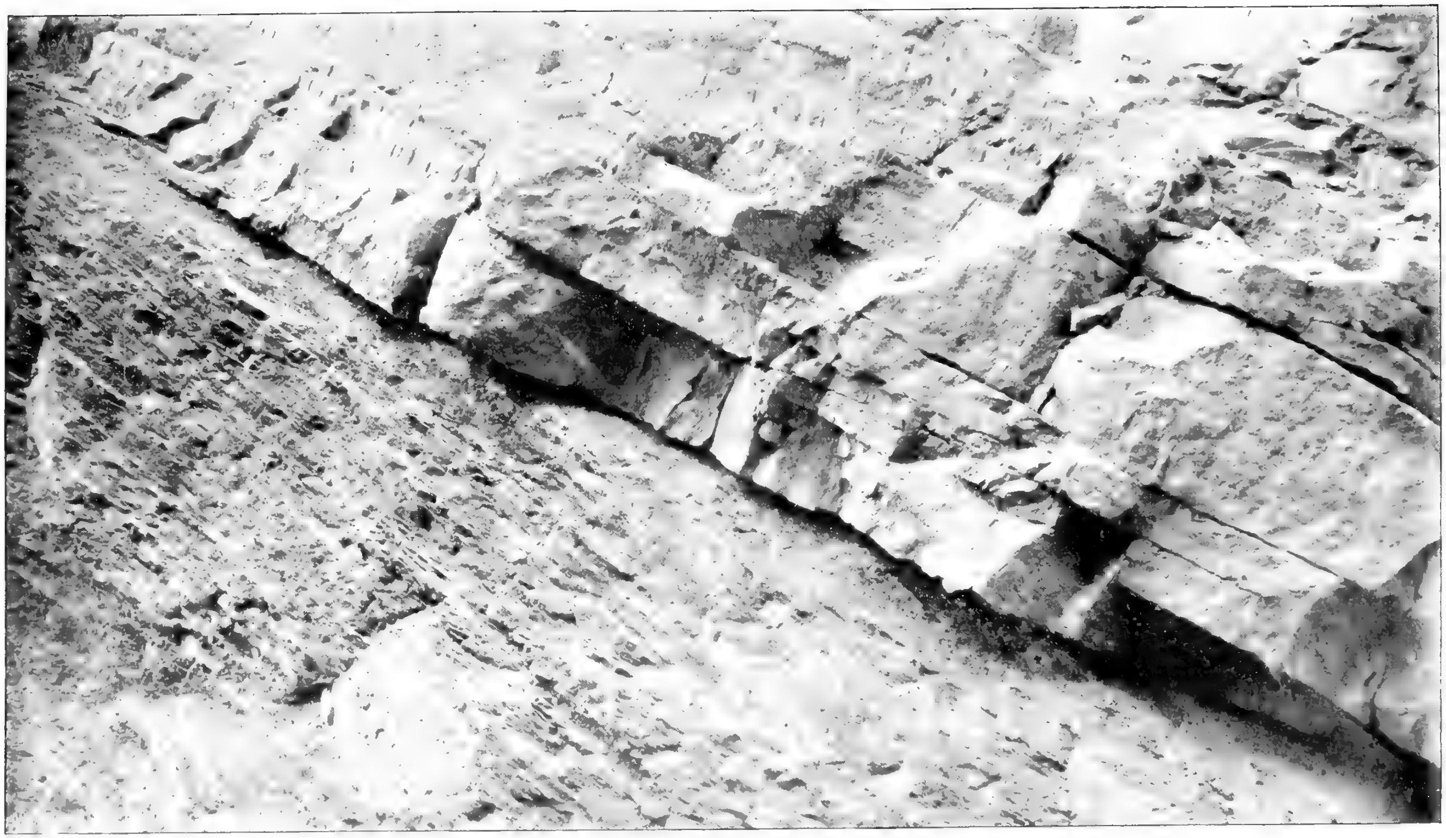
One-half mile to the north is an outcrop of shale along the roadside by an old barn. It occupies a small triangular area. Above it on the hill the Cambrian limestone appears, as well as to the north of it in a quarry by Mr. Rose's house. At this latter locality the dip is to the southeast. The exact relations are here again obscured by the drift, but the Trenton may rest on the Cambrian, and the Hudson river shales may rest either on the buried Trenton or directly on the Cambrian, by thinning out of the Trenton or by faulting.

To the southwest of Balmville, which is on the northern edge of Newburgh, the limestone again begins and extends, as an elliptical area of four miles in length, in a southwest direction to Washington lake. The width of the area is about one mile and a quarter. To the northwest it rests on the Olenellus quartzite, and this in turn on the gneiss of Cronomer's hill. The rest of the distance it is overlaid by the Hudson river slates. On the southeast, the limestone dips in part under the slates, and is faulted against the steep northwestern side of Snake hill. The dip of the limestone is generally southeast. There is doubt whether all of the limestone of this area is of the same age. Over the larger portion of the area it is a crystalline, cherty limestone, very much resembling that of the other Cambrian areas, but in the southeastern part, in Miller's quarry, the rock is more evenly bedded, and less massive.

Some years ago Professor R. P. Whitfield published the discovery of probable *Maclureas* in parts of the limestone. This indicates the Chazy age of a portion of the limestone, the greater part of which is probably Potsdam, according to an opinion expressed to the writer by Professor Dwight (See also, *A. J. S.*, iii., XVIII., 327, 1879). The specimens were fragmentary, and none have since been found. Professor W. B. Dwight informs the writer that he has found a few ill-defined Calciferous fossils in the limestone of this area northeast of Washington lake.

Southeast of Washington square, the Hudson river slates extend around the south end of the limestone area and rest uncomformably against the gneiss at the south end of Snake hill. The slate crops out along the road at the southern end of the hill (407a), and extends along the east side of it, appearing at several points, and especially on Mr. Hasbrouck's race-track, where it has a strike of N. 40° E. and dips west. Farther south along the road, the dip is east. The slate is also seen at the north end of Snake hill, at 215 feet A. T., along the road leading to the pavilion on the summit, and along the road by the ice-house at the northwest base of Snake hill. The

PLATE XX



Unconformity between Oneida conglomerate and Hudson river slates in railroad cut west of Otisville.

limestone crops out on the same road to the south of the slate, as well as on the opposite side of the ice pond. The fault between the gneiss and limestone on the west side of the hill seems to pass to the north between the latter and the slate, or may die out.

The gneiss of both Cronomer's hill and Snake hill is a granular mixture of quartz and feldspar, with little or no mica. In a small gneiss area south of Snake hill the rock is often graphitic.

The Hudson river slates extend to the foot of the mountain between Mountainville and Cornwall, and are possibly faulted against the gneisses of the Highlands. The two can be seen close together at several points about one mile and a half south by east of Canterbury, the slate apparently dipping under the gneisses (420). The gneiss strikes N. 30° E., and dips southeast.

One-half mile south of Cornwall (421) is an old road-metal quarry in limestone. It is a dark grey, finely crystalline rock, striking N. 80° E., and dipping 45° S. There are interbedded grey brown, siliceous layers, and numerous black patches of carbonaceous matter along the bedding planes.

The limestone passes under the slates and probably belongs to the Olenellus quartzite, certain members of which it resembles very closely. About twenty-five feet of limestone are exposed (422). The dipping of the quartzite against the Pre-cambrian gneiss would at first suggest a fault, but it may be the southern side of a fold caused by the quartzite being thrust against the gneiss. This, Professor Dwight informs me, is sometimes the case in Dutchess county. The slate and gneiss are seen almost in contact a few feet east of the quarry.

The writer mentioned this limestone quarry to Professor Dwight, who has done much field work in the neighboring counties, and he has written in reply: "In 1883, I found that there is a thin stratum of impure, hard limestone overlying the gneiss, and underlying the Hudson river shale along the northern and northeastern base of Storm King and south of Cornwall.

"This occurs, as I then ascertained and noted, on the estate of Mr. S. B. Young, whose house is at the northeastern base of the mountain, south of Cornwall. This stratum of limestone was encountered in making excavations for the cellar of his house, and for his ice-house. Blocks of the excavated limestone lie around, and some of them were built into the walls forming the approach to the ice-house."

Further on in his letter, Professor Dwight says, in referring to the quarry: "I take the limestone in question at Cornwall to be the Lower Cambrian limestone (Olenellus horizon)."

THE HIGHLAND AREA OF GNEISSIC ROCKS. The following notes on the Highland region are to be considered as merely preliminary and in the nature of a reconnaissance. The crystalline rocks of this region present a most interesting field for study, and it is hoped that opportunity will be afforded for a further and more detailed consideration of their relations. Such detailed work requires a most careful examination of all the outcrops and careful petrographic examination with the microscope. Considerable has been published hereupon in the report of Mather,* and certain portions of his work will be referred to further on. Britton and Merrill also refer frequently to these rocks in connection with their work on the Highland area in New Jersey.†

Excluding the areas of gneiss forming the western half of Pochuck mountain and another strip along the northwestern side of Bellvale mountain, the gneissic rocks cover all of the townships of Tuxedo and Highland, and about one-half each of those of Monroe, Woodbury and Cornwall.

TUXEDO TOWNSHIP. The gneiss rises steeply along the eastern side of Greenwood lake with a dip of 60° E. It is often massive, and sometimes much shattered by joints at right angles to the stratification. These joints not uncommonly represent fault planes. The gneiss is a mixture of quartz, red orthoclase and hornblende. Specimens of this same gneiss, collected from a point on the New York and New Jersey state line, were examined by Professor Kemp in 1885 (*N. J. Geol. Surv.*, 1886, p. 102), and the orthoclase found to be full of curious little inclusions.

Northeast of Greenwood lake, the gneiss is strongly laminated and is composed of biotite, feldspar and much quartz. The region between Greenwood and Sterling lakes is heavily wooded and has not yet been examined. On its eastern edge the rock along the shore of Sterling lake (346) is a dark-colored, fine-grained basic gneiss. A section of the fine-grained portion of this gneiss, from half way up the west side of the lake, shows it to consist of plagioclase, hypersthene and magnetite. The plagioclase is in large plates, fresh, and full of beautiful apatite crystals. The hypersthene is strongly pleochroic and the magnetite grains associated with it are large and rounded. The dark, massive gneiss, one and one-half miles north of Sterling lake, may be a continuation of this area (301). Sections of it afford much microperthite and some quartz.

The dark hornblendic gneiss surrounds most of Sterling lake and contains the ore-bodies at the southeastern end of the lake. At this point are two

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* Geology of New York, First District, 1842.

† Geological Survey of New Jersey, 1885.

Figure 13. Calcite with magnetite; from Oneil mine.

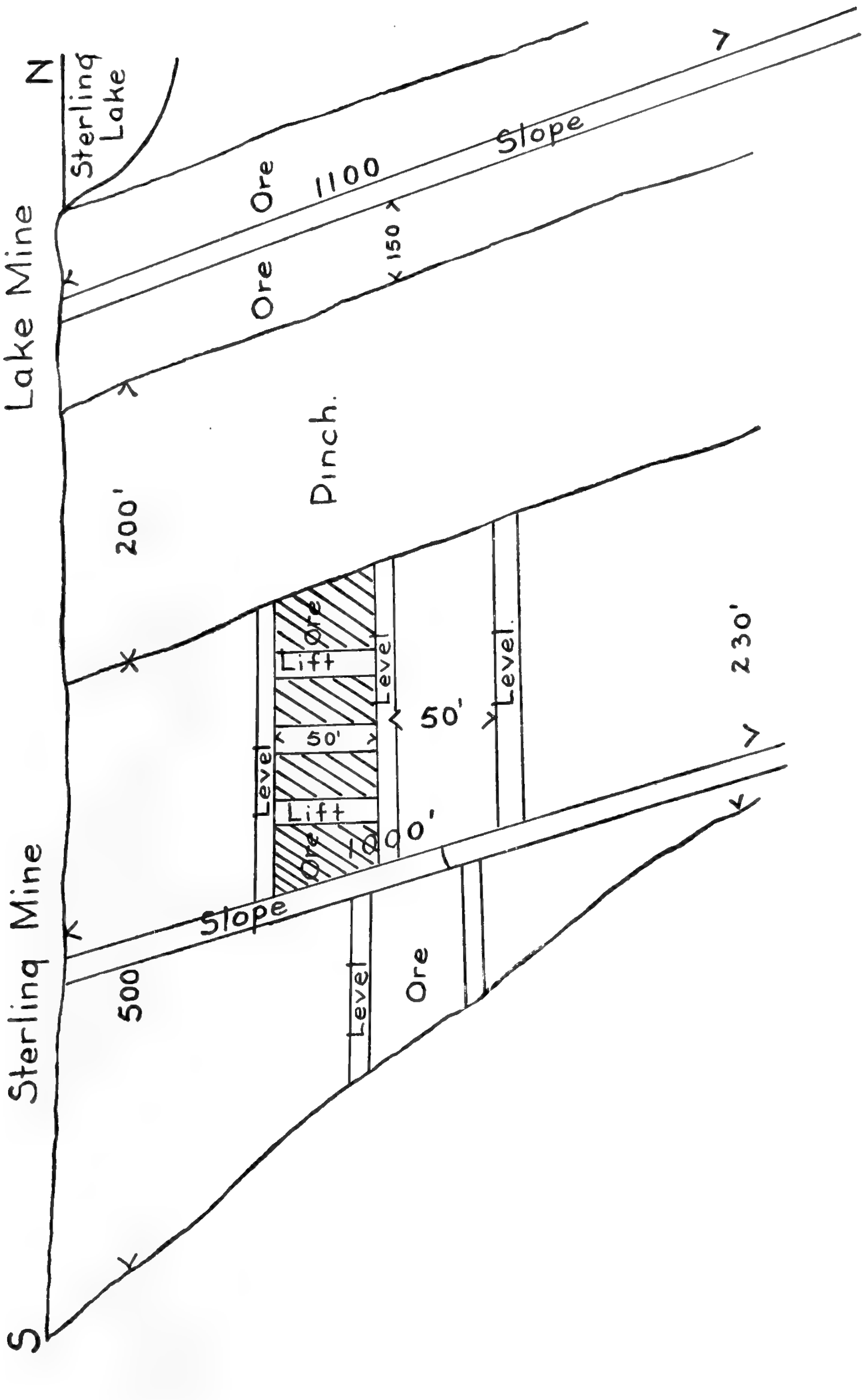


FIGURE 14. Section through Sterling and Lake mines; showing outline of ore-body and method followed in mining the ore.

beds of magnetite, the Sterling and the Lake. They are evidently portions of the same bed cut in two by a pinch. The direction of their longer axes is about northwest and southeast, and this strike carries the Lake ore-body beneath Sterling lake. The length of the Sterling ore-body at the surface is 500 feet, and 230 feet at the bottom of the workings. The length along the slope, which runs obliquely down the dip, is 1,000 feet. The pinch is about 250 feet long and is succeeded by the Lake ore-bed, whose outcrop is of the same length, but its depth is not known, as it has never been fully exploited. The slope is 1,100 feet long.

The ore-bed varies in width from five to twelve feet and is sharply defined. The ore formerly extended up the surface of the hill at whose base the entrance to the present workings is situated, and quarrying methods were therefore employed for operating this upper portion of the ore-bed. In a few places on the face of the hill where the hanging wall remained, as in the Clark mine, chamber-working was followed. The Clark ore-body dips to the northeast, and swells and pinches in a remarkable manner. At one place in the footwall, two narrow anticlines have been produced, as shown in Figure 15.

The wall rock is a basic gneiss, with much hornblende, and the roof of the chamber-working is a very coarse-grained mixture of plagioclase feldspar and hornblende. Just above the ore at the northwest end of the open working is a feldspar vein, twelve inches thick, which extends for about twelve feet and then suddenly pinches out. Veins of epidote and milky quartz crystals occur in the wall rock and frequently cut across the strike. The gneiss around the ore-body contains less hornblende than that farther down the hill towards the Lake mine.

The Lake mine has afforded quite a variety of minerals which occur on the edge of the magnetite bed. The commonest are pyroxene and amphibole either in distinct crystals or forming granular aggregates with the magnetite. At other times there is present in these granular mixtures both white and red feldspar, the former surrounding the latter. Clusters of small epidote crystals are seen, usually in association with pyroxene. Some beautiful pegmatitic intergrowths of quartz and tourmaline are found in the Lake mine, but in just what part of it, the writer was unable to ascertain. Sometimes this intergrowth is surrounded by red feldspar, and the latter encircled by magnetite. On the hill and along the highroad about 500 feet northeast of the Lake mine, are several small lenses of magnetite in the gneiss. The stringer is lens-shaped and near the outer margins contains some granular quartz.

PLATE XXI

Shawangunk grit in quarry west of Otisville. The rock dips to the northwest.

The wall rock is feldspathic and has no hornblende, as indicated by the light color which it has in the figure.

From the Sterling mine the basic gneiss continues northeastward towards the Augusta mine which is also on the property of the Sterling Iron and Railway Co. The strike of the gneiss at this mine is N. 40° E. and the dip 50° E. The rock is made up of alternating bands of feldspar and hornblende, and the ore seems to favor the latter, dipping with the rocks. According to the sections drawn from a survey made several years ago, the ore-body is long and flat. There is a notable fault exposed in the hanging wall at the entrance to the mine. The layers of the gneiss have been drawn down by

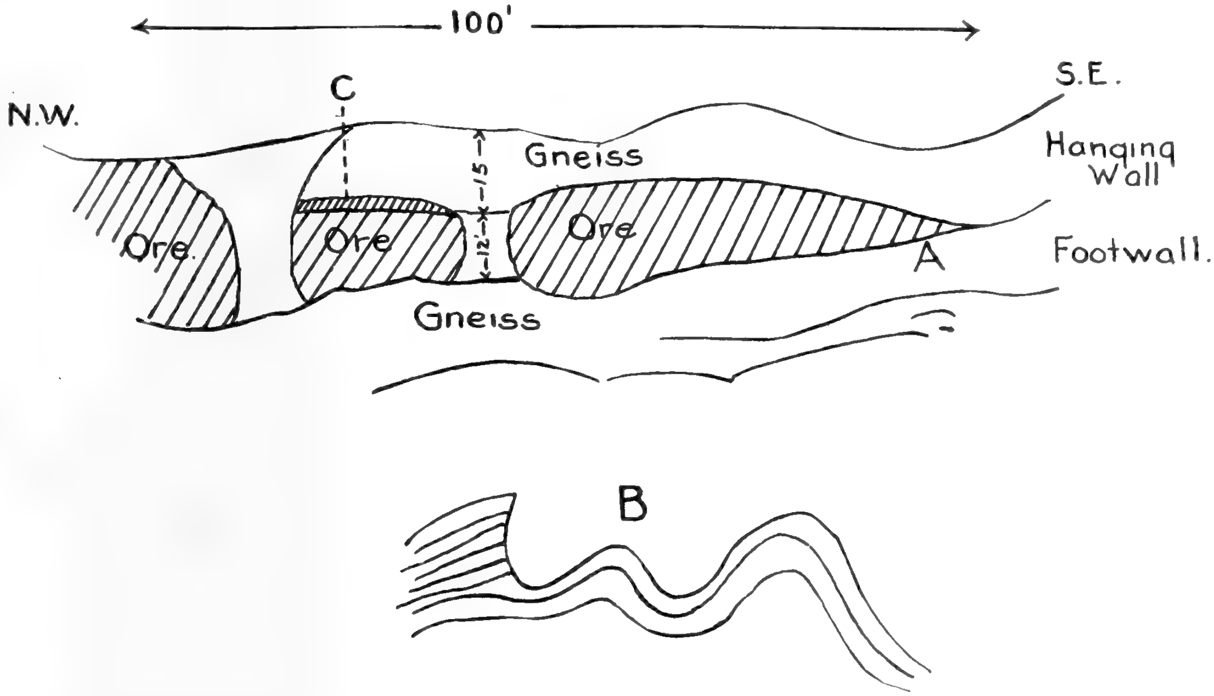


FIGURE 15. Diagrammatic view of Clark mine, at Sterling; showing swelling and pinching of the ore-bed. The section is N. W. and S. E. C is a vein of feldspar and hornblende, one foot thick, which is pinched out. B is a N. E. and S. W. section of foot-wall at A.

the shearing action of the faulting. The foot-wall of the Augusta mine contains much granular dark green pyroxene. There are many coarsely crystalline veins of quartz and feldspar which cut the gneiss in the walls of the Augusta mine. They not uncommonly cut directly across the strike and are often branched.

The Mountain mine is about three-quarters of a mile north of the foregoing, and consists of several long narrow parallel beds. At the Scott mine, the gneiss is more acid and contains little or no hornblende, not even in the walls of the ore-body. Orthoclase feldspar abounds. The rocks around the ore-bed have been much sheared and strained, but no actual faults were found on the surface. One of the specimens showed a breccia of feldspar and magnetite. One mile northeast of the Oregon mine, the grey gneiss again appears, being a mixture of quartz, feldspar and biotite. It dips 40° E.

Along the road leading from Greenwood lake to Tuxedo and in the area due north of Sterling lake, the gneiss is, at times, very massive, with red feldspar, and resembles granite. Just northeast of the cross-roads, on the road to Southfield (305), the rock is a massive, red, feldspathic gneiss with some quartz and much garnet. It strikes N. 20° E. and dips 70° S. E. Little or no mica is present.

This may be only a local variation, for about a mile and one-half farther to the north the common grey gneiss again appears, striking N. 25° E. and dipping 40° E. The strike is, however, very variable.

From Southfield Works to Helmsburg, south of Mount Basha lake, the gneiss preserves a remarkably constant character. It is fine-grained, light grey, strongly laminated and composed of quartz, orthoclase feldspar and biotite. Some plagioclase is present, and hornblende is not uncommon. The strike near Southfield Works is N. 40° E., dip 60° S. E. Farther to the east, along the road, it is N. 20° E., dip 60° S. E. At this point the gneiss sometimes contains dark bands of more basic rock, which in appearance resembles the gneiss around Sterling lake.

Much of the gneiss in Tuxedo park is fine-grained and very basic, that at the southern end of the park, especially, containing considerable quantities of pyroxene, with strong basal parting. The dip is nearly always to the east. Along the Switchback road, near the summit of the hill and at a point about 330 feet higher than Tuxedo station, there are numerous veins of a coarse red granite identical with that found near Stockbridge's hotel, east of Central Valley.

On the circuit road within Tuxedo park there are many exposures of a well banded grey gneiss with alternating light bands of quartz and feldspar and dark ones of hornblende, with some biotite. The gneiss strikes N. 40° E. and dips 50° S. E.

One mile before reaching the north gate and on the circuit road, are large outcrops of an extremely coarse dioritic rock, similar to one southeast of Southfield. It is much coarser, however, and contains some quartz. In close association with it is a fine-grained granular gneiss and stringers of the diorite often penetrate it.

Figure 16. Lens of magnetite in gneiss, near Sterling.

Mather refers to a cliff of limestone one-quarter of a mile southwest of Tuxedo lake, and states that it is traversed by a faulted dike. A search was made for this outcrop at the point indicated by Mather, but the writer was unable to find it. Quartzose gneiss forms a steep and possible fault cliff in the road-metal quarry south of Southfield, striking N. 40° E. and dip 70° E.

One mile south of Southfield, along the road through the woods, is an area of very coarse diorite. The rock is a coarse mixture of labradorite and hornblende, and shows well the crushing which it has undergone. This same rock also crops out in the field along the upper side of the road, until the latter begins to curve around the hill, when it is succeeded by a massive gneiss, with quartz orthoclase and biotite. This gneiss becomes very coarse in places, when the biotite is replaced by hornblende. It continues with somewhat variable character to Little Long pond, with a strike that varies from N. 20 to 50° E. and a prevailing steep eastern dip. At the west end of this pond, the gneiss strikes N. 20° E. and dips 30° E., while at the east end it dips 80 to 90° E. Along the road leading up the hill west of the pond, is a pegmatite vein cutting the gneiss, and this latter is cut by five camptonite dikes in a space of 200 feet. They may be possibly branches of the same dike. They vary in width from two inches to one foot.

MONROE TOWNSHIP. The gneisses cover nearly one-half of the township, their western border being along the eastern side of the valley, extending from Greenwood lake to Monroe.

East and northeast of Long pond, which is two and one-half miles south of Monroe, the normal grey gneiss is composed of orthoclase, quartz and biotite, with subordinate hornblende. The rock sometimes becomes coarsely crystalline, with an increase of the hornblende, and this passes into the normal facies again. Southeast of Long pond, and on the crest of the ridge, the strike is N. 20° E., dip 70° W. A common form of the gneiss in this region is a red rock consisting of quartz, orthoclase, plagioclase and some biotite. The plagioclase frequently exceeds the orthoclase in amount. The quartz commonly has a zonal structure and contains apatite and zircon as inclusions.

In the region south of the Clove mine the grey gneiss is generally quartzose, with few variations. On the eastern side of Mount Basha lake it becomes garnetiferous.

The O'Neil mine is three miles southeast of Monroe. It is a large opening about 200 feet west of the road, and below it. The pit is about fifty feet deep and 600 feet long, extending northeast and southwest. The wall rock is a coarse feldspathic gneiss, that on the north wall being somewhat more quartzose. The rock strikes N. 30° E. Near the west end of the main cut is an olivine camptonite dike six feet wide, which cuts across the ore-body. The ore was mined out around it and the dike has been left standing like a wall. Another dike of the same rock, or a branch of the first one, is found in the next pit, about 200 feet to the southwest. Just west of the first dike, and next to it, is a coarsely crystalline rock of granitic structure (shown in upper left hand portion of the adjoining figure), and consisting of feldspar and serpentine; the latter, however, is evidently an alteration product of either pyroxene or hornblende, perhaps the latter, as Mather records a syenite rock penetrating the ore-body.

Next to the ore, the wall rock becomes very basic, and contains a mixture of magnetite and pyroxene, or hornblende. In places, the latter has changed almost completely to serpentine, as in the northwest wall just east of the dike. In the pit where the second dike occurs, the rock, on the north side is an altered syenite, but next to this second dike the rock is a mixture of calcite with hornblende or magnetite. Lying in the pit are several masses of calcite, filled with a reticulation of magnetite streaks. Just what part of the mine this came from could not be determined, but the occurrence of it in this large quantity is somewhat suggestive of a possible sedimentary origin.

The wall rock is traversed by many joints, and the great masses of rock which have fallen into the pit obscure the relations considerably. Two chambers have been driven at the eastern end of the pit. The mine has not been worked for sixteen years. Probably no locality in the county except Edenville has afforded so many minerals. The most abundant are beautiful little octahedral crystals of magnetite. Pyroxene and amphibole crystals have also been found.

A list of the minerals which this mine has afforded is given in Mather's report on the Geology of New York, First District.

The Forshee mines are on a neighboring hill about one-half mile south-west of the O'Neil mine. The main working is an open pit, about 400 feet long, fifty feet wide and fifty feet deep. The country rock is a feldspathic gneiss striking N. 20° E., and dipping 40° S. E. The ore is very lean and associated with a peculiar pyroxenic rock with a bronze lustre. It very strongly resembles enstatite, but sections of it give an inclined extinction. The rock is very hard and rather coarse-grained. It is traversed in places by quartz veins. The rock at and around the base of the hill is the ordinary grey gneiss.

Figure 17. Old Revolutionary furnace, near Sterling

The Clove mine is about a mile and one-half south of Monroe. The workings are full of water and little of their relations can be made out. According to Mather* the ore occurs in several parallel veins. This may be due to faulting. The walls of the mine are a hornblendic gneiss which, at times, becomes very schistose, and the ore has much hornblende and a silvery mica mixed with it. Pyrite is occasionally present. The nearest gneiss exposure to the east of the mine is very quartzose and does not represent the normal rock. On the west are several outcrops of a feldspathic granitic gneiss. The ore-body is evidently cut by a dike, judging from the numerous angular fragments of it which were found on the dump heap. The dike is a fine-grained black rock, cut by numerous thread-like streaks of pyrrhotite.

WOODBURY TOWNSHIP. The gneissic rocks cover about five-eighths of the area of the township. The line of faulting which has given rise to the Ramapo valley south of Turners, passes northward along the base of the gneiss ridge east of Turners and Central Valley, and then along the narrow valley east of Pine hill, at whose north end the fault-line probably passes into the Highlands. Up to the point east of the north end of Pine hill, the fault line is between the gneiss and the Cambrian limestone. A contact of the two is well exposed in the limestone quarry a mile and one-half northeast of Arden. A fine fault cliff is also to be seen on the western side of the valley just north of Arden. The grey gneiss, which is faulted against the limestone in the upper portion of the limestone quarry, dips steeply to the east. It is a fine-grained granular mixture of quartz and plagioclase with a little orthoclase and biotite. The rock shows the effect of crushing, and the larger grains are embedded in a crushed matrix of the same minerals cemented with decomposed biotite and limonite.

About one mile below the quarry, a road leaves the main one of the valley and turns to the east through a shallow ascending valley to the other side of the ridge where it turns to the north. Just beyond a church and where the road turns, a granular gneiss appears, which is cut by numerous granite veins. It strikes N. 20° E., and dips 70° S. E. (284). The gneiss in section is seen to consist of quartz, plagioclase and some orthoclase. The quartz grains often show a zonal structure, and the twin lamellae of the plagioclase are not unfrequently bent. The rock is considerably decomposed. This gneiss passes into a very hornblendic facies.

* Geology of New York, 1842, p. 571.

About one-quarter of a mile beyond Mr. Harriman's house, the gneiss becomes very quartzose and shows many crumples and slickensides. It is a mixture of plagioclase, biotite, and pyroxene. The two latter occur as parallel growths and the same cracks traverse both minerals. Another specimen of the same gneiss from farther up the road (281), shows, in sections, a similar character but the pyroxene is often nearly colorless and much corroded, while magnetite is present in small amounts. The strike is N. 40° E., the dip 45° N. E. The gneiss once again becomes dark-colored, very massive, and hornblendic and is cut by an east and west dike about one foot wide. The rock on either side of the dike is broken by many joints running parallel to the dike, and the gneiss strikes N. and S. with a dip of 60° E. The gneiss again passes into the normal form along the road above the waterfall. It will be thus seen that there are alternations of the normal gneiss and the hornblendic form.

At Mr. Cunningham's house, about a mile and one-half up the road from Mr. Harriman's, the road branches off to the east. Just behind Mr. Cunningham's, the gneiss contains a small bed of iron-ore. A small pit was sunk in it to a depth of nearly forty feet and a little ore taken out, but most of it was very lean. Across the road to the north a small dike cuts the gneiss.

About a mile farther east, are several more small iron mines south of the road. They are the Greenwood, Hogencamp, and Tompkins mines. The wall-rock of each is a hornblendic gneiss with some granular pyroxene. The largest mines in this region are the Bradley mines, one and one-half miles north-east of Cunningham's house, and on the road to Queensboro. Judging from the size of the opening, a large amount of ore has been taken out. The ore crops out above the road and a cut was made to intersect it at a lower level. The bed of magnetite dips to the north and is fully forty feet thick. Associated with the ore are great quantities of calcite containing crystals of magnetite, apatite, pyroxene, titanite, amphibole, and grains of pyrite. Two dikes also cut the ore-body, one a porphyritic camptonite, the other a fine-grained quartz porphyry. This latter is a new one to the Highland region of Orange county. They are both hereafter described in further detail.

From Cunningham's house to Two Ponds, the road leads through the woods and there are few outcrops. Where these are found, the rock is generally a massive gneiss dipping to the east and striking from N. 20° E. to N. 40° E. At a point where the road swings around to the west, just before passing between Two Ponds, the gneiss is cut by a dike which may be an

FIGURE 18. CAMPTONITE DIKE, NORTHEAST OF ARDEN

offshoot of the large knob penetrating the gneiss south of the road. This rock was found to be much decomposed in the sections examined, but is probably a camptonite. In front of Stockbridge's hotel, east of Central Valley, the gneiss strikes N. 40° E. and dips 80° S. E. From the road crossing the mountain just north of Stockbridge's, up to the next road across the mountain, about two miles further, the gneiss is cut by many veins of coarsely crystalline red granite. This is a mixture of bright red feldspar, large flakes of biotite and a little quartz. One of these veins crops out along the road opposite the entrance to Stockbridge's lane.

The gneiss ridge north of Stockbridge's, judging from a number of strikes and dips taken, is apparently a synclinal fold. On the eastern side of the valley east of this ridge, and about one and one-half miles north of Stockbridge's, there is, along the road, a ledge of rock, which in many respects resembles the contact zones at Mounts Adam and Eve, in Warwick township. In the lower portion of the ledge and a few feet above the road, the rock is a coarse-grained mixture of pyroxene, scapolite and feldspar, with some quartz and calcite. Where cavities exist in the rock, good crystals of pyroxene are not uncommonly developed, but terminations are rare. The feldspar is most abundant at the northern end of the exposure and higher up the slope. Up this slope the rock becomes a coarsely crystalline aggregate of feldspar and pyroxene, the former predominating. Some quartz is present. No good bedding was noticed except in the ledge a few feet above the road, where there seems to be a low dip to the east. The rock on the west side of the road across the brook, is a hornblendic gneiss which, in the bed of the stream, is cut by two dikes, one four inches wide, the other six feet; they are both camptonites. The exact relations of this scapolite–pyroxene zone and its significance require further examination before they can be explained. It is possible that this may represent a contact zone between a probable granite rock to the southeast and the hornblende gneiss, or a limestone which has been removed by erosion or faulted out of place. There is a short belt of limestone about a mile to the north in this valley, but no outcrops of limestone were found between these two points. The limestone belt mentioned thins out at its southern end.

At the south end of Popolopen pond, is a small bed of limestone forming a natural bridge. It is a bed about forty feet wide and has a length of about four hundred feet from the south end of the lake to its southern extremity where it disappears under the meadow. The limestone is interbedded with coarse-grained gneiss which strikes N. 50° E., and dips 70° E. on the western side of the limestone. The latter shows no distinct bedding planes, but the lines of minerals, especially the serpentine, strike about N. 35° E. Scattered through the limestone are bunches of the ferro-magnesian minerals, pyroxene, mica and hornblende. They form a dark strip several feet wide on the western boundary of the limestone at the north end of the bridge. At the south end and just behind a small barn, the gneiss contains an abundance of magnetite in grains and lumps up to an inch in diameter. The gneiss on the eastern side of the limestone contains much pyroxene along the contact and is distinctly laminated, but farther to the east in the field it contains many coarsely crystalline granite veins.

Around the Forest-of-Dean mine and the adjoining reservoir, the gneiss is a mixture of quartz, feldspar, hornblende and biotite, the two latter in variable proportion. The gneiss dips southeast and pitches about 22° to the northeast. The ore-body is described under the economic division of this report. The ore-bed is cut by a camptonite dike and two others occur along the road to the southwest by the reservoir.

HIGHLAND TOWNSHIP. The gneisses of this township are often quite massive. Along the Hudson river the prevailing grey gneiss is composed of quartz, orthoclase and biotite. A little plagioclase is present, and the quartz often contains cavities. The general strike is from N. 40° to 80° E., and the dip generally to the east. Pegmatite veins are common and form a prominent feature of the gneiss. They usually run parallel to the bedding of the gneiss, rarely cutting across it, and they also commonly partake of the folding or other distortion which the gneiss has undergone, while their boundaries are not always sharply defined. On the road from Cranstons to Fort Montgomery and a short distance north of the latter are several outcrops of graphite schist; it also occurs in the woods to the west and about one and one-half miles southwest of the village of Fort Montgomery, along the road to the Forest-of-Dean mine. In all of these exposures the rock is much decomposed and stained from the disintegration of pyrite. The gneiss is very basic south of Little Long pond, and is intersected by several dikes.

CORNWALL TOWNSHIP. The gneisses form the southern half of the township, extending from Mountainville around the base of the mountain to Cornwall-on-Hudson. They vary from massive to a bedded variety, and are normally a mixture of quartz, feldspar and biotite, but sometimes contain hornblende in great abundance. Towards Cornwall they become very quartzose and are seen in contact with the Hudson slates along a fault line.

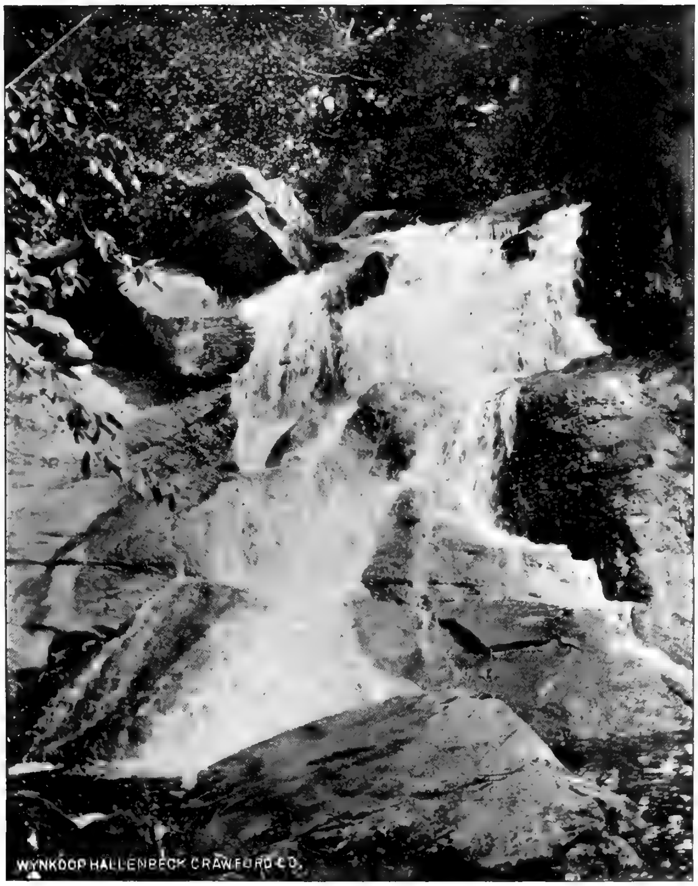


FIGURE 19. WATERFALL NORTHEAST OF ARDEN.

DIKE ROCKS. The only detailed account hitherto published of dikes from the Highland area in Orange county, are two papers by Professor Kemp which appeared in 1888*, both treating of camptonite dikes, which at that time were thought to be comparatively rare rocks. The first of these is a camptonite from the north end of the first railroad cut above Fort Montgomery. It is a dense black rock, and the dike extends twenty feet or more vertically, running diagonally across the lamination of the gneiss. Under the microscope the rock consists of small, well developed hornblende crystals with sharp faces. There is some plagioclase and a few grains of magnetite, and the dike has a more or less porphyritic structure. Duplicate analyses of this rock, which are of value, were made by Professor Dennis*, of Cornell University. They show:

	a.	b.
$Si\ O_2$	44.85	44.87
$Al_2\ O_3$	17.20	17.281
$Fe_2\ O_3$	11.20	11.04
$Fe\ O$	——	——
$Mn\ O$	trace	trace
$Ti\ O_2$	6.578	6.738
$Ca\ O$	7.52	7.54
$Mg\ O$	5.02	4.946
$K_2\ O$	2.992	2.621
$Na_2\ O$	1.390	1.611
$P_2\ O_5$	.383	.447
$C\ O_2$	——	——
Loss on ignition	2.387	2.491
	99.52	99.585

There are no dikes between Fort Montgomery and Crow's Nest mountain, but extending up the face of the latter are six dikes which have been noted by Professor Kemp. They are holocrystalline aggregates of hornblende, augite and plagioclase with subordinate magnetite, apatite and biotite, and sometimes orthoclase and quartz.†

The hornblende and augite are generally associated, but may occur singly; the augite especially in spots where the dynamic action has been greatest.

* A Diorite Dike at the Forest-of-Dean mine, Orange county, N. Y.—*A. J. S.* (3), xxxv p. 331 and The Dikes of the Hudson River Highlands—*Amer. Nat.* xxii p 691.

† For a review of other occurrences of camptonitic rocks and their classification, see *Bull. 107, U. S. G. S.*—The Dikes of Lake Champlain by. J. F. Kemp and V. F. Marsters.

The hornblende is brown and in irregular masses, with magnetite and apatite inclusions. It is often bleached to a green variety. The augite contains the same inclusions as the hornblende. The feldspar is well twinned, and inclusions of magnetite and apatite are not uncommon.

Another camptonite dike has been described by Professor Kemp from the Forest-of-Dean mine. The dike is about six feet wide and cuts across the ore-body at an acute angle. It consists of plagioclase, hornblende and magnetite, with alterations of the first two. Secondary magnetite also occurs.

An analysis gave:

$Si O_2$	48.19
$Al_2 O_3$	16.79
$Fe_2 O_3$	18.37
$Ca O$	6.85
$Mg O$	1.32
$K_2 O$	1.11
$Na_2 O$	5.59
Loss on ignition	2.31
	100.53

These two dikes are the only ones from the Orange county Highlands which have been described in detail.

The writer, during his field work this summer, found several other camptonite dikes in this region, which are very similar to each other and to those described by Professor Kemp.

One of these is at the turn of the road, south of the Forest-of-Dean mine, near the east end of the reservoir pond. The dike is six feet wide and extends east and west through the biotite gneiss. The latter strikes N. 10° E., and dips 50° E. The dike rock is light grey and has minute acicular hornblende crystals which are visible in hand specimens. Sections of the dike show it to consist of hornblende on plagioclase, both much decomposed. The hornblende needles and shreds lie with their longer axes parallel. Another dike cuts the gneiss at the west end of the pond. It is almost under the bridge crossing the creek at this point. This, however, is an olivine-augite camptonite. The section of this rock shows granular pyroxene, lath-shaped plagioclase and magnetite grains in the ground-mass, with phenocrysts of olivine. There is also some glassy material in the ground-mass. The olivine is altered to serpentine along the cracks and around the edges, with the development of curiously shaped magnetite grains.

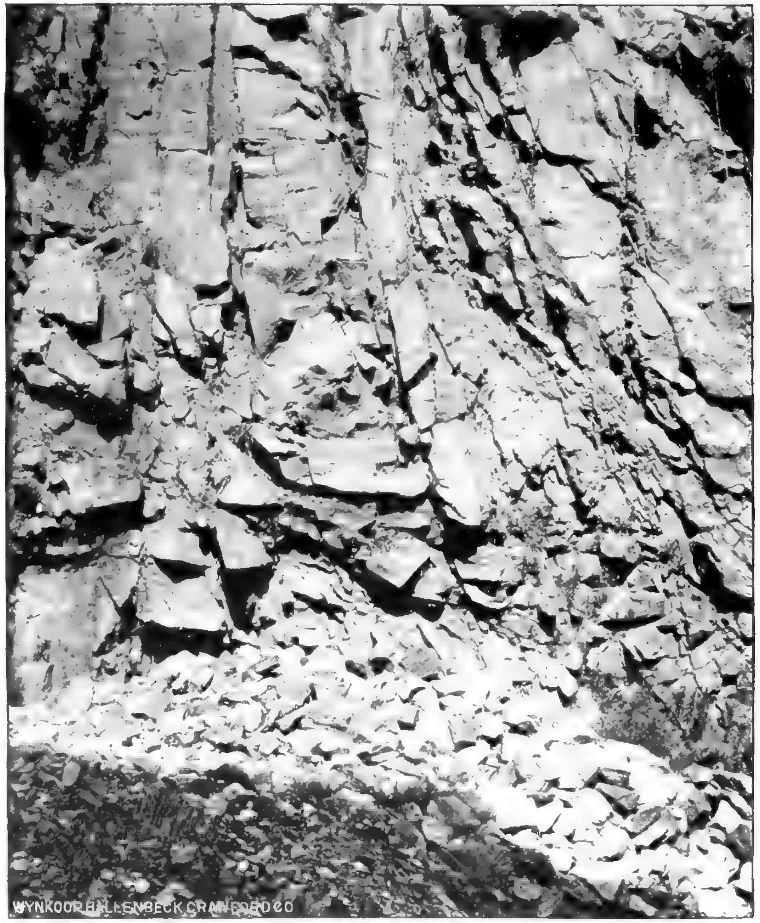
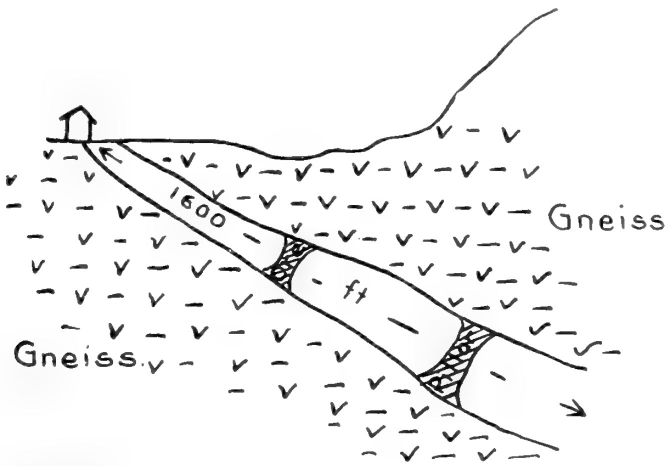
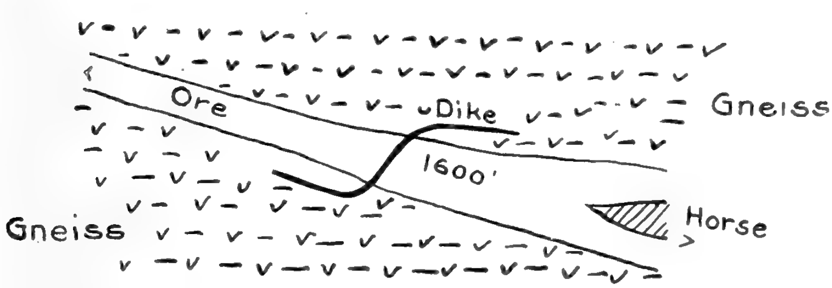


FIGURE 20. GNEISS WITH VEINS OF RED GRANITE, EAST OF HIGHLAND MILLS.

A fine example of a camptonite dike occurs in the Bradley mines, northeast of Arden, and in Monroe township. The rock is composed of plagioclase and hornblende, with some magnetite. The plagioclase is altered to a serpentine-like granular material. The hornblende is brown, strongly pleochroic and idiomorphic, in lath-shaped individuals or six-sided sections showing pris-



Section of Forest of Dean Ore body



Plan of Forest of Dean Ore body

FIGURE 21.

matic and orthopinacoid faces. There are also large porphyritic hornblendes, which commonly show zonal structure and twinning parallel to $\infty P \infty$.

Two more camptonite dikes cut the granitic gneiss about one mile (512), and a mile and one-half east of Stockbridge's hotel, which is on the mountain east of Central Valley. They are both much finer grained than the preceding, and contain numerous round or square grains of magnetite. The feldspar is much decomposed. The first of these two dikes (512) is interesting on account of the manner in which it branches and incloses some of the wall-rock. The second also branches, and is about two feet wide. It cuts both the gneiss and a granite vein. The gneiss strikes N. 45° E., and dips 60 to 70° E.

In the bed of the stream along the road, at a point about one-half mile north of the cross-road coming over the mountain from Highland Mills to Forest-of-Dean, are two additional camptonite dikes, cutting the gneiss parallel to each other. The one is four inches wide and contains phenocrysts of hornblende a sixteenth of an inch in diameter; the other is six feet wide and contains none. Sections show plagioclase, hornblende and magnetite of the

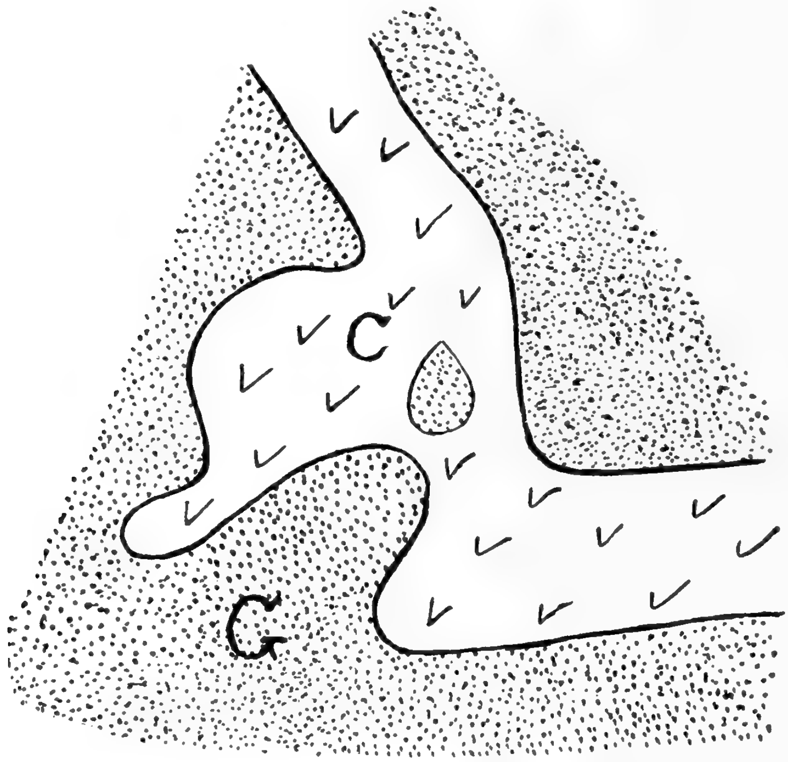


FIGURE 22. Dike of camptonite, C., cutting a granitic gneiss, G., one mile east of Stockbridge's hotel, near Central Valley, and showing inclusion of the wall-rock.

habit common to this class of rocks. The large hornblendes of the first generation are both zonal and twinned. These dikes are close to the curious pyroxene-scapolite ridge of rock.

Still other dikes of this kind occur north of the Forest-of-Dean mine, and at a point along the road south of Little Long pond, also about two miles east of the mine.

The great abundance of these dikes in this region and their constantly close similarity suggest very forcibly a common derivation, but whether the

PLATE XXII

QUARRY IN PENTAMERUS LIMESTONE, SOUTHWEST OF OTISVILLE.

parent mass is exposed anywhere, the writer is unable to say, as, in the time at his disposal, he was unable to examine the Highland region in sufficient detail.

The distribution of the dikes is not confined to the area of Highland or northwestern Woodbury townships. A narrow porphyritic camptonite dike cuts the gneiss northwest of Arden, along the road from Arden to the O'Neil mine (490).

At the west end of Little Long pond southeast of Southfield, is a curious little group of five such dikes, which may be branches of the same dike. These do not penetrate the gneiss to any extent, but are mostly in a pegmatite vein which cuts it. They are all composed of idiomorphic

FIGURE 23. Section of hypersthene-gneiss from west side of Sterling lake. The hypersthene is marked with interrupted striations; the magnetite forms irregular black grains and the pyrite square ones. The plain white is plagioclase, containing inclusions of apatite, magnetite and pyrite. (Specimen No. 346.)

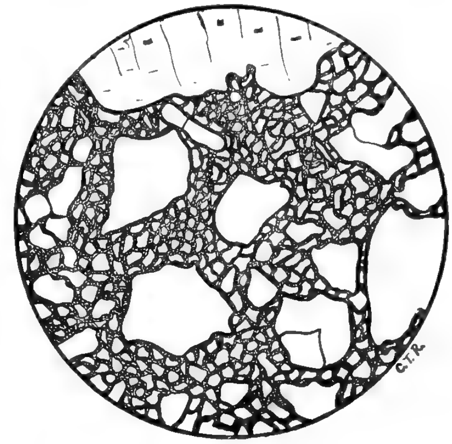


FIGURE 24. Section of gneiss along fault-line in limestone quarry, N. E. of Arden, showing large fragments of quartz and feldspar (orthoclase) in a crushed matrix of the same minerals, cemented by limonite and decomposed biotite (?). (Specimen No. 273.)

hornblendes in a ground-mass of plagioclase with grains of magnetite. The grain becomes finer as the width of the dike decreases. The gneiss strikes N. 20° E., with a vertical dip. The dike nearest the lake is two feet wide and strikes N. 70° W.; the next one, one foot wide, striking N. 50° W.; the third, N. 70° W.; the fourth, N. 50° E. and two inches wide; the fifth, N. 30° W., and four inches wide. The camptonite dike which intersects the ore-body at the O'Neil mine is an olivine camptonite. The ground-mass is composed of idiomorphic hornblende and plagioclase, with subordinate magnetite. There are also phenocrysts of olivine. Scattered through the rock are cavities filled with calcite which may result from the alterations of the feldspar. Some of the cavities contain feldspar which has altered to chlorite around the edges, while the centre of the crystal is a mass of small green epidote grains. Another camptonite with a structure somewhat resembling diabase, cuts the red gneiss northeast of Long pond near Monroe.

A much sheared dike occurs on the east side of the road, one-half mile north of the Sterling mine. The section shows a fine-grained ground mass of a greenish mineral resembling serpentine, and small rods of feldspar, mostly Karlsbad twins. There are also phenocrysts of a monoclinic feldspar. Little can be said of the relations of this rock on account of its being so decomposed.

Quartz-Porphyry. A dike of this rock occurs in the Bradley mines. The hand specimen resembled a fine-grained quartzite, but the section shows

FIGURE 25. Olivine-augite camptonite; showing phenocrysts of olivine in a ground-mass of plagioclase, granular pyroxene and magnetite. (Specimen No. 316.)

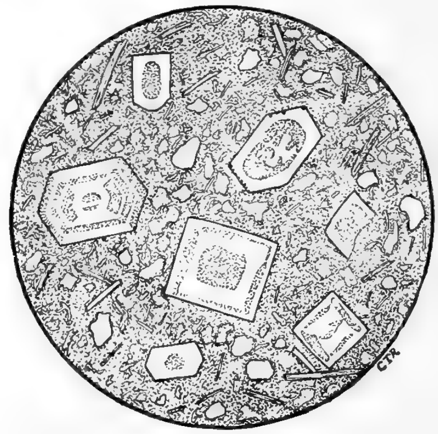


FIGURE 26. Quartz-porphyry from Bradley mines; showing phenocrysts of zonal feldspar and a granular ground-mass of quartz and feldspar, with shreds of decomposed mica and secondary limonite. (Specimen No. 354c.)

a finely granular ground mass of quartz and feldspar, with shreds of decomposed mica and secondary limonite. The phenocrysts are monoclinal feldspar showing a well developed zonal structure, the zones being a granular decomposition product, probably serpentine. The occurrence of this dike is unique, surrounded as it is on all sides by the more basic camptonites. Quartz porphyries have not been hitherto recorded from the Highland region of Orange county.

Pleistocene Deposits.

The pleistocene formations of the county consist of gravel and sand deposits, boulders, clays, and lacustrine, as well as alluvial beds. There is a drift mantle of varying thickness over the rolling country underlaid by the

PLATE XXIII

Cliffs of Esopus slate along Neversink river at Huguenot.

Hudson river formations. In the valleys this is often of considerable thickness, due to glacial stream accumulations. The valley of the Neversink river is filled to a considerable depth with gravel, which forms a broad, flat bottom, and with its covering of loam produces an admirable farming land. A hole was drilled through the drift at Port Jervis to a depth of 113 feet, without striking bottom. Boulders were abundant in the upper thirty feet, but below that, the material was mostly quartz sand with an occasional boulder.* Similar gravel accumulations occur in the valley of Shawangunk kill along the eastern base of Shawangunk mountain. The modified drift here partakes of the nature of hillocks, whose summits are all at about the same level of 900 feet A. T. The intervening depressions are often occupied by ponds. These hills extend south of Otisville for some distance, but are there less conspicuous. They also extend around the spur of the mountain to the southwest of the village.

Around the edge of the Drowned Lands, the gravel rises in rounded knolls sometimes to a height of eighty feet. There is also a conspicuous series of kames around Campbell Hall, north of Goshen. Gravel hills also line the sides of the Wallkill valley.

An interesting train of boulders is to be seen stretching from the Marlborough mountains across Newburgh and New Windsor townships and as far south as the Forest-of-Dean iron mines. They are of variable size and shape and sometimes fossiliferous. West of Newburgh they are sometimes so thickly strewn over the fields as to make cultivation impossible. M. J. N. Weed, of Newburgh, who has carefully mapped the limits of this train of boulders, informs me that he has found these erratics on the slopes and summit of Snake hill, and farther south in the Highlands at an altitude of 1,200 feet A. T. Two of these boulders are of such large size that it seems worth while recording the information that Mr. Weed kindly gave me concerning them, because they have been partially destroyed by the improvements made in the city. Mr. Weed writes:

"The 'Big Rock' boulder, formerly located in the city of Newburgh, on the northeast corner of First and Stone streets, was measured in September, 1890, just after the workmen had begun to blast it away. At that time it measured sixty-two feet from north to south, and eighty-eight feet from east to west, and was fourteen feet high. The measurements were made at the ground but, according to the laborers, fully six feet had already been blasted off the top. The boulder had a rounded form above ground.

* Report G 6, Pennsylvania Geological Survey.

"The second boulder is on Gidney avenue, near the limestone ridge and cliffs, known as "Limestone hills," on the south side of the avenue, and about 200 feet from it. It lies on a gentle east-southeast slope, and the longer axis lies in a line N. 20° E. The length of the boulder in this direction is seventy-one feet; breadth at right angles forty-nine feet, nine inches; circumference parallel with the surface at half the height, 188 feet; longitudinal measurement over the top, from ground to ground, 130 feet; transverse, over the top, 87 feet."

Mr. Weed further writes that the sandstone boulders occur in abundance on Cronomer's hill, about New Mills in the city, at Stewart's farm, southeast of Powder Mills (very large and abundant), and at Vail's Gate.

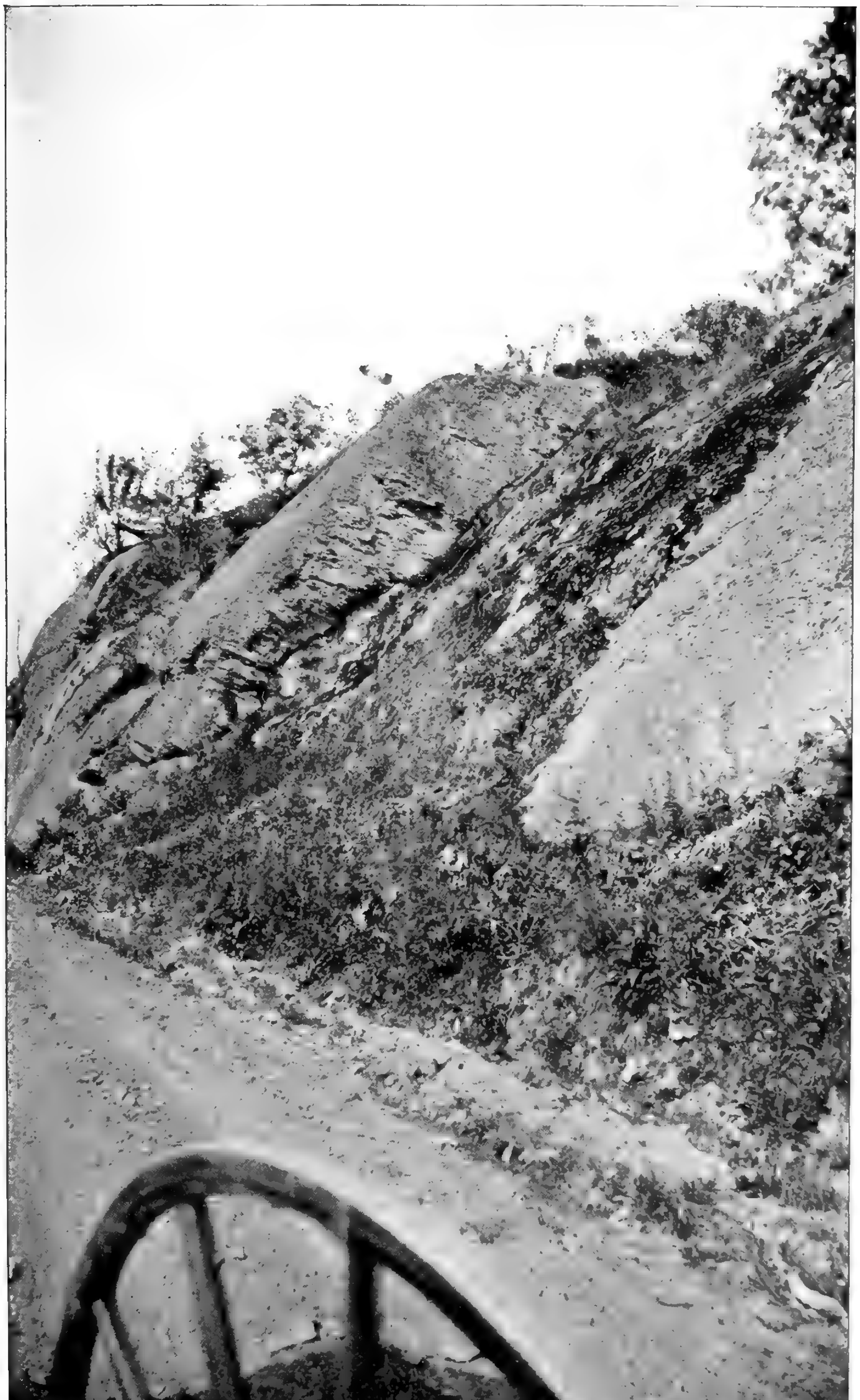
Another area of boulders occurs in Tuxedo township, west and southwest of Southfield. They are all of gneissic rock and occur singly or in groups. Several large limestone boulders were found on the slopes of Mounts Adam and Eve. The peculiar manner in which they have weathered is well shown in the accompanying plate.

The terraces in the valleys are of two classes, estuary terraces and stream terraces. The stream terraces are best developed in the valley of the Delaware river. The first terrace above the river and one representing its flood plain, is 420 feet A. T. The greater part of the villages of Port Jervis and Matamoras are built on it. There is a second terrace about 475 feet A. T. It forms a broad, level bench on which the upper portion of Port Jervis is built. It is underlaid by more coarse material than the lower one. This bench extends up the Neversink valley to a considerable distance.

Along the Hudson river from Roseton to Cornwall-on-Hudson and around West Point there is a level or very gently sloping quaternary terrace of variable width. It is mostly underlaid by clay and sand, but sometimes by boulder till. The clay, which is of great economic importance, was deposited during a post-glacial depression of the Hudson river valley which amounted to eighty feet at New York city and 240 feet at Albany. The terrace at Newburgh extends up to 210 feet, and at West Point it is 180 feet. At Roseton the terrace is only 120 feet, but it may represent the lower terrace which is found at other points along the river. The estuary material at Roseton is also found at higher altitudes.

South of Newburgh, the terrace broadens rapidly until it reaches its greatest development around Cornwall. This town as well as Newburgh and New Windsor are situated on the terrace. At Cornwall, much of the terrace is underlaid by boulder drift, and an excellent section is

PLATE XXIV



GRITS OF ESOPUS FORMATION, WITH EASTERLY DIPPING CLEAVAGE, SOUTH OF HUGUENOT.

seen at the north end of the Cornwall station of the West Shore railroad. Around the mouths of Moodna river and Quassaic creek, the delta deposits form a large portion of the terrace escarpment. The southern portion of Newburgh is built on the delta deposits of Quassaic creek. The deltas show a characteristic structure and their materials are coarse sand and gravel, with patches of coarser material in places where the currents were swifter. They often overlie the clay to a thickness of from ten to fifteen feet.

Good sections of the Moodna delta can be seen from the train as it crosses the New York, Ontario and Western railroad bridge about one and one-half miles northwest of Cornwall. The clays underlying the terrace vary in thickness. At Roseton there are 270 feet of clay under the terrace, 108 feet of which are above river level. The clay is greyish blue and generally weathers yellow in its upper portions. It is often capped by several feet of fine sand and gravel. At New Windsor the clay is yellow, tough, and frequently contains glaciated boulders three to four feet in diameter. Just north of Cornwall, at Hedge's brick yard, the clay at the time of a previous visit by the writer in 1891, showed that peculiar crumpling of a few layers between undisturbed ones, noticed at other localities and described in the Tenth Annual Report of the New York State Geologist, page 189. This distortion is produced, either by a slip, or by pressure of the overlying delta deposits.

Another terrace area begins north of West Point on the southern slopes of Crow's Nest, and continues to a short distance south of the point. The shore line here is 180 feet A. T., and the government buildings are situated on the terrace. The underlying material is mostly boulder till, which is well exposed in the railroad-cut just north of West Point. From West Point to Fort Montgomery there is little evidence of terrace material, probably because the low ridge of gneiss along the river prevented the deposition and facilitated the erosion of much estuary material.

Of importance among the quaternary deposits of Orange county are the numerous old lake-beds which especially abound in the Hudson river area. The lakes were formed by the damming up of the valleys and depressions between the slate ridges, and they disappeared through the subsequent filling of their basins or the cutting down of their outlets. Black soil underlies the surface to a depth of from five to fifty feet, and this, according to Mather*, is, in turn, underlaid by marl. I was not able to find any evidence of this, either by personal observation or inquiry. The largest of these old lake bottoms is

* Geology of New York, First District, 1842, page 16.

the Drowned Lands, which until fifty years ago was an undrained and useless swamp, but is now rich farming land. This area extends from Denton on the north to the New Jersey state line, a distance of twelve miles. Its width is from two to three miles and its area within the county, 17,000 acres. The lake had its origin in a drift dam northeast of Denton. The Wallkill river follows a winding course along the western side of this area, and submerges it entirely during the spring floods. Other lake bottoms are the Greycourt meadows, Black meadow swamp, Pine swamp, etc.

Several excellent examples of lake-filling are to be seen in Orange county. Of these the swamp at the north end of Orange lake west of Newburgh shows the former extent of the lake. Others are Glenmere lake east of Florida, Little Cedar pond two miles southeast of Sterling, and Little Long pond two miles south by east of Southfield. The rocks are often scratched and smoothed by the ice, and a fine example of glacial polishing northwest of Monroe deserves special mention. This is in a field west of the road from Monroe to Bagg's clove and just before a road turns off to the east along the base of Bull hill towards Oxford. The Oriskany quartzite has here been polished until it presents a surface like a mirror, and objects can be distinctly seen reflected in it. On Shawangunk mountain the striae are N. 30° E. and N. 60° E.

Economic Geology of Orange County.

ROAD MATERIALS. Orange county has an abundance of good road-making materials, but in few sections of the county are they taken advantage of, owing either to indifference on the part of those persons on whom the maintenance of the roads depends, or to a lack of the knowledge of the value of these materials.

The old method of working the roads by digging a mass of loose stones, dirt and roots from the roadside and throwing it upon the road, is still followed to a large extent, with the usual poor road resulting. This is the mode in regions where good material is near by, and even known to the road repairers. Their use, however, requires a trifle more labor.

The road-metals found within the county are: slate and shale, limestone, sandstone, granite, and gravel.

Gravel and Sand The gravel has the most extended use of the available road materials of the county. The localities furnishing it are too numerous to require mention, and are found in every township. When the gravel is

PLATE XXV

Granite quarry on Mount Eve.

argillaceous or contains a great admixture of fine sand it makes only a fair road, but a top-dressing of five or six inches of moderately fine gravel, evenly laid, generally produces good results. In Tuxedo township very excellent roads are maintained by using sand and gravel, but this is partly because a few men are constantly employed going over the roads and repairing any break that appears. This method costs the township $40 per mile per year, and there are 2,400 miles of road to be repaired.

Slate. About two-thirds of Orange county is underlaid by slate, and the roads within this area are usually good where there is not a deep covering of drift. A layer of siliceous slate produces a smooth, hard road, which in dry weather makes comparatively little dust. This material is extensively used in the Neversink valley northeast of Port Jervis, and the roads in that region are among the best in the county.

A gritty shale or slate causes less mud than an argillaceous one. The red Longwood shales northeast of Highland Mills make an excellent road-metal and are extensively used around Central Valley, Highland Mills and Woodbury Falls. Several large quarries have been opened in this rock on the southwestern slope of Pine hill.

Around Port Jervis the Marcellus and Hamilton shales are also used with satisfactory results.

Sandstone. The Shawangunk grit makes one of the best road materials in the county. Its chief use, however, is for railroad ballast, and there is a large quarry in this rock one mile west of Otisville. This quarry is on the property of R. Roberts, of Otisville, but it is leased at an annual rental by the New York, Lake Erie & Western railroad which operates it with a force of one hundred men for about five months every year, with a daily output during that period of about 275 tons a day. The bore-holes have to be made with hand drills on account of the numerous irregular cracks which traverse the rock. The stone is broken in a Blake crusher at the quarry.

Granite. The stripping and trimmings from the granite quarries at Mounts Adam and Eve are used to some extent for making macadam roads in Goshen.

Limestone. The Calciferous limestone is quarried southwest of Newburgh for macadam roads. It is somewhat siliceous and makes a good paving material after being crushed and screened at the quarry which belongs to the Miller Brothers. The stone sells for $1.00 per ton, and the quarry is operated about two months every year.

Gneiss. A mile southeast of Southfield and along the Erie railroad is a large quarry in the quartzose gneiss. It is operated solely for road-paving purposes. The rock is crushed and screened at the quarry.

Mr. Josiah Mead is the owner. The material is all shipped to Colfax & Steele, of Paterson, N. J.

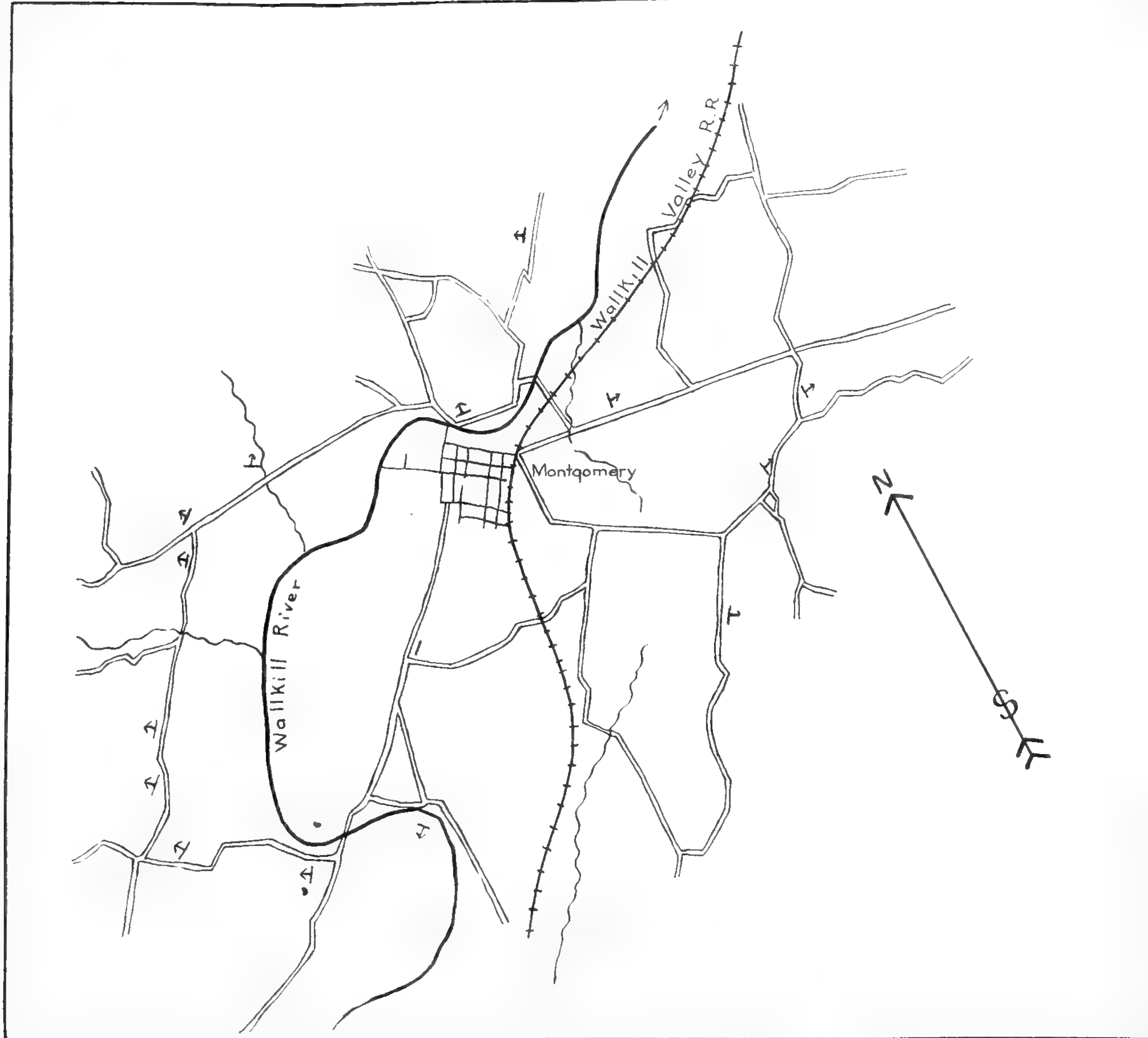
BRICK-CLAYS. These are the only grades of clay found in the county. The important and most extensive development of this material is along the Hudson river, in whose valley there exists the greatest brick manufacturing industry of the United States. The clay beds extend almost continuously from Roseton on the north to Cornwall on the south. The firms engaged in the manufacture of brick in this area together with the location and the capacity of their brickyards, are enumerated in the following list:

Locality.	Workers.	Owner.	Capacity in millions.
Roseton. . . .	Jova Brick Works,	Jova Brick Works,	22
	J. Rose & Co.,	Rose Brick Co.,	40
New Windsor,	E. Lang,	E. Walsh,	8
	J. Gillis,	J. Gillis,	4
	H. Davidson's Sons,	H. Davidson's Sons,	4
	W. Lahey,	W. Lahey,	10
	David Carson,	David Carson,	4
Cornwall, . . .	C. A. & A. P. Hedges,	C. A. & A. P. Hedges,	10
Goshen, ...	I. van Lengen,		2

The chief market for all, except the last on the list, is New York city and Brooklyn.

A detailed account of these clay beds has been given by the writer in the Tenth Annual Report of the New York State Geologist, and only a general mention of them need be made here. The greatest known thickness of the Hudson river clay is at Roseton, where there are 108 feet of clay above the river level and 170 feet below it, as determined by a drive-well, giving a total thickness of 278 feet. Between Newburgh and Cornwall the clay is generally tough, with more or less boulders scattered through it, and there is a varying cover of delta material. The clay at Roseton and Cornwall-on-Hudson is, on the contrary, well stratified and very soft, but it is likewise overlaid by delta deposits. The soft mud process of manufacture is the one used at all the yards, and only common brick is made.

The following is an analysis of the clay used by the Jova Brick Works and furnished by them:



MAP OF THE REGION AROUND MONTGOMERY SHOWING THE STRIKES AND DIPS OF THE HUDSON RIVER SLATES WHICH UNDERLIE THIS AREA.

Silica,	55.00
Iron and alumina,	34.54
Lime,	5.33
Magnesia,	3.43
Alkalies,	.48
Water,	1.22
	100.00

The clay deposit at Goshen is local, covering several acres and having a depth of about thirty feet. The yard is run to supply the local demand. Drain tile is occasionally made.

The following analysis of clay from the Drowned Lands is given in the New Jersey Geological Survey's report, 1891:

$Si\,O_2$	53.00
$Al_2\,O_3$	23.00
$Fe_2\,O_3$	7.2
$Ca\,O$	.70
$Mg\,O$	2.60
Alk.	4.10
$H_2\,O$	9.70
$Ti\,O_2$	.50
	100.80

LIME. The limestones of Orange county are all magnesian with the exception of those of the Helderberg series. While many of the large ledges in the county have been quarried for lime at one time or another, but little is made at the present day. There are several kilns in operation two miles southeast of Monroe, and considerable lime is also being made from the Cambrian limestones west of Newburgh. These are the only two active localities. There was formerly a very large amount of quarrying done in the limestone ridge northeast of Arden to supply flux for the furnaces. Another active quarry was southwest of Otisville, in the Pentamerus limestone. It is probable that most of the Orange county limestones contain a rather high percentage of silica.

LEAD. Lead occurs in fissure-veins at many points along the Shawangunk mountain, and the prospecting of these caused considerable excitement in former years. The largest opening made was at Guymard, in Mount Hope township, eight miles from Port Jervis. The deposit is a true fissure-vein.

It is three to four inches wide and runs N. 70° E. Several shafts were sunk, and one was carried down 400 feet. The surface rock is Shawangunk grit, but the vein no doubt reaches the conglomerate.* Crushers and jigs were used to concentrate the ore and separate the sphalerite. The mine has been abandoned for fifteen years.

BUILDING STONE. The most important quarries are in the granite of Mounts Adam and Eve, and Pochuck mountain, all in Warwick township.

The Adam and Eve quarries are in a coarse-grained granite, but those on Mount Adam have been little worked on account of the variable character of the granite which is cut by numerous irregular pegmatite veins. The Mount Eve quarry, however, is worked by the Mount Eve Granite Co. The granite of Pochuck mountain is coarse grained and lighter colored than that of the two preceding quarries. The quarry has been in operation for about five years. It is situated about one-third the distance up the mountain. The owner is Mr. Hinchcliffe, of Paterson, N. J. Large dimension blocks are obtained from this quarry, and most of them are sent to Orange, N. J. The limestone of Mount Lookout has been used to a limited extent for building purposes. It has been put in the Presbyterian, Methodist and Roman Catholic churches at Goshen.†

The Shawangunk grit has been used by the Erie railroad for abutments.

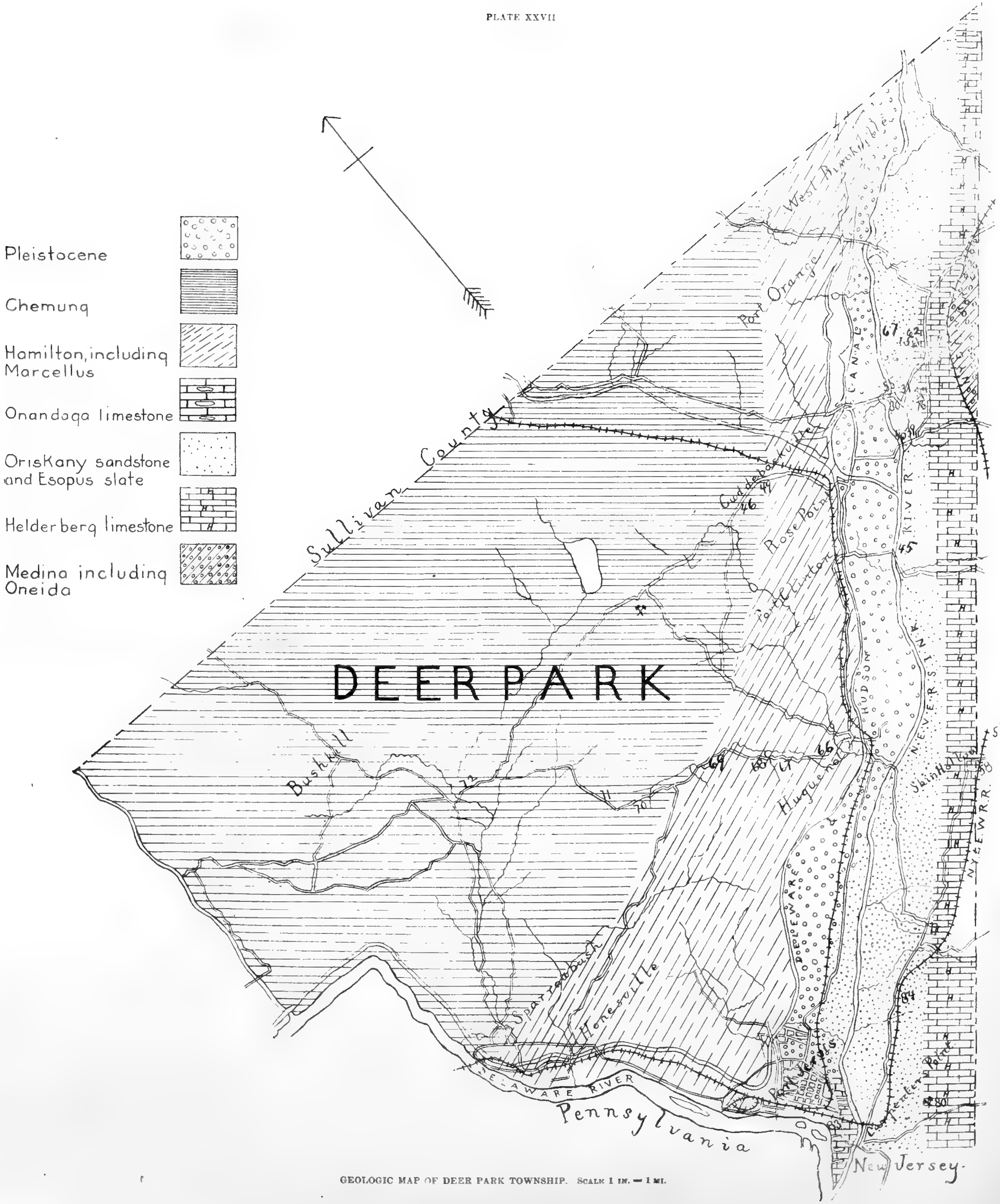
FLAGSTONES. The Hamilton and Chemung flaggy sandstones have been utilized to a small extent for paving, the former being obtained from Skunnemunk mountain in Monroe township, and the latter from the western part of Deer Park township.

Those on Skunnemunk mountain are the Davidson quarries below the Seven Springs Mountain house, and farther down the mountain on O. H. Cooley's land, northwest of Monroe. The strata are thin-bedded sandstones of irregular thickness, and are often broken by many joints. Those thus far opened have been of little value on account of the irregular character of the rock.

In Deer Park township the stone is of similar nature, but slightly better. Many openings have been made and a few of these are still operated at times to supply the local demand. The more important ones are those of Mr. Myers and the Jackson Bros., west of Rose Point, and Robert Coulter's, north of Sparrowbush.

IRON ORES. There are many small and a few large deposits of iron ore in the Highland region of Orange county, and in former years there were

* Report G 6, Pennsylvania Geological Survey, p. 161.
† Bulletin New York State Museum, Vol. II, No. 10.



GEOLOGIC MAP OF DEER PARK TOWNSHIP. Scale 1 in. = 1 mi.

many active mines. The majority of these are no longer in operation, owing to the poor quality of the ore and the cost of operating them. In many instances the ore had to be hauled three or four miles. The two active mines are the Forest-of-Dean, in Woodbury township, and the mines of the Sterling Iron and Railway Company in Tuxedo township, at the southern end of Sterling lake. The Sterling mines were in operation during the Revolutionary war and have so continued since. Many openings have been made in the area around the lake, and abandoned after being worked to various depths. The company owns 20,000 acres of land and the following mines are on it: Crawford, Behring, Moorhead, California, Sterling, Clark, Lake, Oregon, Spruce Swamp, Hard, Cook, Scott, Mountain, Causeway, Long and Augusta. The oldest and most important is the Sterling mine which was opened in 1750, and a furnace built in 1751. The ore-body is of large size and, according to Smock*, has undulating foot-walls, the rolls running N. E. and S. W. There is said to be a fault on the south side of the mine by which the ore is displaced ten feet. At present the slope of the Sterling mine has gone down 1000 feet on the dip. Levels are run off every fifty feet (see figure) and after all the levels are driven, lifts will be sunk between them. The thickness of the bed varies from five to twelve feet and the ore is sharply defined from the walls.

The Lake mine lies to the north of the Sterling and evidently is a portion of the same ore-bed which has been divided by a pinch. This pinch, is about 250 feet long. The slope of the Lake mine, which descends diagonally on the dip, is 1100 feet long and the ore-body extends under the lake. The wall-rock of these two mines is a hornblendic gneiss; associated with the magnetite along the border of the ore-body are amphibole, pyroxene, epidote, red and white feldspar, tourmaline and quartz. Beautiful intergrowths of quartz and tourmaline are common.

The Sterling ore averages sixty per cent. iron and four per cent. phosphorus; the Lake mine, fifty-nine per cent. iron and nine per cent. phosphorus, while the monthly output of the two mines is respectively 4000 tons and 2000 tons.

Compressed air is used to operate the drills and one of the compressors is run by water-power derived from Sterling lake. Plate XLII shows the surface workings of the mines, the dump-heaps seen up the hill being from the quarry workings of some of the abandoned ones, for the ore-body of the Lake and Sterling mines formerly extended up the surface of the hill, there

* The Iron Ores of New York.—Bulletin New York State Museum, Vol. II., Number 7.

being little or no rock covering the ore. The old Clark working is half-way up the hill, and affords a fine example of pinching and swelling of the ore-bed, as shown in a foregoing figure. Considerable ore has been obtained from this mine.

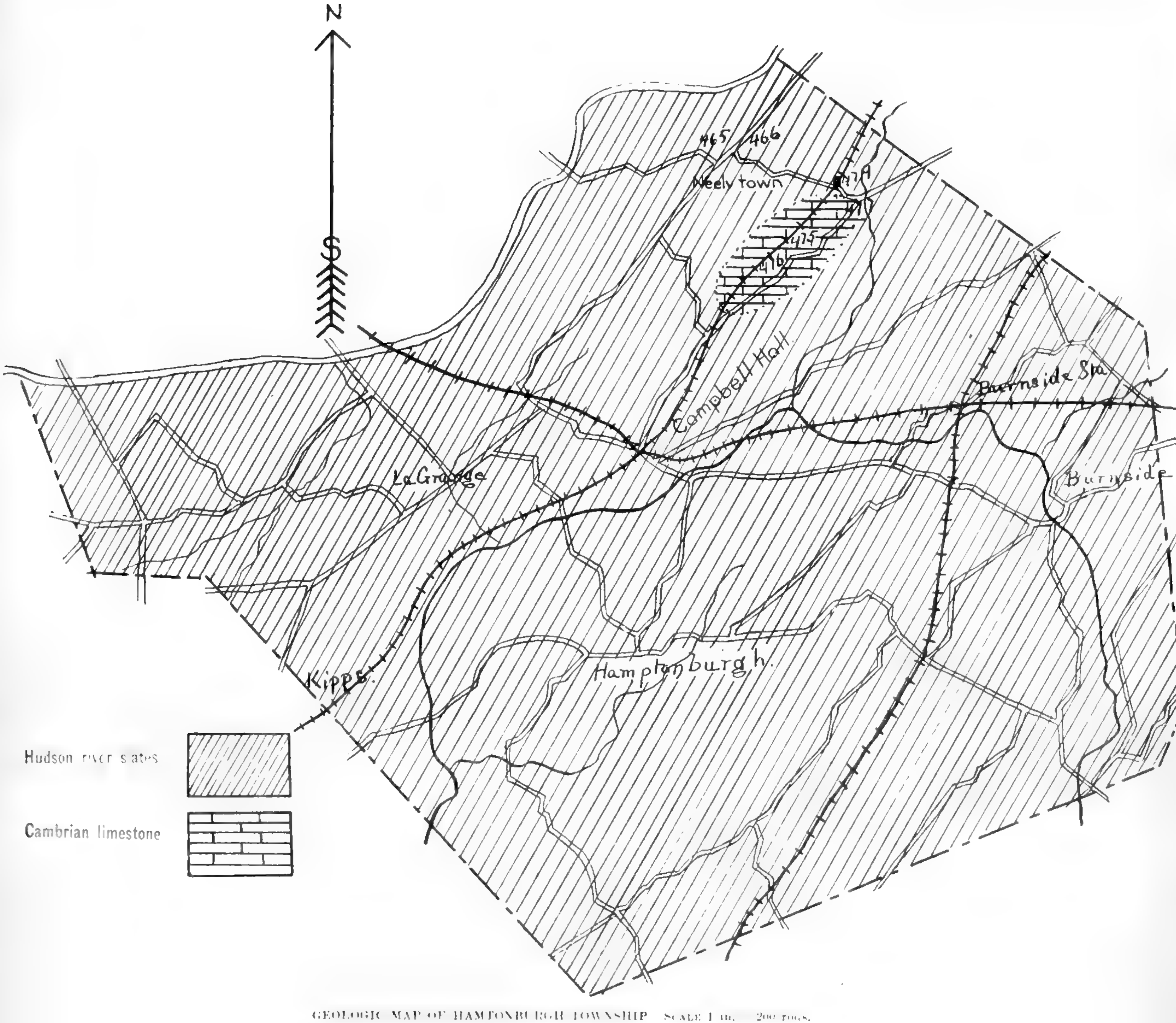
One mile to the northeast of the Sterling mine, is the Augusta mine, which was of considerable importance in former years. A plan of the ore-body is shown in Plate XLIX. The ore had been mined for a distance of 100 feet on the dip. This mine has been recently opened again. A longitudinal section, or rather side elevation of the section, is given in the lower portion of the same plate, and in Plate L are shown a number of transverse sections drawn along the lettered lines indicated in the upper drawing of the previous plate. It will be seen from these that the ore-body was long and flat. A fine fault is exposed in the hanging wall at the mouth of the mine (Plate XL). The exact amount of displacement is not known and it does not show in the sections of the ore-body.

The Causeway and Mountain mines include several small and parallel ore-bodies, which are shown in plan in the upper portion of Plate L. A side elevation of the section of those of the Mountain mine is also shown in the upper right-hand portion of the same plate. It will be seen from this that in each case the ore cropped out at the surface, and that in one instance the bottom of the ore-body had not been reached when the mine was shut down. The writer is indebted to Mr. Knox, the superintendent of the Sterling mines, for permission to reproduce these sections and also for other information concerning the mines in this region.

The Scott mine is a mile and one-half northeast of the Sterling, and was formerly of considerable importance. According to Smock*, it has reached a depth of 430 feet on the slope and its levels have an extreme length, along the strike, of 900 feet. The ore-bed is four to eighteen feet thick. At the Cooke mine, which is south of the Scott, the shaft has a vertical depth of 250 feet. None of these mines afford bessemer ores.

The Forest-of-Dean mine is situated five miles west of Fort Montgomery. It has been inactive for a considerable period, but was started up again last August. The mine is owned by the Port Henry Iron Co. and is operated by the Forest-of-Dean Iron Co. The ore-body is large and somewhat lenticular, with a thickness of ten to forty feet, and a width of as much as eighty feet in places. A slope is sunk on the pitch which is 22° N. E. and the full width of the vein is stoped out. Pillars are left at intervals to

[3] *Loc. cit.*



GEOLOGIC MAP OF HAMTONBURGH TOWNSHIP Scale 1 in. = 200 rods.

support the hanging wall. The wall-rock is a feldspathic biotite gneiss which dips steeply to the east. The ore-body is cut by a camptonite dike six feet wide, and a horse divides the ore at the roof, but farther down extends across the ore-body. According to Smock, this horse shows a synclinal structure. Figure 21 gives a section and plan of the ore-body.

The ore is non-bessemer and the following analysis of it is given in Smock's report:

Silica,	5.00
Alumina,	trace
Lime,	5.51
Magnesia,	1.19
Manganese,	.63
Peroxide of iron,	83.56
Phosphorus,	2.30
Carbonic acid,	1.05
Water,	.20
	99.44

The slope is about 1,600 feet long, and the ore is raised in a car. It is trammed to a point within two miles of Fort Montgomery, whence it is carted to the river. This item of transportation would greatly increase the cost of operation of the mine were it not for the fact that the entire plant is operated by water-power. This is generated by two overshot wheels forty feet in diameter and six feet wide. The mine-water is raised through a vertical shaft located 900 feet east of the mouth of the slope. The ore is used in the furnaces at Poughkeepsie.

Soils. About two-thirds of the county is underlaid by the Hudson river slates, which are usually thinly covered with drift. The soil of this region produces excellent hay and the area is extensively given over to dairy farming, the products of which have made the county well known. Very little else is raised in the slate region, except in the northeastern portion, where the stony soil and hilly ground produced by the coarse drift and sandstone, are admirably suited for the cultivation of grapes.

The limestone areas afford a good soil, in their more elevated portions, but they are often areas of depression and occupied by swamp land.

These swamps, however, occur not only in the limestone region, but also in many parts of the slate area and form perhaps the most important agricultural feature of the county. The rich black soil of the swampy tracts is enormously productive, and some of it is worth $300 an acre. This soil is generally planted with onions, and 700 bushels per acre is not an uncommon yield. Potatoes or corn are generally planted in alternate years to relieve the soil. There are about 40,000 acres of swamp land in Orange county. The largest of these areas is the Drowned Lands in Warwick, Greenville, Minnisink, Wawayanda and Goshen townships and covers 17,000 acres. Until about sixty years ago the area was covered by several feet of water held in by a natural dam of glacial drift at the north end. A canal cut through this dam has redeemed the land. From the Drowned Lands there arise islands of limestone or drift, which are named Pine, Great, Pellet's, Gardner's, Merritt's, Cranberry, Black Walnut, Fox and Seward islands. Other important swamp areas are: Greycourt meadows, covering 500 acres and extending from Craigsville to Chester; Black meadow in Goshen township, 1,000 acres; Long swamp, southwest of Edenville in Warwick township, 1,000 acres; Tamarack and Purgatory swamp in Hamptonburgh; Big swamp, north of Orange lake; Great swamp, near Coldenham, New Windsor township; Great Pine swamp, which begins near Howells and extends northward and eastward about seven miles in the town of Wallkill; Little Pine swamp, east of Thompson's ridge; Pine Bush swamp in Crawford township, Pakadasink swamp in Greenville, and Barton swamp in Cornwall township.

MINERAL SPRINGS. The only mineral spring in the county, of which the writer has any knowledge, is a chalybeate one, in the Highlands east of Mountainville. It is known as Sutherland's spring.

WATER POWER. Aside from the small streams furnishing local grist mills, water power is supplied by the Shawangunk kill, Wallkill river, Moodna creek, Quassaic creek and Ramapo river.

The Shawangunk kill is little used, except for small grist mills. The Wallkill river is a sluggish stream with little fall until it reaches Walden and Montgomery, at both of which points it cuts down through the Hudson river slates. Two mills and a paper factory are in operation at Montgomery where the fall is increased by a dam across the river.

At Walden the river has a natural fall of twenty-six feet, but since the dam above the bridge was constructed, a fall of thirty-two feet is obtained. This fall is utilized by the New York Knife Co., employing 350 hands. The water passes though six turbine wheels, which generate 195 horse-power.

Mr. Moore, the superintendent, estimates that, even in dry weather, there is sufficient flow of water to furnish 1,200 horse-power. The reclaiming of the swamp lands farther south has had a material effect on the stream. The

PLATE XXIX

Wallkill river at Walden, with ledges of Hudson river slate

Wallkill Valley Knife Works, below the bridge, receive sixty horse-power from the river. Orange lake supplies Quassaic creek which flows southeast and enters the Hudson river at the south end of the city of Newburgh. The flow of water from the lake is regulated by gates, but there are so many firms receiving power from the stream that in a dry season, like that of 1895, they have to rely wholly or in part on steam-power. Between Orange lake and the powder mills there are several small grist mills receiving power from the creek. In spring and early summer the creek is utilized by the powder mills.

Within the city limits the factories receiving water-power from Quassaic creek are:

Newburgh Woollen Mills, twelve feet fall and one wheel furnishing twenty-eight horse-power. This is used from February to May, depending on the season.

Saxony Silk Co., eighteen feet fall, two turbine wheels, thirty and forty inches respectively, which together furnish seventy horse-power. They are used about seven months of the year.

Ross's flour mill, twenty-four feet fall, sixty horse-power. Used nine months of the year.

Newburgh Bleachery, twenty-one feet fall, and one hundred horse-power derived. Used eight months of the year. This factory has a large reservoir.

Adams & Bishop Paper Mill, Little Falls Paper Co., and Hudson River Woollen Mill. These three all receive a small amount of power from the stream.

Moodna creek is utilized at Salisbury Mills, but otherwise is of no special importance.

The Ramapo river furnishes power to several grist mills at Monroe and one at Turners. Its branch entering at Arden is an active stream with considerable fall and could no doubt be profitably utilized.

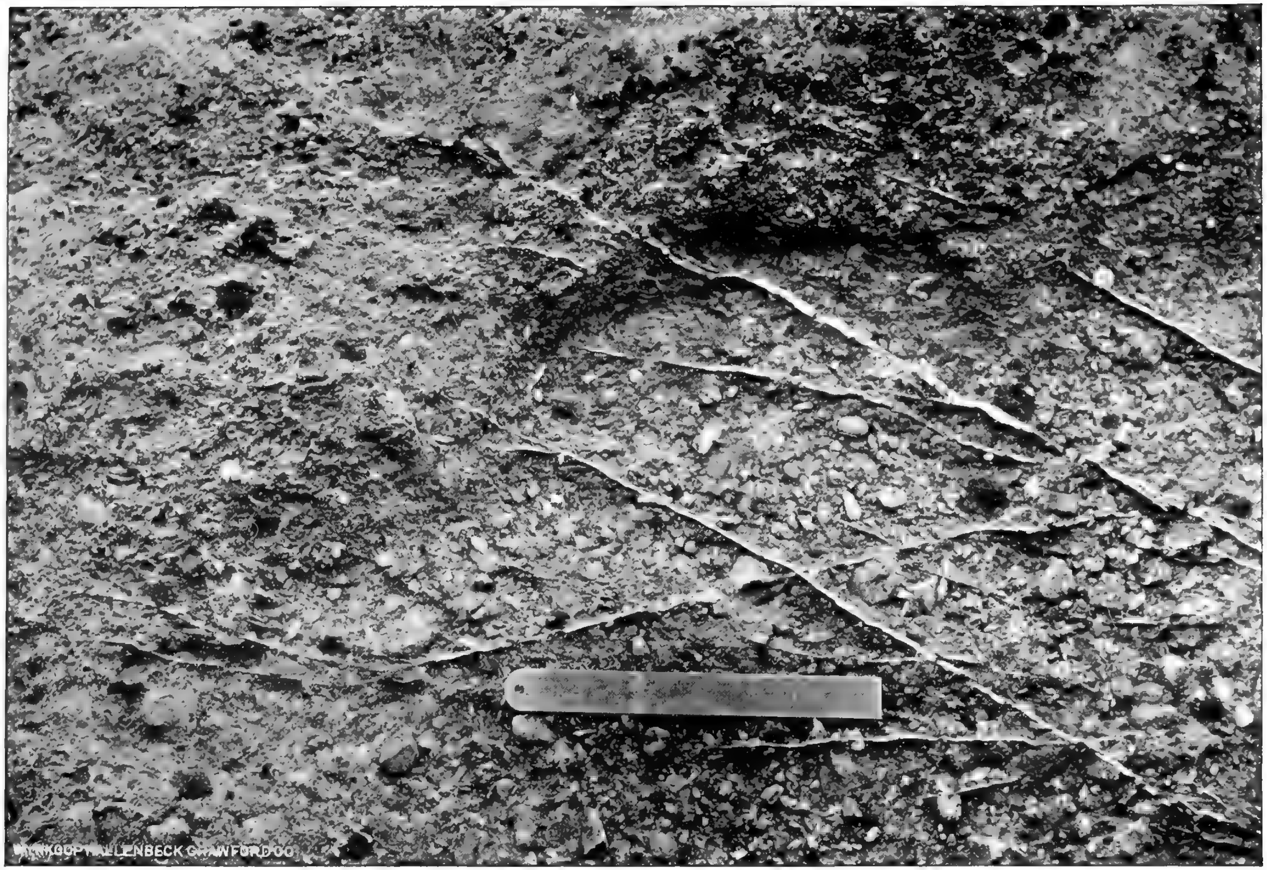
The Neversink river is not utilized for water-power and has little fall within the limits of Orange county.

WATER SUPPLY. A word should be said regarding the water supply of the towns within this county. There is a large number of lakes, especially in the Highland region which contain an abundant supply of clear water. Of these Long pond, south of Monroe, supplies the town of Chester, and a pipe is being laid from Mount Basha lake to supply the town of Monroe, two miles north of it. Little Long pond in Highland township, furnishes the Government reservation at West Point, while Little pond west of Newburgh furnishes that city with its drinking water. The city of Middletown has constructed a reservoir by damming the valley of a creek to the northwest of the town.

PLATE XXX

GEOLOGIC MAP OF NEWBURGH AND NEW WINDSOR TOWNSHIPS. SCALE 1 IN. = 2 MI.

PLATE XXXI



Trenton limestone along River Road south of Newburgh.

PLATE XXXII

ONEIL IRON MINE

PLATE XXXIII

Fault in hanging wall of Augusta mine, near Sterling.

PLATE XXXIV

Sterling lake, looking south. The iron mines are at the farther end of the lake.

PLATE XXXV

DIKE CUTTING ORE-BODY AT ONEIL MINE.

PLATE XXXVI

General view of Greenwood lake, looking south.

PLATE XXXVII

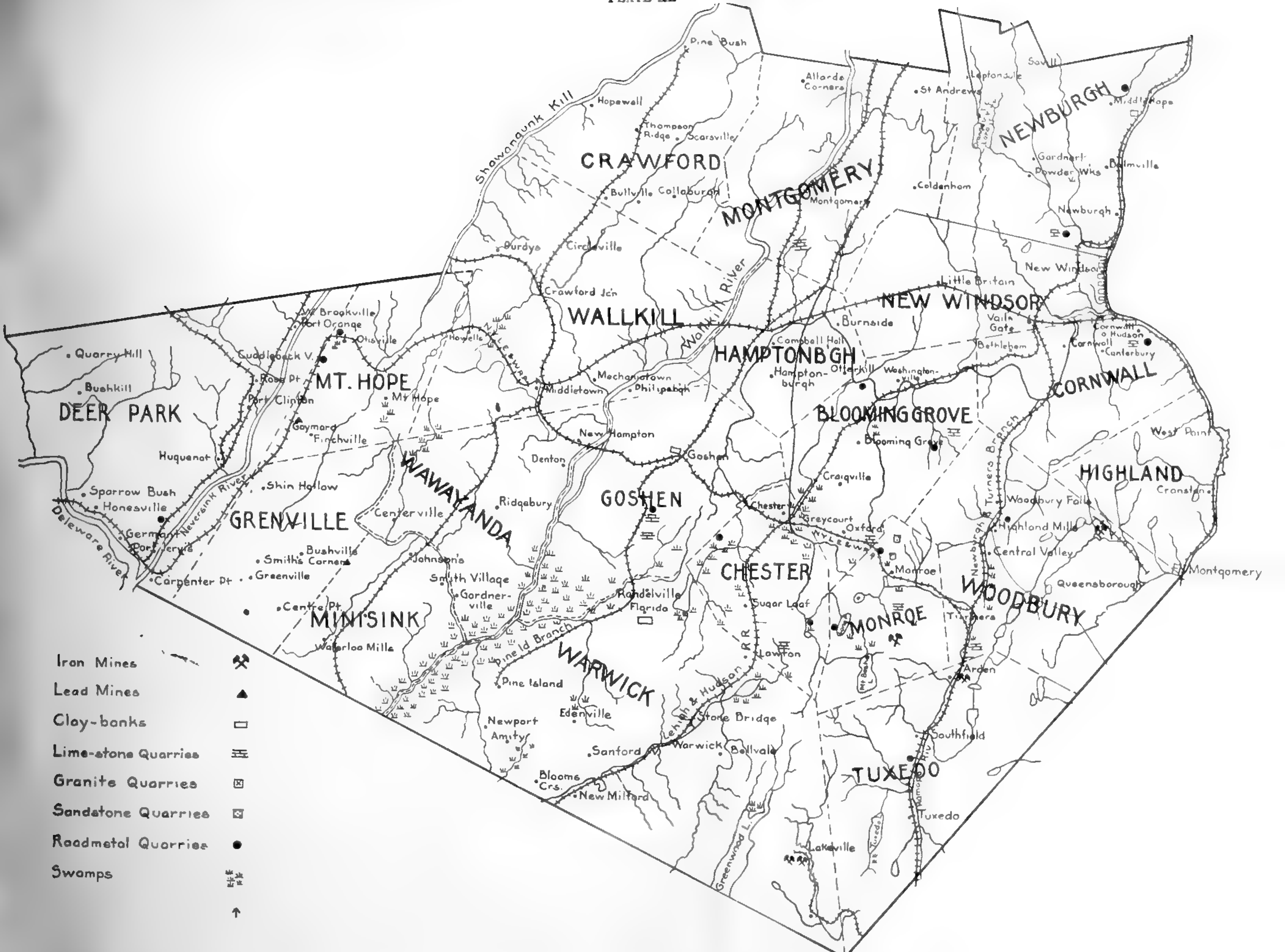
TUXEDO LAKE, LOOKING NORTH.

PLATE XXXVIII

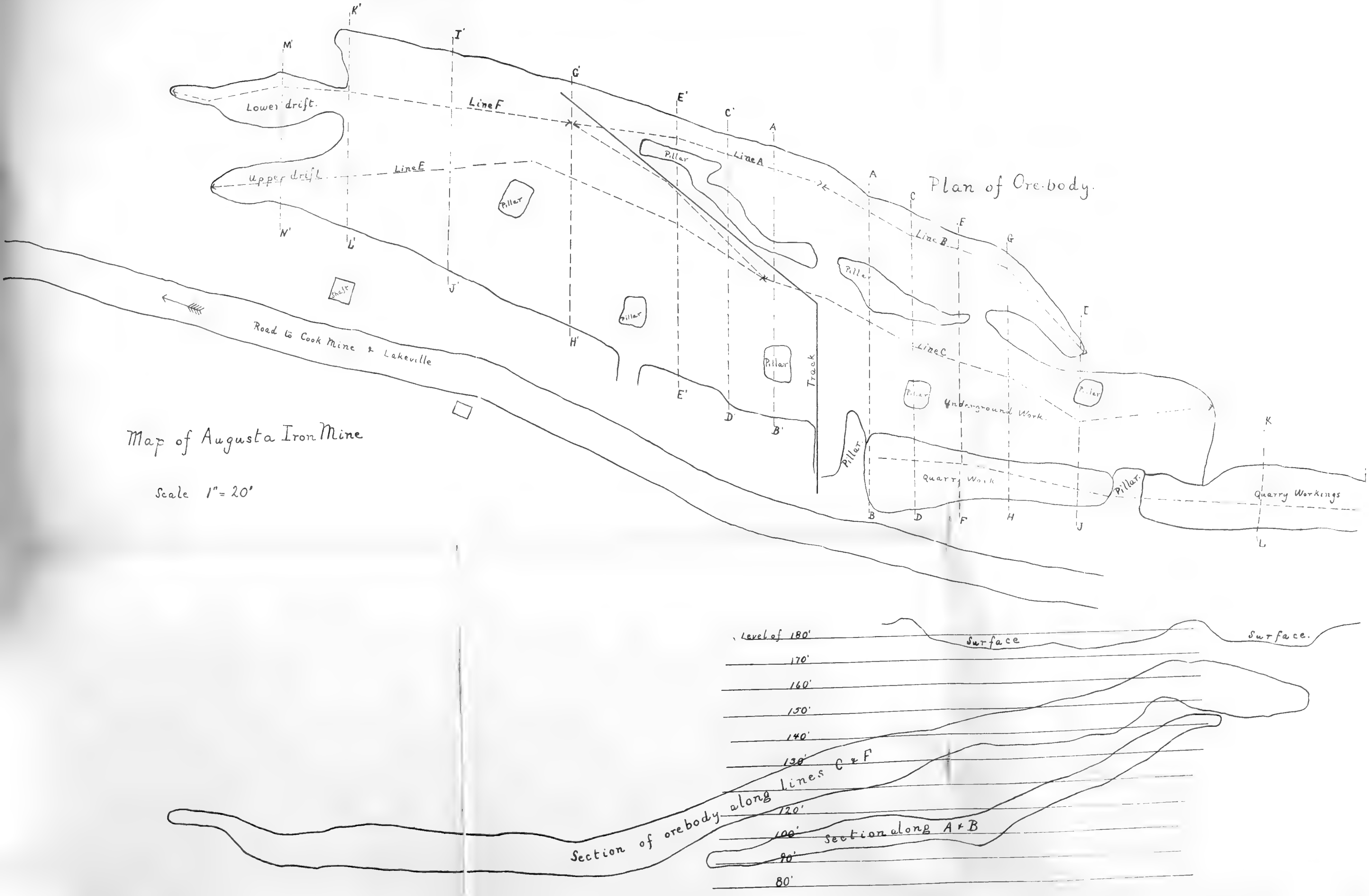
LIMESTONE BOULDER NEAR EDENVILLE.

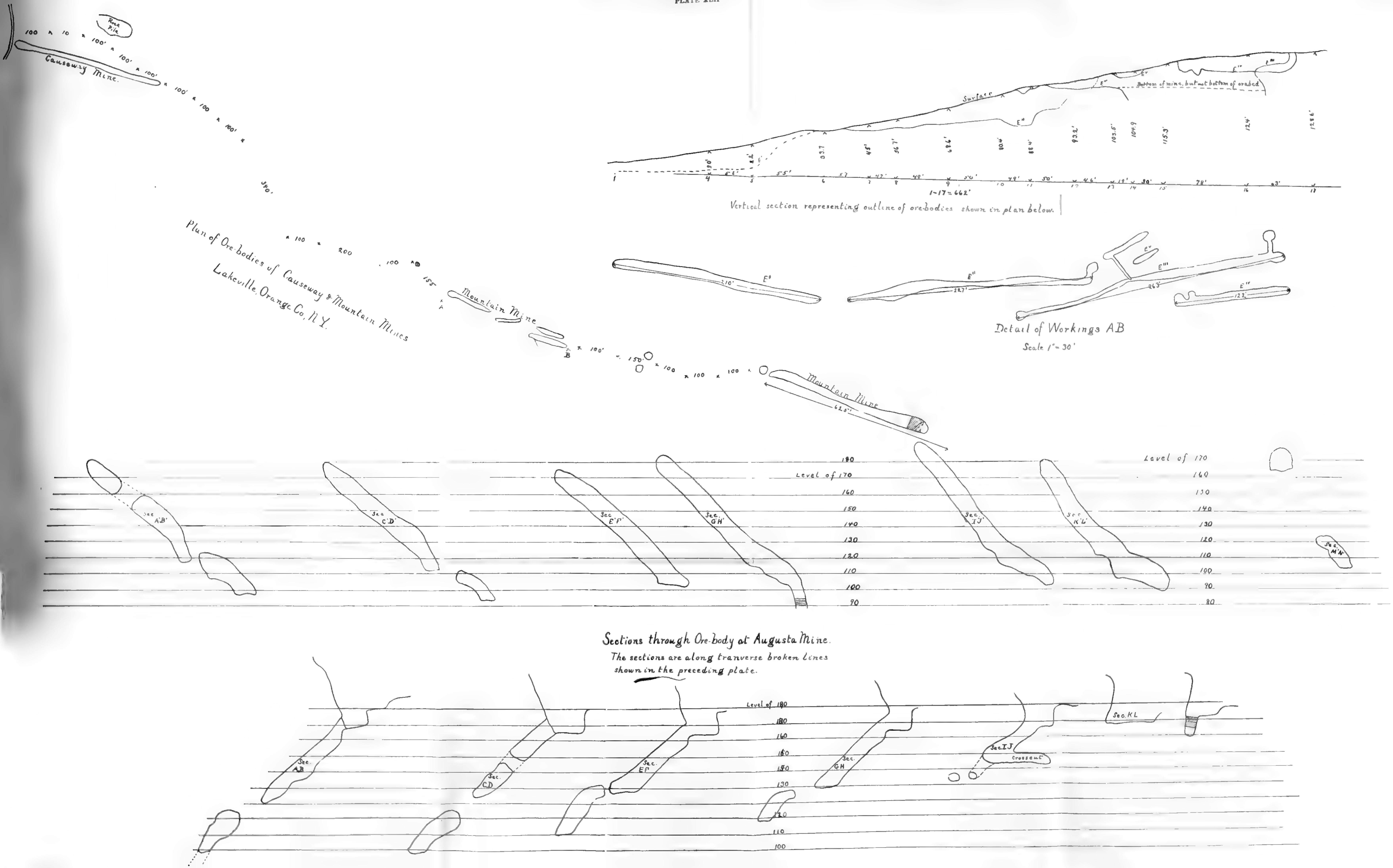
PLATE XXXIX

View of the Highlands, looking north from West Point.



MAP OF ORANGE COUNTY, ILLUSTRATING ITS ECONOMIC GEOLOGY.


Map of Augusta Iron Mine
Scale 1" = 20'
Plan of Ore-body.
Lower drift.
Upper drift
Line F
Line E
Line A
Line B
Line C
Pillar
Shaft
Road to Cook Mine & Lakeville
Track
Underground Work.
Quarry Work
Quarry Workings
Surface
Surface.
Level of 180'
170'
160'
150'
140'
130'
120'
100'
90'
80'
Section of orebody along Lines C & F
Section along A & B


Rock Pile
Causeway Mine.
Plan of Ore-bodies of Causeway & Mountain Mines
Lakeville, Orange Co., N.Y.
Mountain Mine
Mountain Mine
625'
Surface
Bottom of mine, but not bottom of orebody
1–17 = 662'
Vertical section representing outline of ore-bodies shown in plan below.
Detail of Workings AB
Scale 1" = 30'
Level of 170
Level of 180
Sections through Ore-body at Augusta Mine.
The sections are along tranverse broken lines shown in the preceding plate.
Sec. KL
Sec. IJ
Crosscut

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

(GEOLOGICAL MAP.)

REPORT
ON THE CRYSTALLINE ROCKS OF ST. LAWRENCE COUNTY.

JAMES HALL,
State Geologist.

C. H. SMYTH, JR.,
Assistant.

1895.

JAMES HALL, *State Geologist.*

SIR:—Herewith I submit a report on the crystalline rocks of St. Lawrence county.

Respectfully yours,

C. H. SMYTH, JR.

HAMILTON COLLEGE, CLINTON, N. Y., *Jan. 1, 1896.*

Report on the Crystalline Rocks of St. Lawrence County.

By C. H. Smyth, Jr.

The field work done in St. Lawrence county during the summer of 1895, consisted in a continuation of the reconnaissance of the crystalline rocks of the region, begun some time since, and carried on in part privately, and in part under the direction of the State Geologist. This reconnaissance has now been extended over about two-thirds of the crystalline area of St. Lawrence county, and also considerable tracts in Jefferson and Lewis counties, the total area covered approximating 2,000 square miles.

The present report is particularly concerned with results obtained in a new territory comprising the towns of De Peyster, De Kalb, Hermon, Edwards, Canton, Russell, Potsdam, Pierrepont and Parishville; together with points re-examined in the towns of Gouverneur, Rossie and Fowler, which were covered in the examination made during 1893. Certain facts observed during 1894, in the towns of Pitcairn, Fine, Clifton, and Diana, Lewis county, which have been already described in part,* may prove of value in this connection.

In making this reconnaissance, the main object was to learn the distribution of the crystalline limestone formation, for which the name *Oswegatchie series* was suggested in a previous report.† A special effort was also made to ascertain as many facts as possible bearing upon the question of the origin of the great areas of gneisses, and the relation existing between these rocks and the limestones.

Distribution of Crystalline Limestones. As a wider territory was covered, the distribution of limestones was found to conform to the same order as in the case of the more limited areas previously described. They form belts, many square miles in extent, stretching in a northeast and southwest direction; and, in addition to these, small scattered patches, irregularly distributed, and varying greatly in size. By far the largest limestone belt is that which is traversed longitudinally by the Rome, Watertown & Ogdensburg railroad from Antwerp to a point some two miles east of De Kalb junction. The belt begins at the former village, but extends some miles northeast of the latter,

* Bulletin Geological Society of America, VI, pp. 263-284.

† Report of State Geologist for 1893, pp. 493-515.

the railroad leaving it at the point stated. Scarcity of outcrops prevents a precise location of the limit in this direction, but it is probably cut off by gneiss about two miles south of Canton village. It may possibly, however, be connected with an area of limestone in the southwest corner of Potsdam, although the latter appears to be entirely surrounded by gneiss.

The linear extent of this belt from Antwerp to its probable end in Canton, is about thirty-five miles. Its width in a northwest-southeast direction is extremely variable. Beginning in Antwerp with an average width of about two miles, it expands rather suddenly to six or eight miles in Gouverneur, narrowing again as it passes out of this township to the northeast. Along the northern boundary of Gouverneur, gneiss appears in long, narrow strips, whose precise extent is uncertain; so that it is not clear whether or not the Gouverneur limestone belt is separated entirely from a large area which extends from Theresa, across Rossie and Macomb, and disappears under the Potsdam, in De Peyster. If distinct, these two belts can have only a very narrow strip of gneiss between them to the west, and the indications are that this disappears entirely in the vicinity of Yellow lake, in Rossie. Eastward, in De Peyster and De Kalb, a large area of gneiss comes in between the two limestone belts. The southern edge of the Gouverneur belt is more clearly defined, and an extensive area of gneiss separates it from the next belt to the south. The latter, which may be called the Edwards belt, begins in Fowler, crosses Edwards, and seems to run out in the western part of Russell. Its area is much less than that of the Gouverneur belt, but it is of economic importance on account of its talc deposits. This belt is quite sharply defined, although along its southern edge there is a rather confused mingling of limestone and gneiss, of much interest and deserving careful investigation. Another wide stretch of gneiss separates the Edwards belt from the Diana belt, which crosses the towns of Diana and Pitcairn with a width of about two miles. Directly southeast of this belt, that is, normal to the trend of the belts, the country has been examined for only a few miles, but to the south it has been traversed some thirty miles or more without the finding of any limestone. However, it is not certain that other belts may not exist in the forested region to the southeast, although facts to be stated below indicate that this is probably not the case.

These four belts, or, if the Macomb and Gouverneur belts be considered one, three belts, comprise a large proportion of the crystalline limestone of the region examined. The remainder is found in the scattered patches to which reference has been made. These occur both near, and at considerable distance from, the large belts, and range from less than a mile to several square miles in area. There is nothing to distinguish them from the larger belts except their limited dimensions, and they must be regarded as constituting a portion of the limestone series.

As to the character of the limestone in the various areas, it is scarcely necessary to speak here, descriptions having already been given in the papers above cited.* It is always highly crystalline, ranges in color from white to dark bluish grey, and often contains disseminated and aggregated silicates. Of these, the most important are serpentine, forming ophicalcite, and tremolite. The latter renders the rock more resistant to weathering, and sometimes is so abundant as to constitute a tremolite schist. The limestone contains a variety of gneissoid rocks, some of which are doubtless interbedded, while others are probably altered intrusives. These gneisses often show a great amount of contortion and crushing, as a result of the application of intense pressure. The limestone itself, on the other hand, presents a massive undisturbed appearance, with no indication of its subjection to pressure beyond the development of polysynthetic twinning—½R. Owing to the difference in the nature of the rocks they have been affected very differently by pressure, the gneiss having yielded by folding and fracture, the limestone by flow. It is quite possible, however, that a considerable amount of fracturing actually occurred in the limestone, but this has been obliterated by subsequent recrystallization.

In considering the small patches of limestone, a point which should not be overlooked is that, owing to the easy weathering of the rock, outcrops are more generally wanting than in the case of the surrounding resistant gneiss. For this reason, the real extent of these areas is probably often greater than it appears, while there are, doubtless, many such patches that have been entirely overlooked.

When the distribution of the limestones is viewed in a broad way, it becomes apparent that these rocks have their greatest development in the northwestern part of the region, decreasing as the eastern and southern parts of the county are approached. In the former district lie all of the extensive belts, while in the latter only scattered patches of limestone occur, gneiss being the prevailing rock. This relation is very marked and is probably persistent throughout this portion of the Adirondack region. There can be little doubt that the combined Macomb and Gouverneur belts constitute the most extensive area of crystalline limestone, and that the rock decreases rapidly in passing

* *Op cit* ; also, Transactions New York Academy of Sciences, XII., pp. 97-108 and 203-217.

southeastward into the heart of the region. Nevertheless, no fixed limit has been found in this section beyond which the limestone can be said not to extend. It does not disappear, but simply decreases, occurring in smaller and more scattered areas. If it were regarded as a distinct formation (a point to be considered later), it could not be mapped as constituting a clearly defined and continuous area, but would necessarily be represented in detached portions; and facts now at hand indicate that such portions occur scattered all through the Adirondacks. Hence the distribution of the limestone formation is, in a sense, co-extensive with that of the entire series of crystalline rocks comprised in the Adirondack region; and the task of mapping the limestone formation, be it called Huronian, as has been suggested, or, as preferred by the writer, by the local term Oswegatchie, involves the entire problem of the Adirondack geology. For to map the limestone formation, its geologic limits must be first ascertained, and this necessitates the determination of its relations to the associated rocks. In the case of the anorthosites and gabbros, this has been done, as well as for some minor developments of granite, etc. But the origin of the gneisses which cover the greater part of the western Adirondack region, and their relation to the limestone are, as yet, unsettled, and constitute a problem requiring careful study for its solution. If, from such study, it should appear that the limestones and gneisses together constitute a single series, it would make up the whole of the area comprised within this report, except where certain intrusive rocks occur, and would, indeed, with this latter exception, probably make up the entire Adirondack region. On the other hand, should the limestone and gneiss prove to belong to entirely distinct formations, it would be a simple matter to trace their boundaries. But, finally, should it be learned that some portions of the gneiss belong with the limestone in one formation, while other portions belonged in another formation, then, judging from experience in the field, it would become a very difficult matter to trace the boundaries of the formations, on account of the perfect gradations generally shown between different varieties of gneiss. The foregoing points were, in part, touched upon in a previous report, but it seems worth while to refer to them here, bearing, as they do, upon the whole question of aims, methods and results of geologic investigation in the Adirondack region. One fact may be safely premised, namely, that the different crystalline rocks of the region are so related to one another that the study of one involves, to a greater or less extent, the study of all, and the history of one portion can not be clearly stated without reference to other portions. This is, of course, meant to apply to the broader problems, and of these, one is certainly the distribution of the limestones and their relation to the other rocks.

The mere facts of distribution have been given above, their bearing upon the question of relation to other rocks will be considered in dealing with the relations of the limestones to the gneisses. This question requires, however, for its discussion, a previous consideration of the probable origin of the gneisses.

Origin of the Gneisses. From the foregoing it is evident that the gneisses afford the chief problem of the region. This problem is twofold, involving both the origin of the gneisses and their relation to the limestones. While these two questions are intimately connected, and facts bearing on one are often equally important in their relation to the other, it may be more convenient to consider them separately.

In the outset it should be stated that neither question is regarded as finally settled. It is often very difficult to procure data which bear definitely upon these questions, and as the rocks involved cover a great area, it is dangerous to generalize upon a basis of facts gathered in a small portion of the area. This difficulty has been somewhat reduced by the agreement of phenomena occurring at widely separated points, but it is, nevertheless, a real difficulty. In many cases, perhaps in most, no direct evidence is at hand, and it is necessary to reach conclusions by analogy. For these reasons, particularly on account of the limited amount of study as compared with the extent of the region, it is not deemed wise to state any very broad final conclusions, but merely to present such facts as seem to be of importance in their bearing upon the major problems of the region. What this bearing is, and to what conclusions the facts in hand seem to lead, must, of course, be stated; but the endeavor will be made neither to exaggerate the importance of the data, nor to deal with them dogmatically.

Without going into the history of opinion on the subject, it may be stated that the gneisses have generally been regarded as metamorphosed sediments, such parallel structures as they possess being considered as resulting from original bedding.

The term *gneiss* is here used in a very broad sense, embracing rocks having a wide variation in structure and composition. The chief value of the term, when used without any qualifying word, lies in its breadth, and this value largely disappears if the term is restricted to a rock having the composition of granite. Such a broad term is essential in the present discussion, not only on account of the lack of detailed investigation, but chiefly because the different varieties of rock included under it, so constantly shade into each other, or are so intimately associated as to render their precise differentiation difficult or impossible.

In composition, the rocks range from acidic, like granite, to basic, like gabbro. In structure they range from fine to very coarse, and from distinctly gneissoid, or even schistose, to entirely massive. The prevailing type, in the region here covered, is a fairly acid, light-colored rock, of medium or fine grain, and rather obscure foliation. It often looks as though its fine grain had resulted from a crushing of larger constituents. Other important varieties are: a coarse augen-gneiss and a porphyritic gneiss often extremely coarse, and nearly or quite massive. The dark-colored basic varieties seem to be much more limited in extent, the only large area noted being in South Russell. Brief accounts of some of these varieties have been given elsewhere, and need not be repeated, as such details as are necessary will be brought out in discussing the origin of the rocks.

When this latter question is considered, three possible explanations present themselves as being worthy of careful consideration. According to one of these, the gneisses are metamorphosed sediments; according to the second they are of ingneous origin; while the third comprises both of the others, regarding the gneisses as in part sedimentary and in part igneous.

Dealing with the internal evidence alone, the parallel structures of the gneiss afford the only support for the hypothesis of metamorphosed sediments. And when the evidence is examined it appears very weak, for, as a rule, there is only a foliation which could not be regarded as in any way connected with original bedding, but is clearly a secondary structure, and often very inconspicuous. Distinct banding that might represent original stratification is rare, and such bands as do occur are generally widely scattered and of limited extent, demanding, as shown below, a different explanation. Indeed, rather than showing pronounced banding, the rocks are very uniform in texture and composition over wide areas, and where they change, do so gradually. It may be safely stated that there is nothing in the structure of the gneiss as a whole, which demands, or even suggests, that it should be regarded as derived from a sedimentary formation. On the contrary, the complete absence of clastic structure, the lack of any trace of stratification, and the uniformity over wide areas are all opposed to such a view.

The chief support for this hypothesis is found in the limestone associated with the gneiss. This is doubtless a metamorphosed sedimentary rock and its presence in long belts, whose trend is parallel to the foliation of the gneiss, suggests that they may be parts of one great series. This idea is strengthened by the fact that on the borders of the gneissic areas, as the limestone is approached, the gneiss is often finely laminated and quite similar to narrow bands of gneiss which seem to be interbedded with the limestone. But these laminated gneisses between the massive gneiss and limestone have been found to be the exception, not the rule, as was formerly thought, and hence, are of little importance in this connection. As to the parallelism of the foliation of the gneiss with the strike of the limestone, it is a necessary result if the foliation is a secondary structure resulting from the same pressure that folded the limestone.

The alternation of broad belts of limestone and of gneiss, in the northwestern portion of the region, is suggestive of a sedimentary series, in spite of some peculiarities of distribution, difficult to explain; but the scattered patches of limestone occurring in wide areas of gneiss to the south and east, are difficult to harmonize with this view. It has been thought probable that the limestone was confined to the region of the extended belts, and that the associated gneiss might be distinct from that of the southern and eastern parts of the county. But, as shown above, the limestone has no such limitation, and there is nothing to distinguish the gneisses of the northern townships from those of the southern. They must be considered together, at least for the present, as one great formation, with the limitations and conditions cited below. It seems clear that if the gneisses of the northern towns belong to the limestone series, those of the southern towns do as well. On the other hand, if the latter do not, neither do the former. The reasons, so far as the relations of the two are concerned, for regarding the gneisses as part of the limestone series having been stated, it must be admitted that they are extremely inadequate. On the other hand, the gneisses themselves, with the exception of limited areas, lack every characteristic of a sedimentary series. Thus, both lines of evidence fail almost completely to establish the sedimentary origin of the gneisses. Nevertheless, the mere absence of proof that they are sedimentary cannot be taken as proving that they have not this origin. For it is entirely possible that the absence of proof results from extreme metamorphism, and the evidence sought for might be found at any time, provided that some other origin can not be established. This latter condition leads to the consideration of the second hypothesis named above: that of *derivation of the gneisses from igneous rocks.*

Taking up first, as before, the internal evidence bearing upon the question, there are certain characteristics of the gneisses that are of importance. They form wide areas between belts of sedimentary rocks, but themselves, as above stated, showing no trace of sedimentary origin. On the contrary, they show the uniformity of character that might be looked for in plutonic rocks, together with the gradual variation so common in rocks of this class. Such parallel structures as appear in the gneisses have been shown to have nothing in common with the bedding of a sedimentary series, while they are precisely such structures as appear in plutonic rocks as a result of pressure, or of flow before solidification.

Sections of the widespread, fine, light-colored gneiss show it to consist of orthoclase, plagioclase, and quartz, with mica, hornblende or pyroxene. Either feldspar may predominate, and microperthite is nearly always present. As a rule, the ferro-magnesian minerals are in small amounts. With the exception of the quartz, the constituents are in grains, which often appear to have resulted from the granulation of larger grains, that is, the structure is cataclastic and the original rock must have been a coarse, holocrystalline aggregate, such as is typically afforded in the class of plutonics. Such a rock under pressure would yield the gneisses, and at many points the latter pass by insensible gradation into such a rock. That they have been derived from it by pressure is clearly indicated. In some cases this massive core is a coarse, evenly granular aggregate, in others it is more or less distinctly porphyritic. The latter is perhaps the most common type, forming considerable and widely distributed areas. The case is analogous to that of certain gneisses of Canada, in which, as shown by Adams,* the cataclastic structure is usually accompanied by other indications of an igneous origin; while, in the same region, gneisses lacking this structure are thought to be derived from sediments. The fact that a gneiss is formed by crushing of a coarse holocrystalline aggregate does not prove its igneous origin, as this aggregate may have been formed by crystallization of sediment. But in the absence of distinct proof of the latter supposition, the probabilities favor the former; and if all other kinds of evidence lead in the same direction, the cataclastic structure may be regarded as an important indication of igneous origin.

The role of the quartz in the gneisses requires some special consideration, being, as above indicated, somewhat exceptional. Quite often the mineral shows the effect of crushing less than do the other constituents. While they are in small rounded grains, the quartz is often in large masses or long spindles. As the quartz could hardly flow while the feldspar fractured, the conclusion is obvious, and seems to be well grounded, that, in the case of the quartz, there

* American Journal of Science; (III) L., pp. 58 to 69.

has been crystallization after the production of cataclastic structure in the rock. While in many cases the quartz was probably an original constituent and has recrystallized; in others, it is doubtless secondary, the gneiss being more acid than the parent rock. The microscopic details upon which these conclusions are based need not be stated here.

Where the cataclastic structure is lacking, the gneisses have the holocrystalline granular structure of plutonic rocks, the grain varying considerably, and, in the coarse varieties, porphyritic structure being particularly common. Rapid variations of grain are often shown by the coarse porphyritic varieties, fine phases coming in quite irregularly, forming bands and masses with the aspect of the common, fine gneiss. They lack, however, the crushed aspect, and appear to be primary variations. The microscopic study necessary to determine this point has not yet been undertaken. The same localities often show the passage from the massive into the finely laminated crushed gneisses, the transition sometimes occurring within a few feet. It often happens that the passage from a coarse, massive, to a fine, well laminated gneiss is attended by a darkening of the color.

But in other cases, where the coarse, light-colored gneiss occurs with a fine dark-colored variety, there is good reason for believing that a different relation exists between the two. In instances of the latter kind, the fine gneiss is usually cut by abundant granitic veins, which wander irregularly through the rock, with a tendency to follow the foliation if it is at all marked. At the same time, the acid gneiss contains masses of dark rock of great variety of form and size, and, in every respect like inclusions in an igneous rock. That such they really are scarcely admits of a doubt, and all uncertainty is removed where, as has happened in several instances, an irruptive contact is found between the light and the dark gneiss. Such phenomena point to two conclusions: first, all parts of the gneiss are not of the same age; and secondly, the massive, porphyritic gneisses are certainly in part, probably entirely, of igneous origin, being younger than, and intrusive in the fine, dark, gneisses. These facts, however, shed no light upon the origin of the latter variety.

The inference above drawn, as to the true nature of the porphyritic gneisses, becomes important in its bearing upon the general question in hand, when it is remembered that these rocks themselves make up a not inconsiderable part of the gneissic areas, and, moreover, that much of the finer gneiss is probably derived from them.

As regards these finer gneisses, there is a series of facts analogous to those described in the coarser rocks, so far as the inclusions are concerned. At many widely separated points, the fine pink and grey gneisses have been found to contain masses of very dark, rather fine rock. As it seemed probable that these masses might have some bearing on the problem in hand they were examined with care, and in many cases were sketched, or photographed. They may, for convenience of discussion, be divided into two groups: long narrow bands, and irregular masses.

The bands vary in width from a few inches up to two feet or more, and may be some rods in length. They are seldom, however, continuous for any such distance, being divided into segments, evidently at one time continuous but now separated by masses of gneiss, from a fraction of an inch to several feet in width. To form these segments the bands have been broken squarely across, so that the blocks have a nearly rectangular or a rhomboidal outline. The dark rock of the bands is usually imperfectly gneissoid, with foliation parallel to the sides of the bands. Sometimes little fractures or gashes extend into the bands from either margin, and are filled with the material of the surrounding gneiss. Often several of these bands occur close together, when they are usually parallel with each other, as they nearly always are with the foliation of the gneiss. The filling of narrow cracks and veinlets in the bands is often coarser than the surrounding gneiss, but as these become broader, and adjacent blocks are more widely removed from each other the filling material becomes identical with the normal gneiss.

Several explanations may be suggested for the presence of these bands, and these may be briefly considered. In the first place, they may be regarded as indications of bedding in the gneissic series, in which sense they were alluded to above. But their limited and irregular occurrence, as well as their slight extent and sudden termination along the strike oppose this view. Other objections will appear in speaking of the next supposition. According to the latter, the bands are dikes intruded in parallel groups, and broken up by subsequent pressure. At first sight this is a very plausible view, but it seems to be completely negatived by the peculiar separation of the bands into distinct blocks. Such blocks might result from faulting, but, in this case, no faulting has occurred; while, if the dikes had been separated by stretching, the resultant blocks would have a tapering, elliptical shape, totally different from that they show. It is impossible to believe that under pressure the dikes would break into blocks, which would retain a rectangular outline, while the surrounding solid gneiss, under the same pressure, flowed around them. This happens, as shown above, in the case of limestone and gneissic layers, but in the present case the rocks involved are too much alike to permit the acceptance of such an explanation. This objection holds good against the first supposition—that of interbedded layers.

The possibility of the black bands being segregations in an igneous rock is, for the typical cases, excluded by their form, although it may be applicable to some occurrences. There remains the supposition that the black bands are fragments of an older gneiss, included in a gneiss of igneous origin. This explanation is the only one that appears to be in harmony with the facts, and free from serious objection. According to it, the bands owe their shape to their breaking from the parent mass, as they would, in the direction of least resistance. Their occurrence in groups is just what would naturally follow from such an origin, and the same is true of the irregular scattering of these groups. The parallel arrangement of the neighboring bands doubtless results from currents in the molten magma, which would tend to produce such a result. It is probable that the breaking into blocks resulted, in part, from strains applied after the magma was in a pasty and partially crystallized state. The blocks were more or less widely separated, and the intervening space was filled by the magma, which flowed around the blocks without destroying their angular contour, and, at the same time, often produced an obscure flow-structure in the gneiss, parallel to the sides of the inclusions. The fine fissures and cracks were filled with the more acid portions of the magma, which were last to crystallize, and were strained into these cracks, producing the coarser pegmatitic veins. These minor details, are not, of course, in the least essential to the explanation, although suggested by the phenomena observed in the field. The supposition as a whole accounts for the facts stated, and has, as yet, no strong evidence against it.

The irregular black masses occur in much the same way as do the bands, differing only in form and size. They are sometimes nearly circular, or elliptical, but more often extremely irregular, with an outline marked by projections, and deep embayments. They often attain dimensions much greater than those of the bands. The foliation is often pronounced, quite commonly more so than in the surrounding gneiss. The two foliations, that of the black masses and of the gneiss, range from parallel with, to perpendicular to each other. Where the included mass is decidedly elongated in one direction, this is usually parallel to the foliation of the surrounding gneiss. The foliation of the gneiss sometimes follows the sides of the black masses, as though it had flowed around them, and not infrequently, narrow, irregular embayments in the blocks are filled with gneiss showing this structure parallel to the sides.

To account for the masses as anything but inclusions in an igneous rock, is even more difficult than in the case of the bands. All of the phenomena point to this origin, while they present great difficulties in the way of any other explanation. It would seem, then, that at many widely separated points the gneiss contains masses that can hardly be explained as anything other than inclusions of some older formation taken up by the gneiss when it was in a molten state. At some points the evidence is much more decisive than at others, and while in the more obscure occurrences other explanations might suffice, in the typical cases the one offered seems to be demanded.

From the foregoing it is apparent that the gneiss affords considerable internal evidence bearing upon the question of its origin, and all of the evidence points in one direction. To sum up briefly: there is the negative evidence of the absence of all structures pointing to sedimentary origin; there is the uniformity of composition and structure over wide areas, with changes by gradual transition; there is the common occurrence of massive cores, in every way identical with plutonic rocks, and the presence of structures in the gneiss that would result from the application of pressure to such rocks; there is the existence of irruptive contacts between the abundant light-colored gneiss and the less common, and older, dark gneiss, together with the widespread instances of inclusions of the dark gneiss in the light.

While no one of these lines of evidence might be regarded as conclusive, it is believed that, leading as they all do in one direction, their cumulative force is great.

There still remains the external evidence bearing upon the problem; and as this involves the relationship between the gneiss and the limestone, this latter problem must of necessity be considered.

The absence of any sufficient reason for regarding the gneiss and the limestone as portions of one series has been already pointed out. If distinct, the gneiss is either older or younger; and in the former case the relations of the two formations would shed no light upon the origin of the gneiss, while in the latter they might afford important evidence.

No facts are at hand which prove conclusively that any part of the gneiss belongs to a series older than the limestone, but this mere absence of evidence can not be regarded as excluding the possibility of the presence of such an older gneiss series, for, in the nature of the case, positive evidence is difficult to secure. As already reiterated, there is also no evidence that any considerable part of the gneiss is of the same age as the limestone; while many facts are opposed to this supposition. As to the third supposition, that the gneiss is, at least in part, younger than the limestone, there is positive evidence, and of such a nature as to give, at the same time, abundant proof as to the origin of these portions of the gneiss.

An example of this kind in Pitcairn and Diana has been previously described, and need be only briefly referred to here. A large area of plutonic rock, in some parts gabbroitic, in others syenitic or granitic, forms the southern boundary of the limestone belt between Natural Bridge and Harrisville. The igneous nature of the rock is shown not only by its composition and structure, but also by the fact that it is clearly intrusive in the limestone, cutting it along a very irregular line with the production of well defined contact zones containing a variety of minerals.

The plutonic rock is often slightly gneissoid and in thin sections generally shows more or less cataclastic structure. Passing south and west from its boundaries these features rapidly increase and the rock becomes a reddish gneiss of medium grain. In itself there is no important feature to distinguish this gneiss from other gneisses, its only exceptional feature being its evident identity with the large area of plutonic rock intrusive in the limestone. Here then, is an important area of gneiss, for which the two chief problems are solved; it is a modified plutonic rock, and is younger than, and intrusive in the limestone. No other instance has been found where the phenomena are exhibited on so extensive a scale, but facts similar in kind have been noted at several points.

In the paper just referred to, it was stated that the southern border of the gneiss area between the Edwards and Pitcairn limestone belts, was composed chiefly of rocks undoubtedly igneous and intrusive in the limestone. An effort has been made to ascertain the relations on the northern edge, and in the one contact found between the two formations similar phenomena were observed. The locality is about three-fourths of a mile south of the village of Edwards. Here the gneiss is of the ordinary, rather fine type, which is so widespread. Its relation to the limestone is clearly shown, and it is seen to break through the latter formation with a most irregular irruptive contact. As in the case of the Pitcairn rocks, there is pronounced contact-metamorphism resulting in a formation of zones composed largely of coccolite, together with feldspar, scapolite, etc. This locality differs from the first described, in that it is the gneiss itself, and not the parent plutonic rock, which is in contact with the limestone. About two miles south from this locality, towards the centre of the gneiss area, the road crosses a small patch of limestone only a few rods square, entirely enclosed in gneiss. It would be difficult to account for this as anything but an inclusion in an igneous rock, and that it is such, is further indicated by the fact that it is filled with contact minerals. Thus, the gneiss area between the Edwards and the Pitcairn limestone belts shows evidence on both its northern and southern boundaries, as well as towards the centre, that it is in part of igneous origin and intrusive in the limestone. The character of the gneiss throughout the area is such as to render it highly probable that this is true of the greater part of the rock.

About two miles east of the village of Colton, near the town line of Colton and Parishville, the gneiss and limestone are shown almost, but not quite, in absolute contact. The structural relations are not such as to suggest conformity but rather the reverse, while near the contact the limestone is cut through and through by a pegmatitic intrusion. A characteristic contact zone is present, showing coccolite with titanite, tremolite, etc., and the pegmatite contains irregular masses of the same composition, doubtless inclusions of altered limestone. The position of the pegmatite is such as to suggest that it may be a secretion of a plutonic magma represented by the adjacent gneiss, and this idea is greatly strengthened by the fact that the gneiss itself contains coccolite masses precisely like those in the pegmatite, and very difficult to explain as anything but inclusions of altered limestone. The phenomena here are not conclusive but have value in connection with the facts shown at other localities. Within a mile north of this point there are several recurrences of structural relations suggesting intrusions, but showing no contacts. At one point, however, which must be almost, if not exactly, on the contact, limestone is shown with abundant large crystals of altered pyroxene, with other products characteristic of contact action. An analogous case is shown in Hermon, where, though no actual contact is shown, there is, just on the line where the gneiss and limestone should meet, a mass of scapolite, pyroxene and other contact minerals.

The gneiss area north of Gouverneur village shows phenomena somewhat similar to those near Colton. No contact is shown, but the limestone in the neighborhood of the gneiss is often broken through by pegmatite. In this case the limestone shows little or no alteration, but the pegmatite itself becomes rich in titanite near the contact. The gneiss of this area also shows abundant examples of the black inclusions, and of passage into wholly massive phases.

The absence of any marked metamorphism of the limestone at its contact with the pegmatite, is a feature observed at a number of localities in the case of granites, and is of importance as showing that the mere absence of contact products can not be taken as proving an absence of igneous intrusions. An instance of importance is afforded in northern Rossie, where an area of rather massive gneiss is clearly intrusive in the limestone, while the latter shows no change, unless, perhaps, a slightly coarser grain than usual. The gneiss, however, is, like the pegmatite of Gouverneur, rich in titanite near the contact. In the same vicinity, some two miles north of Rossie village, a rather dark, fine rock, in part massive and in part a gneiss, breaks through the limestone with an irregular irruptive contact. At some points along the line of contact, the metamorphism is confined to a zone not more than an inch wide, while at other points great masses of pyroxene, scapolite, apatite, mica, etc., are found, constituting an important mineral locality. The great variation in the amount of metamorphism at different points does not seem to depend upon any corresponding variation in the nature of the rocks involved. A probable cause may be suggested as afforded by an uneven distribution of moisture, the great masses of contact products being formed along channels affording a favorable transmission for heated solutions, and, in some cases, doubtless for gases as well.

The two localities just described not only illustrate the variability in the degrees of metamorphism but also afford further examples of gneiss, igneous in origin and younger than the limestone. The development of large masses of minerals in the last case naturally suggests the possibility that other mineral localities of the region may show similar relations. As a matter of fact, the association of minerals at many of these localities is such as to lead to the inference that they have been formed by contact metamorphism. In the case of the well-known localities east of Natural Bridge this was found to be true, and at many other points similar relations are suggested, although the structure is not so clear.

Numerous pits from which minerals have been collected in quantity have been visited, and in nearly every case they have been found to be opened on, or close to, the contact between gneiss and limestone. Pyroxene, amphibole, scapolite, feldspar and titanite are the common minerals, an association which, taken with their mode of occurrence, is highly suggestive of contact metamorphism. In most cases examined the gneiss is not part of an extensive area, but is rather limited and more like a sheet. For this reason it often has the appearance of being interbedded, thus making the structural relations doubtful. But, as bearing upon this, it should be said that it is a very general rule in the region that intrusions of limited extent tend to assume a form decidedly elongated in the direction of the strike, and, as a result, often have the appearance of being interbedded, even where the facts clearly show their intrusive nature.

The relations between the gneiss and the granite intrusive in the limestone must be considered in connection with the question under discussion. In the previous report it was stated that the granite often becomes very gneissoid, so much so that in some cases it can be distinguished only by its relation to the limestone. On this account no effort was made to separate granite from gneiss in the large areas of the latter. As the gneiss has been more carefully studied, the fact has appeared that much of it is quite as massive as the granite, and decidedly more so than the gneissoid phases of the latter. No petrographic distinction can be made between the massive gneisses and the granite, a fact of much importance in the present connection, for it at once leads to the inference that the granites may be offshoots of the gneiss, affording another indication of the origin and age of the latter. The existence of granitic areas in the gneiss was not doubted in the previous report, but it was felt that they might be of minor extent and importance, and so it was stated that the explanation of the great gneissic areas as intrusive must be employed with caution.

In addition to the facts enumerated above, many cases have been observed where the structural relations of the gneiss and limestone are highly indicative of the intrusion of the former, although the outcrops do not suffice to prove conclusively such a relation.

The data presented in the foregoing necessitate the following conclusions: All parts of the gneiss are not of the same age; some portions, of large extent, are of igneous origin; of these igneous gneisses part, at least, are younger than the limestone. These conclusions are merely the statement of what is clearly and definitely proved; but, with the facts in hand, some more general inferences seem to be entirely justified. Indeed, in the case of extensive areas of the gneisses, positive evidence as to their origin and relation to other rocks will probably never be found, and the problems can be solved only by inference and analogy. Keeping in view what has been stated in regard to the rocks, their uniformity, gradual transitions, massive phases, inclusions, irruptive contacts, etc., scattered over widely separated areas, it would seem that the following inferences may be drawn as, at least, extremely probable:

The gneisses constitute a complex series of rocks, differing somewhat in age, and largely, if not almost wholly, of igneous origin; parts of this series are clearly younger than the limestones, and while other parts may be older than the latter formation, there is nothing as yet to prove that such is the case. An exception to the latter statement is probably afforded by certain laminated gneisses of limited extent, which appear to underlie the limestone, perhaps marking the base of the series. This relationship, is, however, inferred rather than proved.

If these inferences are correct, the task of mapping involves the tracing of the limestones together with such minor portions of gneiss as belong with them; and, so far as possible, the differentiation of the gneisses upon a chronological and petrological basis. As regards this latter part of the work, it is questionable whether, in many cases, any very sharp distinctions can be made out, or definite lines of demarkation laid down, as the nature of the rocks seems to be such as to preclude anything but rather broad generalizations. It may be, however, that under careful study the present difficulties will become less, and greater accuracy be attained than now seems probable. Much that is now obscure will, without doubt, become entirely clear when the whole area is studied with all possible care and detail. Such a general reconnaissance as has been made serves only to prepare the way for this more detailed study, indicating the problems involved, and sometimes pointing to their probable solutions. The region is certainly deserving of such careful examination as will lead to the preparation of an accurate geologic map.

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

(GEOLOGICAL MAP.)

REPORT ON THE GEOLOGY OF CLINTON COUNTY.

JAMES HALL, *State Geologist.* | H. P. CUSHING, *Assistant.*

1895.

James Hall, *State Geologist*,

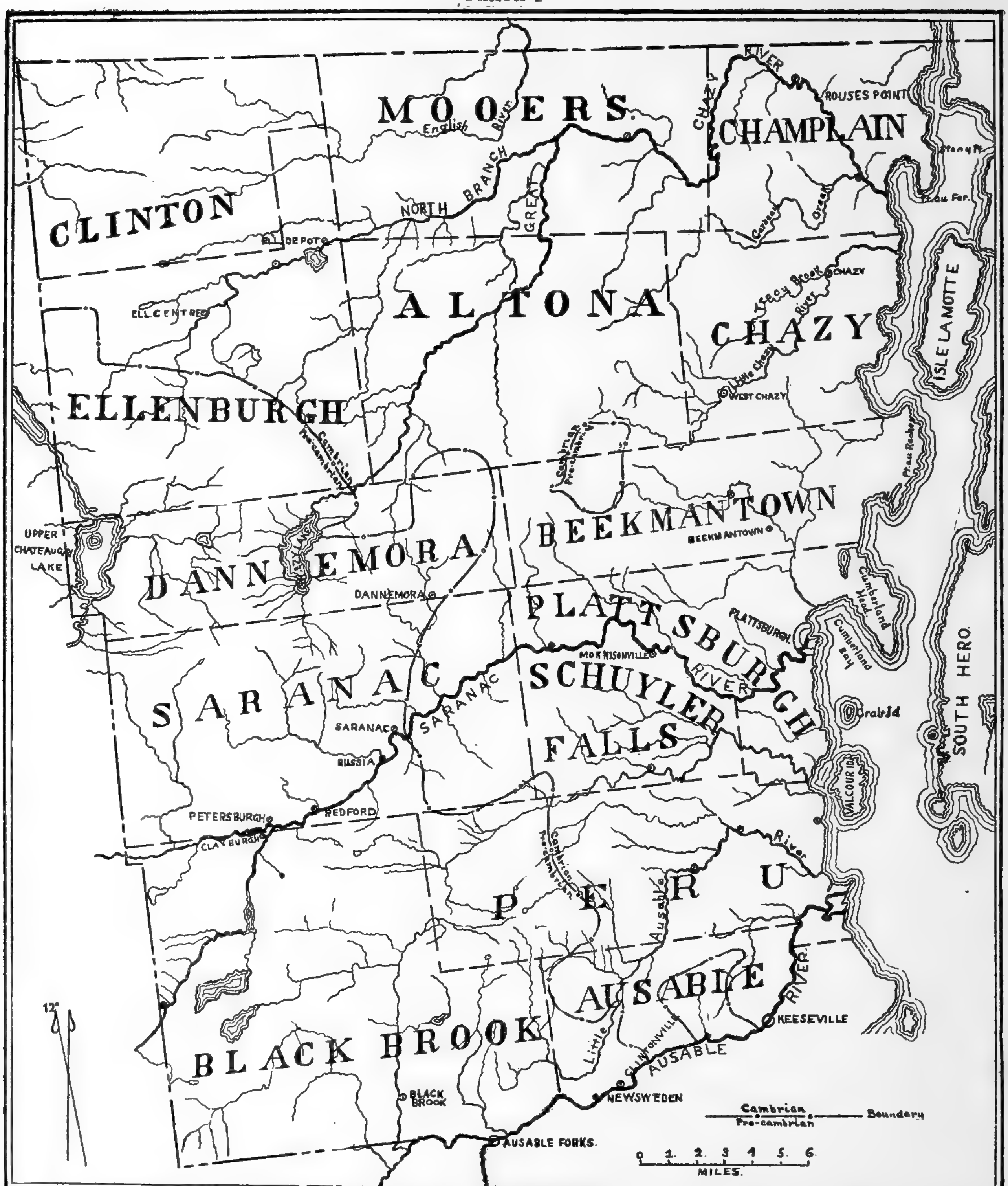
Sir:—Herewith I submit a report upon geologic investigations prosecuted by me in Clinton county.

Respectfully yours,

H. P. CUSHING.

Western Reserve University, *May* 15, 1896.

PLATE I



MAP OF CLINTON COUNTY; SHOWING THE BOUNDARY BETWEEN THE CAMBRIAN AND PRECAMBRIAN FORMATIONS

Report on the Geology of Clinton County.

By H. P. Cushing.

The field work the general results of which are presented in this report, was done during the field seasons of 1893–'94–'95, about four weeks during each being devoted to the work. On the last two occasions, Mr. M. L. McBride, of Cleveland, at his own expense, accompanied the writer as assistant and rendered valuable service. During 1895, a week was spent with Messrs. Gilbert van Ingen and T. G. White, of Columbia College, in inspecting the best exposures of the Ordovician limestones in the county, and Mr. van Ingen's palaeontologic ability was of great service in making clear some perplexing points in the stratigraphy.

The entire county has been traversed and mapped, but only in a general way, the desideratum being the acquisition of a good general knowledge of the district before attempting the detailed work which will be necessary for the proper elucidation of the perplexing problems which have arisen. Furthermore, no good, or even fair maps exist of the greater part of the county, so that, until such are available, it is useless to attempt closer work. A beginning has, however, been made in the detailed mapping of the palaeozoic rocks along lake Champlain, which is necessary in order to fully bring out the structural features, and it is the present expectation to continue this as opportunity offers.

Since the report of Professor Emmons, over fifty years ago, practically nothing has been published on the geology of the county except the beautiful bits of mapping and sectioning done by President Brainard and

Professor Seely. In addition to what they have published, President Brainard writes me that they have mapped the lake shore southward from Plattsburgh. It is hoped that this map will soon be published.*

TOPOGRAPHY.

Clinton is the extreme northeast county of the state of New York, lake Champlain forming the eastern, and the Dominion of Canada the northern boundary. Its area is approximately 1,093 square miles. It lies entirely within the St. Lawrence drainage basin, sloping for the most part to the northeast. Close to the Franklin county line, and nearly parallel with it, ranging northward from Upper Chateaugay lake is a pronounced watershed, west of which the drainage is into the Chateaugay river and thence northward, while east of it the streams flow to the northeast and east. Of the larger streams emerging from the northern Adirondacks, the Saranac and Great Chazy rivers flow clear across the county, while the Ausable forms part of its southern boundary.

Topographically the county is separable into three well marked divisions:

1. A hilly or somewhat mountainous southwestern portion, occupying something over one-third of the county, constituting a part of the northeastern Adirondacks and characterized by their conformation; in other words composed of massive ridges trending northeast and southwest, with intervening steep-sided valleys of very variable width. Occasionally the ridges trend east and west. They commonly have a rather gentle slope on the north side, which is deeply drift-covered and heavily timbered, the rocks seldom protruding above the surface; while on the south the slopes are steeper and often precipitous, exhibiting frequent vertical cliffs of considerable height. The highest elevations in the county are Lyon mountain, 3,809 feet, and Catamount mountain, 3,168 feet. The valleys are for the most part heavily drift-filled, with rock exposures only along the larger streams. They sometimes expand into quite wide parks and are not infrequently occupied by lakes, of which Chazy and Upper Chateaugay lakes in Dannemora, and Silver lake in Black Brook, are the most noteworthy.

2. A high-level plain, beneath which the knobs of the older rocks are submerged, and which extends into embayments between their outlying ridges. It has a maximum elevation of about 1,500 feet along its boundary

* Since the above was written the map and description have appeared. See Bulletin American Museum Natural History, Vol. VIII., 1896, pp. 305-310. The results agree with those obtained by the writer.

with the hilly tract, and slopes thence gently northward to the brink of the St. Lawrence valley. The surface rock throughout in this county is the Potsdam sandstone which lies nearly horizontal, having but a slight northerly dip, so that its descent is not greatly in excess of the average surface fall. The covering of glacial material is widespread but mostly confined to the depressions, and the numerous, often large, marshy tracts testify to its irregularity.

The streams draining northward across the plain have for the most part not channelled it very deeply since the close of the glacial period, on account of the horizontal attitude of the rocks and their resistant character. During the late Tertiary, the plain was much dissected by the drainage, but even then the valleys were relatively narrow, the present summits of the plain consisting of comparatively wide table lands of sandstone instead of narrow ridges and mounds. The new maps cover a portion of this plain in Mooers and Altona and indicate that these summits represent portions of an earlier base level, now tilted to the north.

3. A low strip along the lake, ranging from the lake level to an altitude of 300 feet on its western border, and increasing in breadth going north. From the 300 foot to the 500 foot level, the rise is quite abrupt, especially in Chazy township, and the topography strongly suggests a fault, raising the Potsdam on the west some hundreds of feet above that on the east, and marking the boundary between the low strip and the high plain. Further to the south, the heavy Pleistocene deposits largely obliterate this contrast. This low strip is greatly dissected by faults, and to their presence its minor topographic features are largely due. The fault lines are occupied by marshes or small streams, while between them ledges of rock project at all angles in a seemingly haphazard and at first, quite bewildering fashion.

Throughout this low strip the main streams quite generally follow their pre-glacial channels. The Saranac and Great Chazy rivers have channelled out considerable valleys in the drift and are now widening them. The Great Chazy river is in its pre-glacial channel throughout the low strip, exposing nothing but drift in its banks. At Mooers village it leaves the old channel for a short distance, and thence up-stream this frequently happens, but this channel belongs topographically to the high plain. The Saranac is out of its old course at the pulp mill, two miles above Plattsburgh, thence keeps to its old valley till Cadyville is reached. Here a considerable gorge has been cut in the Potsdam, but this is beyond the confines of the low strip.

The smaller streams, the Little Chazy, Salmon and Little Ausable rivers are wholly or mainly in post-glacial channels, and give little clue to the minor pre-glacial drainage. Such part of the county as is most suitable for agricultural purposes is mainly confined to this strip, and on it are many fine farms.

GENERAL GEOLOGIC RELATIONS.

Professor J. F. Kemp has recently published a resumé of the schemes of classification which have been proposed for the rocks of the Adirondack region, to which he has added a tentative one of his own.*

This, which comprises:

(I.) A basal gneissic series.

(II.) A series of schists and gneisses with crystalline limestone.

(III.) Igneous rocks of the gabbro type.

(IV.) Palæozoic sediments, lying unconformably on the first three.

(V.) Igneous rocks found as dikes cutting all the foregoing, and

(VI.) Pleistocene deposits;

will be followed in this report, emphasis being laid on the fact that it is tentative, and probably simpler than the one finally adopted is likely to be. The writer has elsewhere given reasons for holding that this scheme must be expanded by the insertion of another period of dike formation between (III.) and (IV.).†

As exposed in Clinton county these subdivisions may be epitomized as follows:

Series I. The oldest rocks visible so far as known belong to a great series of gneisses and are well shown in all the western tier of townships except Clinton, and in Peru and Ausable. In their typical development they are easily recognized. They present well-marked varieties, as below, all of which seem to grade into one another.

1. Gneisses, commonly of red color, but also grey, brown, and other shades, composed mainly of microperthitic orthoclase and quartz. Occasionally these are the only constituents, when the gneissoid structure retreats and a red granite rock results which seems to be merely a phase of the gneiss. There has not yet been found in the county a granite which can be shown to be intrusive in the gneiss, like that described by Smyth in St. Lawrence and Jefferson counties.‡ More commonly one or more of the minerals magnetite,

* J. F. Kemp, Report New York State Geologist for 1893, Vol. I., pp 444-447.

† H. P. Cushing, Transactions New York Academy of Sciences, Vol. XV., pp. 248-252.

‡ C. H. Smyth, Jr, Transactions New York Academy of Sciences, Vol XII., pp 208 to 212.

plagioclase feldspar, microcline, biotite, hornblende and titanite are present in varying amounts, and small apatites and zircons are almost universal. Locally a green augite also appears, but this is not a common occurrence in this county. With the appearance of the more basic minerals the foliation of the rock becomes apparent and increases in prominence as they increase in abundance. Sometimes the quartz retreats and locally may be entirely lacking. An increase in plagioclase frequently accompanies this change, so that the rock grades from a quartz-orthoclase into a plagioclase gneiss, often without making any noticeable difference in the external appearance of the rock.

2. Widely exposed in Black Brook township are gneisses of quite different appearance, and, judging from published descriptions of the Adirondack gneisses, of an unusual type. For the most part they are very finely granular, but alternate with numerous, often broad, coarse, pegmatite-like bands. The fine-grained rock is of a prevailing lavender-grey or lilac-grey tint, showing, when freshly broken, small, brilliant cleavage faces of feldspar. It is quite free from basic minerals, hence foliation is not especially apparent. The coarse rock is not unlike similar coarse bands in the ordinary gneisses, but is more abundant here, alternating regularly with the other. There are also present occasional thin bands of a basic gneiss weathering with a rusty hue.

In thin sections, both the coarse and fine varieties are seen to be made up mainly, and often wholly, of microcline and quartz, the microcline having almost universally a markedly microperthitic habit. Apatite is seldom absent, and often abundant. Plagioclase and microperthitic orthoclase are frequently present, sometimes in considerable quantity, and some slides show small amounts of magnetite, biotite and hornblende, these being more plentiful in the coarse bands.

Closely associated with these gneisses are others which, outwardly, more nearly resemble the ordinary gneiss, and which have plagioclase for their most prominent constituent, together with microcline, orthoclase, quartz, magnetite and ferro-magnesian silicates in varying amounts. By their distribution the impression is created that through them the microcline gneisses grade into the ordinary orthoclase gneisses.

These microcline gneisses are in rather close juxtaposition to an area occupied by the limestone series, and perhaps should be classed with that. The thin bands of rusty basic gneiss interfoliated with them resemble gneisses of that series rather more closely than they do the basic bands in the ordinary gneisses. Aside from that indication the field evidence does not lean strongly in either direction.

3. Interbanded with the other gneisses, dark, basic gneisses occur, ranging from an inch to many yards in thickness, and always parallel to the foliation of the enclosing gneiss. They vary much in grain, but in general are rather coarse, and are distinctly schistose in habit. When studied in thin sections they at once separate themselves into two sharply contrasted varieties, the one having the mineralogy of diorite, the other of gabbro. These gabbroic bands are so precisely like the more basic portions of the gabbro masses shortly to be described, that they should unquestionably be classed with them and will be noted in their proper place. The other, and more common variety is composed of plagioclase and hornblende with smaller, but quite constant amounts of orthoclase, biotite and magnetite. Microcline is sometimes present. Quartz may appear in small quantity, and in some instances is found as inclusions in the plagioclase, and there only. Some of these gneisses also carry much green augite along with the hornblende, producing an intermediate rock between the dioritic gneisses and the gabbros. In one specimen there is, instead of augite, a considerable content of an orthorhombic pyroxene which is regarded as bronzite, the pleochroism and double refraction being much weaker than in the ordinary hypersthenes of the region. Measured extinction angles indicate an andesine ranging toward labradorite as the common feldspar.

As has been stated, the mineralogy of the rock is that of a diorite, or, in some cases, of a gabbro-diorite, and its eruptive origin is regarded as highly probable.

The gneissic series contains the workable deposits of magnetic iron ore.

Series II. The rocks of this series consist of coarsely crystalline limestones associated with certain peculiar gneisses and schists quite unlike any members of Series I., and with other gneisses which closely resemble those of that series. But one belt occupied by these rocks exists in Clinton county, so far as known, and in that the exposures are few and meagre so that little knowledge of the group can be obtained here, and the reader is referred to Professor Kemp's descriptions of the numerous better exposures in Essex county.* The Clinton county exposures are in Black Brook township and will be described under the geology of that area.

Series III. This series is constituted of rocks of the gabbro family, which are unquestionably of igneous origin and were intruded into the members of the first two series. The main development of the rocks of this

* J. F. Kemp. Bulletin Geological Society of America, Vol. VI., pp. 241–262; and Annual Report New York State Geologist for 1893, Vol. I., p. 444

group in the Adirondacks, is in Essex county, where they have a greater areal extent than all the other rocks combined, but they pass beyond the borders of that county on all sides. Three outlying areas of this group occur in Clinton county, none of which has been heretofore recognized as belonging to it. The first of these is in Ausable township, extending north and west of Keeseville, and is the direct prolongation northeastward of a great gabbro ridge which comes up to Keeseville from the southwest. The second forms Rand's hill in Beekmantown and Altona townships, is twenty miles north of the last, and interesting as carrying the known Adirondack exposures by that distance nearer to the Canadian; further connecting links, if any, being concealed by the covering of the later rocks beneath which they pass. The third area forms the Catamount mountain ridge in southwestern Black Brook, and Professor Kemp's work during the past season indicates that the Whiteface massive, just over the border to the southwest, is a prolongation of the same. The Catamount mountain exposures are difficult of access, and have not been so thoroughly studied on that account; but the rock, while a little abnormal, is unmistakable gabbro.

In their typical development the Adirondack gabbros, like those of eastern Canada, consist almost wholly of plagioclase feldspar, mostly labradorite, but ranging to anorthite, and to this very feldspathic phase Dr. F. D. Adams has applied the name anorthosite. As the peripheries of the masses are approached, ferro-magnesian silicates appear in increasing quantity, and ultimately the gabbros may become very basic, titaniferous magnetite, augite and sometimes hypersthene being present in large quantity, together with garnet, hornblende and biotite, these latter being largely, if not wholly, secondary. With the appearance of these minerals comes almost always a gneissoid structure in the rock.*

Though the Clinton county gabbro areas are of comparatively slight extent, quite typical anorthosite may be collected from each, occurring in close association with basic gabbro. Sometimes the ordinary gabbro contains narrow bands of a quite basic character, of such persistence and with such sharply defined walls that they closely imitate dikes in appearance. It is more especially such bands as these, or larger masses of the same character, that are quite identical with the bands already mentioned as occurring as basic gneisses in the gneiss series, and which are to be regarded as dikes or apophysae of the main gabbro intrusion which penetrated the gneiss from the parent

* For full descriptions of some phases of the gabbros, see F. D. Adams, Neues Jahrbuch für Min., Vol. VIII., pp. 419-497; J. F. Kemp, Bulletin Geological Society of America, Vol. V., pp. 213-224.

body. When not too finely granulated these basic gabbros show a tendency to the assumption of ophitic structure. Such consist of coarse plagioclase and nearly colorless pyroxene, both extraordinarily full of minute inclusions, embedded in a granular matrix, in large part constituted of secondary minerals, garnet, biotite, hornblende and hypersthene with or without quartz. The feldspar and pyroxene were apparently crystallizing at the same time, for, while the feldspar is frequently idiomorphic against the pyroxene, it also frequently includes the latter, while the reverse has not been observed to occur. These varieties commonly show beautiful reaction rims around the magnetites, similar in all respects to those described by Professor Kemp in the Port Henry gabbro.

Series IV. Unconformably overlying the older crystalline rocks is a group of great thickness of nearly unchanged sedimentary rocks of Cambrian and Ordovician age, which hides the older rocks from view over two-thirds of the county. Unfortunately exposures are not always all that could be desired, and in regard to a small part of the group the stratigraphy is not clear. The whole is seriously in need of thorough palæontologic study, which could not fail to furnish results of great interest and value. The group commences at the bottom with the Potsdam sandstone, and terminates with the Utica slate. No criteria have been found, by means of which an older quartzite series can be discriminated from the Potsdam, as urged by N. H. Winchell for northern New York.* The quartzites and quartz schists of the Grenville series of Canada seem wholly or largely lacking in the eastern Adirondacks, though they may occur on the west. Furthermore, they are an integral part of the series. In the absence of fossil evidence, no division of the Potsdam seems possible in Clinton county, though it is far from certain that the whole is of Upper Cambrian age.

It is by no means impossible that rocks representing the Lorraine stage of the Hudson river group have been deposited on the west side of lake Champlain, but nothing younger than the Utica slate has yet been discriminated.

Potsdam sandstone. The Potsdam is widely exposed in the county, forming the rock surface in two townships and a large part of it in three others. Out of the fourteen towns making up the county, there is but a single one (Black Brook), in which this formation is wholly wanting. It is also found at very varying altitudes. At Coopersville and in the Ausable chasm it is close to the level of the lake, and at the former place the horizon

* American Geologist, October, 1895, p. 207, and Twenty-first Annual Report of Geological Survey of Minn., pp. 99 112.

PLATE II

South face of Silver Lake mountain, showing its precipitous character.

PLATE III

Great Chazy river at Thom's corners; showing Potsdam sandstone in stream bed and bank of till.

is unquestionably near the summit of the formation. In Dannemora it is found at an elevation in the neighborhood of 1,500 feet, and in Ellenburgh, Beekmantown and Altona it runs nearly as high. Here, moreover, it is the base which is exposed.

The color is very varied, from white through various greys, yellows, browns and reds to even blackish appearing layers. Occasionally greenish layers, appearing somewhat glauconitic, occur. In general the reds prevail in the lower beds and are scarce above. The blackish varieties appear to be characteristic of the summit.

The main mass of the formation is made up of quite pure quartz sand. In the basal layers there is a large feldspathic content, mostly orthoclase, but with a little plagioclase and microcline. Occasional grains of pyroxene and hornblende and scales of biotite appear. In some layers zircon is prominent. Garnet has not yet been noted. The basal conglomerates are often very rich in magnetite. Toward the summit, dolomitic layers appear, regularly alternating with those of pure sand, and forming passage beds to the Calciferous above. Sometimes these are of pure dolomite, but prevailingly they are sandy, and the rather large rounded grains of quartz embedded in a fine mosaic of minute dolomite crystals furnish a striking combination in thin section. These dolomitic beds are not, however, confined to the higher layers, but occur sparingly elsewhere, even among red beds well toward the base, strata of such an appearance that it would scarcely occur to one to test them with acid; in fact, the presence of these layers was first made known by thin sections.

When the base of the formation is neared, massive conglomerates become prominent, sometimes attaining great coarseness. They are commonly interstratified with finer red, feldspathic, easily weathering beds, which are much permeated with hematite. It is a curious fact that the materials of which these basal conglomerates are made up are, so far as observed, always of gneissic origin, even when the contacts are with gabbro and a considerable distance from known gneissic outcrops.*

Along the lake these basal beds are seldom exposed, the contacts shown being largely brought about by faults, but on the north they have great prominence, especially in Ellenburgh (as noted by Emmons†), where they have considerable thickness, but by no means make up the whole mass, as stated by him.

* See description of a conglomerate near Keeseville on a following page.

† E. Emmons.—Geology of New York, Second District, p. 309.

A noteworthy characteristic of this formation in the county, is the occurrence of quite pebbly layers at numerous horizons from the bottom to the top. The pebbles are almost invariably of quartz. At the base a few of orthoclase are mingled with them.

The various layers of the rock show great variation in their resistance to weathering. While the major part of the mass is well indurated and very durable, there are many layers in which the induration is much less, and which disintegrate quite rapidly to a coarse white sand. The most unstable portions are the red beds already mentioned as intermingled with the lower conglomerates. These have a large content of orthoclase derived from the gneisses, are permeated with hematite whose origin is uncertain, and break down rapidly to a red, hematitic, sandy clay, which is a very conspicuous feature along some of the roads.

The absolute thickness of the Potsdam hereabouts has not been determined with certainty. As it was deposited on an uneven, probably very uneven, floor, and as this floor was subsiding at the same time, its original thickness must have varied much from place to place. The thickest section susceptible of accurate measurement in the county, is that on the Ausable river where, according to Mr. C. D. Walcott, there is a thickness of 350 feet, with the base and summit not seen.* The impression conveyed by the widespread exposures in the northern part of the county is that the total thickness can scarcely fall short of 2,000 feet, and is quite likely much more. The possible presence of faults increasing the apparent thickness, renders it impossible to speak more definitely. If such are not present, the Potsdam is unquestionably more than 2,000 feet thick.

While it has been impossible to make an exhaustive search for fossils, a sharp lookout has been kept for them, and considerable time spent in the quest; yet none have been found except along the Ausable, where their presence has long been known. The Upper Cambrian age of the higher portion of the Potsdam has been shown, but there is as yet a complete lack of palæontologic evidence as to the age of the lower part.

The Calciferous sandrock. Rocks belonging to this division are spread over a considerable area in the tier of townships along the lake, but are unfortunately so concealed by Pleistocene deposits that the Potsdam-Calciferous boundary is almost completely obscured, and the Calciferous exposures are often disappointing, though excellent sections are exhibited in Beekmantown and Peru. Professors Brainard and Seely have carefully studied the

*C. D. Walcott, Bulletin 81, United States Geological Survey, p. 343.

Calciferous of the Champlain valley,* and their section at Shoreham, Vt., gives to the formation, which they separate into five subdivisions, a thickness of 1,800 feet. How large a part of this thickness the Calciferous possesses in Clinton county, can not be determined, but commonly the different exposures are correlated without difficulty with the various members of Brainard and Seely's section. The basal layers of the formation are shown in Champlain township, conformably overlying the Potsdam. In Peru and Beekmantown are good exposures of the higher and more fossiliferous members. The lower half or two-thirds is made up largely of grey, often sandy dolomites, quite barren of fossils. In the upper third, beds of limestone are mingled with the dolomite, and some sandy beds, weathering with thick yellow sandy crusts, also occur.

Chazy limestone. At Chazy village is the type section of this group which follows the Calciferous in ascending order. Brainard and Seely have, however, shown that the lower one hundred feet is lacking here and that the Valcour Island section is more complete.† Besides the excellent exposures in Chazy township the rocks of this group are also well shown in part just north of Plattsburgh, and on Bluff Point, two miles south of Plattsburgh, extending thence to the south into Peru, where the lower part of the formation is better shown than at any other point in the county on the mainland.

Brainard and Seely have recognized three subdivisions of the Chazy rocks, and their detailed section at Chazy village is reproduced on a later page. The lower subdivision is largely constituted of quite crystalline limestones of grey color, often full of crinoidal fragments and with *Orthis costalis* the most abundant fossil; the middle division is of blue-black fine-grained limestone and contains *Maclurea magna* at nearly all horizons; the upper division is quite variable in character, but is largely composed of somewhat impure blue limestones, carrying *Rhynchonella plena* abundantly.

The aggregate thickness of the Chazy limestone at Chazy village is 740 feet, with the base not shown. On Valcour Island, Brainard and Seely give it a thickness of 890 feet, and there it seems to reach its maximum.

For the most part these rocks are easy of recognition, and even small exposures may be assigned to their proper position without great trouble. There is a considerable quarry enterprise engaged in working the rocks of this group, some beds furnishing an ornamental marble, some a rough building stone, and some being burned for lime.

* Bulletin American Museum of Natural History, Vol. III., No. 1, p. 3.
† Bulletin Geological Society of America, Vol II, pp. 293 to 300.

Black River limestone. The massive dark-colored beds of this rock are well exposed at numerous points in Chazy, directly overlying the Chazy limestone; but outside of this township it is not well exposed. It has a thickness of thirty to fifty feet and is a brittle, black limestone with conchoidal fracture. *Columnaria alveolata* is its most characteristic fossil, but is here confined to a single stratum a few feet thick, at about fifteen feet above the base. Above this is a zone with abundant large Maclureas and large masses of *Stromatocerium*, both of which are closely like the corresponding forms in the middle division of the Chazy, so that, unless care is taken, the two may be confounded, as was done by the writer in one or two instances. On smoothed, mere surface exposures the resemblance is very striking.

Trenton limestone. In Chazy and Plattsburgh townships are excellent exposures of portions of the Trenton. In the bed of the river just east of Chazy village, 150 feet are exposed lying on the Black river limestone. On Crab island, about 200 feet in thickness is exposed, the larger part of which is above the horizon of the beds at Chazy, while the lower fifty feet corresponds to the upper part of that section. The two together give a thickness of about 300 feet, but the summit is not shown. The faunas are being studied by Mr. T. G. White. In general the lower half is characterized by a brachiopod fauna, some bands being crowded with shells of *Leptæna sericea* and *Orthis.*

The upper one hundred feet of the Crab island section holds a lamellibranch fauna, with cephalopods and trilobites, while between the two is a zone with a sparse trilobitic fauna.

This lower portion of the Trenton is mainly made up of black, ringing, somewhat slaty limestone, the different layers presenting much variation in the latter respect.

In northeastern Plattsburgh, and extending into southeastern Beekmantown, occurs a series of black, quite slaty, calcareous rocks, which are excellently exposed on Cumberland Head. As there exposed they have had developed in them a slaty cleavage at a high angle with the bedding, which has already been described.* In Beekmantown this is not so pronounced, but is present. No base nor summit to these slates is exposed, and the stratigraphic evidence concerning their position is not decisive, but points strongly to their being of Trenton age, or, rather to their not being older than the Trenton. As the Chazy and Crab island sections furnish us with the basal 300 feet, and as there is an unknown vertical interval between the two, these

* H. P. Cushing. Report of New York State Geologist for 1893, vol 1, p. 483.

slates must be well up in the Trenton. It will be impossible without prolonged study to arrive at a just estimate of their thickness here. The apparent thickness on Cumberland Head is very great; but there are also evidences there of much disturbance, and it is strongly probable that there is repetition. In addition to the evidence afforded by the slaty cleavage, one or two faults are plainly visible in the slates, and the topography strongly suggests others. Yet, taking all these things into consideration, 200 feet would be a very modest estimate of the thickness here displayed, and double, or even treble that amount would most likely be much nearer the true figure. The entire Trenton in this vicinity, therefore, must be very thick. The writer had the pleasure of conducting Mr. van Ingen to Cumberland Head, and to the exposures of these same slaty rocks in Beekmantown, and since the above was written a letter has been received from him giving the results of his study of their fauna. He pronounces the horizon to be high up in the Trenton, and with features in common with the "Quebec group" of Canada, so that it may turn out to be more nearly allied to the Utica slate than to the Trenton limestone; that is, the Utica as represented in Canada.

Utica slate. On Stony Point, in Champlain township, is an exposure of black, ringing, much-jointed calcareous slates, the joints largely filled with crystalline calcite, which carry the ordinary fauna of the New York Utica slate, *Triarthrus Becki*, *Climacograptus bicornis* and other graptolites, and *Endoceras*. With the exception of this single exposure, shut in on the east and north by the lake, and on the west and south by a marsh along a line of fault, no rocks known to be later than the Trenton limestone occur in the county. The Utica slate is also exposed on the east side of Isle la Motte.

Series V. The various types of dike rocks occurring in the lake Champlain district have been described at length by Kemp and Marsters,* and would need little mention here were it not for the fact that their study in Clinton county has emphasized certain facts regarding their distribution, which are not so apparent in Essex county and along the lake.

The dikes are readily separable into two classes; black, basic dikes of the varieties known as diabases, camptonites, monchiquites and fourchites, and lighter-colored acidic dikes, closely approximating the same type, and known as bostonites, the term being applied to the dike-form of feldspar porphyries or trachytes.

The acidic dikes known in Clinton county (twelve have so far been found) differ considerably from the typical bostonites as found and described

* Bulletin 107, United States Geological Survey.

by Kemp from along the lake.* Those have a prevailing light tint, creamy or brownish white or chocolate, and nearly or entirely lack magnetite and ferro-magnesian silicates. The Clinton county dikes, on the contrary, are either red or mottled dark red and black, or purplish grey in color (one is nearly black), and with one exception contain considerable amounts of one or more of the minerals, magnetite, biotite, hornblende and monoclinic pyroxene in the ground-mass, and dike No. 9 even has porphyritic biotite. Some of them have a pseudo-schistose appearance. Most of them have porphyritic orthoclase, and this mineral makes up the main portion of the rock. The ground-mass has a trachytic structure, most marked around the phenocrysts. In these last two respects they agree with the typical bostonites, and they are not necessarily more basic because of the greater prominence of bisilicates, so that they are regarded as bostonites varying somewhat from the type, and seem to represent an intermediate stage between these type bostonites and the "granite" dikes described by Marsters from lake Memphremagog.†

Professor Kemp, some time ago, called attention to the fact that the basic dikes are more numerous in the Pre-Cambrian rocks than in the Palaeozoic series,‡ and further, in discussing the relations of diabase and camptonite, to the confining of the diabases to the former, and of the typical camptonites to the latter rocks. Many of the diabases of the region, however, grade strongly toward camptonites and augite-camptonites, and in two instances of this sort in Clinton county, the dikes are very narrow and seem almost certainly to be off-shoots from large dikes of typical diabase near by, recalling the camptonite apophysae from a laccolite of diabase described by Brögger.

The diabase dikes are found abundantly throughout Clinton county wherever the Pre-Cambrian rocks are exposed. The camptonites, monchiquites and fourchites seem to decrease in number north of Port Kent, and north of Plattsburgh are wholly lacking, in so far as negative evidence can be depended upon. This peculiarity of distribution, coupled with the fact that all along the northern line of contact between the Potsdam and the older rocks in the county the diabase dikes are found numerously on one side of the line and not at all on the other, has led the writer to elsewhere express the opinion that there were two periods of dike formation in this vicinity,§ one preceding and one following the deposition of the Palæozoic rocks of Series IV. The diabase dikes belong to the earlier, and the bostonites,

* These differences have been noted by A. S. Eakle, who described the first bostonite known in the county. American Geologist, July, 1893, pp 32 and 33

† V. F. Marsters, American Geologist, Vol. XVI., pp. 25-29.

‡ Bulletin 107, United States Geological Survey, p. 27.

§ H. P. Cushing, Transactions New York Academy of Sciences, Vol. XV., pp. 248-252.

monchiquites, fourchites and camptonites to the later period; though on account of the facility with which the diabases and camptonites shade into one another, it may not always be possible to determine to which of the two a given dike in the Pre-Cambrian rocks should be referred.

The diabase dikes are very common and widespread. Scarcely an outcrop of any extent of the Pre-Cambrian rocks can be found without disclosing the presence of one or more of them. But, as was to be expected, their distribution is irregular, as they are only occasional in certain areas, whereas others are fairly seamed with them. Sometimes a veritable plexus of dikes is exhibited, anastomosing in all directions, enclosing great horses of the country rock, and so variable from place to place that no satisfactory generalized measurements can be made. The most notable example in the county is in southeastern Altona township, where the Old Military road crosses the northeast spur of Rand's hill. Cutting the gabbro here is a grand exhibition of dikes, which will be more fully described under the discussion of that township.* Another striking exhibition of dikes is found along the west shore of Upper Chateaugay lake, and yet another on Dannemora mountain.

Appended is a tabulated list of the dikes found in the county by the writer. Kemp has noted the occurrence of others in the Lyon mountain iron mines, and two from Palmer hill, and three others have been described by Eakle.

* See E. Emmons. Natural History of New York, Geology, Part II., p. 28.

No.	Township.	Locality.	Width.	Strike.	Walls.	Name.	Remarks.
5	Altona	First gneiss exposure on edge of Rand's hill by turnpike, going northwest. School district No. 5	3 ft. ±	N. 80° E.	Gneiss	Diabase	....
6	Altona	West of road, 30 yards south of No. 5	3 ft. 6 in.	N. 80° E.	Gabbro	Diabase	Quite decomposed.
7	Altona	By-road, 110 yards north of No. 5	2 ft. 7 in.	S. 80° E.	Gabbro	Bostonite	Porphyritic. Has considerable hematite and some chlorite. Is faulted for its own width.
8	Altona	Begins 140 yards beyond No. 7, east of road	40 ft. +	N. 60° E.	Gabbro	Diabase	Dike described on page 565. For a width of 150 yards the gabbro is all split up by its branches.
9	Altona	10 yards north of No. 10, showing on east side of road	10 ft. 3 in.	N. 60° E.	Gabbro	Bostonite	Phenocrysts of orthoclase and biotite. Much biotite, some apatite and diopside in ground-mass. Trachytic structure not well marked.
10	Altona	Where lane up Rand's hill leaves turnpike, not far south of School No. 5	8 ft 4 in.	N. 60° E.	Gabbro	Diabase	Faulted 4 feet at the road.
11	Altona	⅛ mile northwest of schoolhouse, 40 yards south of small stream along Gabbro-Potsdam contact	5 ft. 2 in.	N. 50° E.	Gabbro	Diabase	Much decomposed.
12	Altona	20 yards north of No. 11 and somewhat nearer the road	15 ft.	N. 50° E.	Gabbro	(?)	Not a dike, but a shear-zone in the gabbro.
13	Altona	A little southeast of No. 11, on the east side of road	8 ft. ±	S. 80° E.	Gabbro	Olivine diabase	Coarsely porphyritic. A dike plexus of several branches, the whole occupying a width of 75 ft.
14	Altona	50 feet north of No. 15	6 ft. ±	N. 65° E.	Gabbro	Olivine diabase	A variable dike plexus instead of a single dike.
15	Altona	At School No. 5	2 ft. 10 in.	S. 80° E.	Gabbro	Olivine diabase	Porphyritic olivine, augite and plagioclase phenocrysts.

No.	TOWNSHIP.	LOCALITY.	WIDTH.	STRIKE.	WALLS.	NAME.	REMARKS.
16	Altona	¼ mile up lane, ascending Rand's hill, just south of school-house................	8 ft.	N. 75° E.	Gabbro	Diabase.........	....
17	Altona	120 yards further up lane.....	4 ft. 10 in.	N. 60° E.	Gabbro	Diabase.........	In three branches, two of them of 1 foot each.
18	Altona	8 yards north of Dike No. 7 ...	3 ft. 8 in.	S. 80° E.	Gabbro	Diabase.........	Decomposed.
68	Au Sable......	Back of Mr. Keese's house....	5 ft. 9 in.	S. 15° E.	Gabbro	Diabase.........	Has two parallel branches each 15 in. wide. Approaches augite camptonite.
69	Au Sable......	Extreme northeast part of gabbro area.....................	3 in.	S. 80° E.	Gabbro	Diabase.........	....
72	Au Sable......	¼ mile southeast of School No. 5, west of Keeseville, and 100 yards south of road.....	3 ft.	N. 80° E.	Gabbro	Diabase (?)......	Highly decomposed.
75	Au Sable......	Near road at toll gate, ¾ mile east of Dike No. 76	1 ft. 9 in.	N. 60° E.	Gabbro	Olivine diabase .	Porphyritic; much decomposed.
76	Au Sable......	River bank at big bend, 2¼ miles west of Keeseville, close to river road; Sec. 20.......	3 in.	N. 70° E.	Gabbro	Diabase.........	Porphyritic.
77	Au Sable......	200 yards northeast of Dike 78	2 ft.	N. 60° E.	Gneiss	Diabase.........	....
78	Au Sable......	Close by river road just east of Clintonville	2 in.	N. 65° E.	Gneiss	Diabase.........	....
79	Au Sable......	½ mile north of Clintonville, just west of road	3 ft. 6 in.	N. 50° E.	Gneiss	Diabase.........	Amygdaloidal; much biotite and some brown hornblende in ground-mass.
80	Au Sable......	100 yards north of first house on road north of Clintonville	6 ft. 5 in.	N. 60° E.	Gneiss	Olivine diabase .	Porphyritic.
105	Au Sable......	Back of Mr. Keese's house, not far from No. 68	2 ft.	S. 30° E.	Gabbro	Diabase.........	A network of small branches bearing in all directions.

No.	Township.	Locality.	Width.	Strike.	Walls.	Name.	Remarks.
27	Beekmantown.	Northwest part of School district 7, ½ mile west from road	20 ft.	E.	Gneiss	Bostonite	Very large orthoclase phenocrysts; augite, hornblende and biotite in ground-mass.
28	Beekmantown.	Rand's hill, near Mr. Sanger's	6 ft.	S. 75° E.	Gabbro	Bostonite	Contains sparse augite phenocrysts, and a small amount of hornblende in the ground mass.
29	Beekmantown.	40 yards north of No. 28	1 ft. 10 in.	E.	Gabbro	Bostonite	12 feet exposed at the surface; the east half is faulted 6 ft. to the south. Contains magnetite and hornblende.
30	Beekmantown.	Not far from last	(?)	(?)	Gabbro	Diabase	Highly decomposed, and poorly exposed.
31	Beekmantown.	Near Mr. Golden's	1 ft.	N. 80° E.	Gneiss	Bostonite (?)	Contains much biotite and green hornblende, and appears very basic for a bostonite. Has orthoclase phenocrysts.
103	Beekmantown.	Near summit of road, 3 miles south of Jericho	3 ft. 9 in.	S. 80° E.	Gneiss	Bostonite	Considerable magnetite and numerous small green hornblendes in ground-mass. Excellent flow structure.
104	Beekmantown.	Close to Dike No. 27	(?)	(?)	Gneiss	Diabase (?)	Badly decomposed and not well exposed.
81	Black Brook	200 yards north of School No. 6, ½ mile west of Au Sable town line	1 ft.	S. 10° E.	Gneiss	Diabase	Approaching augite camptonite. Two small branches found, both pinching out.
82	Black Brook	First dike in gneiss exposure just east of Au Sable Forks along railroad	10 in.	N. 60° E.	Gneiss	Diabase	Closely approaching augite camptonite.
83	Black Brook	150 yards east of No. 82	2 ft. 6 in.	N. 65° E.	Gneiss	Diabase	Where seen was in four divisions.
84	Black Brook	Several rods east of No. 83	6 ft.	N. 65° E.	Gneiss	Diabase	Porphyritic; very fresh material to be obtained.

No.	Township.	Locality.	Width.	Strike.	Walls.	Name.	Remarks.
85	Black Brook ..	At east end of gneiss outcrops along river, just east of the Forks	6 ft.	N. 55° E.	Gneiss	Diabase	Many included horses of gneiss.
86	Black Brook ..	By road just north of Black Brook village, east side of brook	1 ft.	N. 20° E.	Gneiss	Olivine diabase	Large augite phenocrysts; quite fresh.
87	Black Brook ..	Just north of fork in road, a few rods south of No. 88	9 in.	S. 35° E.	Gneiss	Diabase	Closely approaching augite camptonite.
88	Black Brook ..	By road, where outlet of Slush pond enters Black brook	2 ft.	N. 65° E.	Gneiss	Diabase	Similar to No. 89, and probably a branch of that.
89	Black Brook ..	7 yards south of No. 88	(?)	N. 65° E.	Gneiss	Diabase	....
90	Black Brook ..	A few rods west of Mr. Fitzgerald's; Sec. 46	7 ft.	N. 65° E.	Gneiss	Diabase	Porphyritic.
92	Black Brook ..	¾ mile west of Clayburgh, a few yards south of road	4 in.	S. 85° E.	Gabbro	Diabase	Greatly decomposed.
93	Black Brook ..	By south branch of Saranac river, on west bank, ¼ mile above junction with west br.	2 ft. 6 in.	N. 65° E.	Gneiss	Diabase	Badly decomposed.
94	Black Brook ..	In Boyne ore-bed near Williamsburg	(?)	(?)	Gneiss	Olivine diabase	From dump. Not seen in place.
19	Crab Island ...	South end of island in loose blocks	(?)	(?)	Trenton limestone.	Fourchite	Amygdaloidal. Augite in two generations, with biotite and magnetite; olivine infrequent; no hornblende; analcite.
20	Dannemora ...	In wall of pit back of Clinton prison	1 ft. 8 in.	N. 70° E.	Gneiss	Diabase	Large plagioclase phenocrysts.
24	Dannemora ...	First dike seen by road over Dannemora mountain, ¾ mile north of Dannemora	4½ in.	E.	Gneiss	Diabase	Much decomposed.
21	Dannemora ...	50 yards north of No. 24	15 in.	N. 80° E.	Gneiss	Bostonite	Considerable magnetite, but no ferro-magnesian silicates.

No.	Township.	Locality.	Width.	Strike.	Walls.	Name.	Remarks.
22	Dannemora ...	100 yards north of No. 21	2 ft. +	E.	Gneiss	Diabase.........	....
23	Dannemora ...	Over ½ mile north of No. 24, and 25 rods north of No. 25......	4 ft. 2 in.	N. 55° E.	Gneiss	Diabase (?)	Very much decomposed.
23a	Dannemora ...	10 ft. north of No. 23..........	9 in.	N. 55° E.	Gneiss	Diabase.........	Presumably a branch.
25	Dannemora ...	Near summit, 25 rods south of No. 23	6 ft. (?)	E.	Gneiss	Bostonite	Porphyritic orthoclase; considerable biotite and hornblende.
26	Dannemora ...	Northwest of road on west side of lower end of Chazy lake....	15 ft.+	E. (?)	Gneiss	Olivine diabase .	Seams the gneiss in all directions for a width of 50 feet. Porphyritic augite.
46	Dannemora ...	Roadside east of creek at Lyon mountain village	20 ft. (?)	N. 55° E.	Gneiss	Diabase.........	Dark-colored: much hornblende and biotite as inclusions; some hornblende secondary after augite; apparently some plagioclase.
50	Dannemora ...	Just beyond west end of ore-pit close to Lyon mountain depot	3 ft. 6 in.	N. 50° E. (?)	Gneiss	Diabase.........	Does not fault the ore.
51	Dannemora ...	17 yards west of No. 50.......	(?)	N. 50° E. (?)	Gneiss	Diabase.........	Compass readings affected by the ore-body.
52	Dannemora ...	200 yards west of No. 51	6 ft. 10 in.	N. 50° E. (?)	Gneiss	Olivine diabase .	....
53	Dannemora ...	Near south end of Chateaugay railroad cut on hillside at head of Upper Chateaugay lake......................	6 ft.	E.	Gneiss	Diabase.........	....
54	Dannemora ...	9 yards north of No. 53	2 ft. 1 in.	N. 15° E.	Gneiss	Diabase.........	....
55	Dannemora ...	85 yards north of No. 54	5 ft.	N. 70° E.	Gneiss	Diabase.........	....
56	Dannemora ...	55 yards north of No. 55	11 in.	S. 80° E.	Gneiss	Olivine diabase .	....
57	Dannemora ...	75 yards north of No. 58	5 ft.	S. 80° E.	Gneiss	Diabase.........	Decomposed.
58	Dannemora ...	300 yards north of No. 56	2 ft. (?)	N. 85° E.	Gneiss	Diabase.........	Decomposed.

No.	Township.	Locality.	Width.	Strike.	Walls.	Name.	Remarks.
59	Dannemora ...	At boat house, Indian Point hotel	4 ft. 7 in.	N. 80° E.	Gneiss	Diabase.........	Dikes 59 to 67 are all shown on the west shore of Upper Chateaugay lake. It is uncertain which two Mr. Eakle described.
60	Dannemora ...	17 yards south of No. 59	2 ft. 3 in.	N. 80° E.	Gneiss	Diabase.........	Much like No. 59.
61	Dannemora ...	200 yards north of No. 59	2 ft. 6 in.	E.	Gneiss	Diabase.........	Porphyritic.
62	Dannemora ...	20 yards south of No. 61	2 ft.	E.	Gneiss	Diabase.........	....
63	Dannemora ...	30 yards north of No. 61	3 ft. 6 in.	N. 80° E.	Gneiss	Diabase.........	Porphyritic. Similar to No. 61.
64	Dannemora ...	25 yards north of No. 63	3 ft.	N. 75° E.	Gneiss	Diabase.........	Like No. 61.
65	Dannemora ...	20 yards north of No. 64	3 ft.	S. 80° E.	Gneiss	Diabase.........	Porphyritic.
66	Dannemora ...	30 yards north of No. 65	2 ft. 5 in.	N. 70° E.	Gneiss	Olivine diabase .	Approaching camptonite; idiomorphic hornblende in ground-mass.
67	Dannemora ...	Quite a distance north of 66, at a club house nearly opposite Ralph's	9 in.	E.	Gneiss	Diabase.........	Dikes 59 to 67 are all shown on the west shore of Upper Chateaugay lake. Two of them were described by Eakle, but which two is not certain.
49	Ellenburgh ...	East side of road south from Webster's, opposite Mrs Hewitt's, nearly 2 miles from Webster's	1 ft. 6 in.	N.	Gneiss	Olivine diabase .	Porphyritic feldspar and olivine; quite fresh.
48	Ellenburgh ...	¾ mile south of No. 49, near by-road on east side	7 in.	N. 15° E.	Gneiss	(?)	Cataclastic structure; either a sheared dike or shear-zone in gneiss.
47	Ellenburgh ...	30 yards south of No. 48	15 ft.	S. 75° E.	Gneiss	Diabase.........	....
95	Ellenburgh ...	2 miles west of Webster's, near road	30 ft.	N. 70° E.	Granite	Bostonite	Numerous large orthoclase phenocrysts; considerable green hornblende in the ground-mass.
96	Ellenburgh ...	A few yards south of No. 95...	2 ft.	N. 70° E.	Granite	Diabase.........	Very fresh; augite quite pleochroic.

No.	Township.	Locality.	Width.	Strike.	Walls.	Name.	Remarks.
97	Ellenburgh ...	On south side of West hill, close to the road near Mr. Secor's	2 ft. 5 in.	E.	Gneiss	Diabase........	Grades into augite camptonite; is faulted.
98	Ellenburgh ...	120 yards north of No. 97	3 ft.	N. 80° E.	Gneiss	Olivine diabase .	This and the succeeding three are very similar, somewhat amygdaloidal.
99	Ellenburgh ...	160 yards north of No. 98	3 ft.	N. 70° E.	Gneiss	Olivine diabase .	....
100	Ellenburgh ...	75 yards north of No. 99	15 ft.	E.	Gneiss	Olivine diabase .	....
101	Ellenburgh ...	25 yards north of No. 102	5 ft.	N. 65° E.	Gneiss	Diabase........	Porphyritic feldspars of large size; branches of very variable width.
102	Ellenburgh ...	¼ mile southwest of Star P. O.	3 ft.	S. 75° E.	Gneiss	Diabase........	In four branches of 3 ft., 2 ft., 2 ft. and a few inches respectively.
2	Peru	In first field south of Day's quarry, near lake........	4 ft.	S. 70° E.	Chazy limestone...	Camptonite	Not fresh.
3	Peru	80 rods south of No. 2, in field between road and lake......	3 ft.	N. 80° E.	Chazy limestone...	Monchiquite	Considerable olivine; some biotite and brown hornblende in the ground-mass in addition to augite.
44	Peru	North slope of Terry mountain, ½ mile south of Ormsbee's house	7 in.	N. 15° E.	Gneiss	Diabase........	Probably a branch of 45.
45	Peru	Close to No. 44	1 ft. 6 in.	S. 85° E.	Gneiss	Diabase........	Faulted twice within a few feet.
71	Peru	A few rods back of Eell's house	3 ft. 10 in.	N. 60° E.	Gneiss	Diabase (?)	Highly decomposed.
70	Peru	⅛ mile south of No. 71........	4 ft.	N. 10° E.	Gneiss	Diabase........	Is faulted 4 feet.
73	Peru	By road north of east edge of Mount Etna	10 ft. (?)	N. 60° E.	Gneiss	Diabase........	Decomposed.

No.	TOWNSHIP.	LOCALITY.	WIDTH.	STRIKE.	WALLS.	NAME.	REMARKS.
74	Peru	About the centre of School District No. 11..............	17 ft. (?)	N. 70° E.	Gneiss	Olivine diabase .	Approaching camptonite; porphyritic and fresh; idiomorphic brown hornblende and biotite in the ground-mass; is in eight divisions averaging 5 yds. apart.
1	Plattsburgh...	By road from Plattsburgh to Bluff Point, 125 yards north of Bluff Point railway station	5 in.	S. 80° E.	Chazy limestone ..	Monchiquite	Abundant olivine; quite fresh material may be obtained.
4	Plattsburgh...	Toward south end of Trenton exposures along lake just north of Bluff Point	2 ft. 9 in.	E.	Trenton limestone.	Fourchite.......	Olivine seldom; little biotite, but no hornblende; much analcite.
32	Saranac.......	Just north of road east of Saranac village, near Saranac bridge	10 ft.+	S. 80° E.	Gneiss	Bostonite	Contains considerable green biotite.
33	Saranac.......	Just east of Russia, north of road........................	4 ft.	S. 40° E.	Gneiss	Diabase.........	Much decomposed; gneiss is brecciated along contact.
34	Saranac.......	By the Saranac river, 40 rods above the High falls	5½ in.	N. 80° E.	Gneiss	Diabase.........	....
35	Saranac.......	20 yards south of No. 34	3 in.	N. 80° E.	Gneiss	Diabase.........	Two divisions, one of 2 in., the other 1 in.
36	Saranac.......	100 yards east of first bridge over True brook, by the roadside.....................	(?)	S. 80° E.	Gneiss	Diabase (?)	Only fragments close to the gneiss are preserved, showing glass with microlites.
37	Saranac.......	40 yards south of No. 36 by the brook	6 ft.	N. 85° E.	Gneiss	Diabase.........	Considerably decomposed.
38	Saranac.......	½ mile west of first bridge over True brook..................	3 ft.	N. 85° E.	Gneiss	Diabase.........	Decomposed; much epidote in the slide.
39	Saranac.......	10 yards west of No. 38	3 ft. 4 in.	N. 85° E.	Gneiss	Diabase.........	Decomposed.
40	Saranac.......	Just west of third bridge over True brook..................	9 ft.+	N. 80° E.	Gneiss	Olivine diabase .	In three divisions, the largest 7 ft. 2 in.

No.	Township.	Locality.	Width.	Strike.	Walls.	Name.	Remarks.
41	Saranac	A branch of No. 40	2 ft. 2 in.	N. 80° E.	Gneiss	Olivine diabase	Typical; quite fresh, even the olivine being partly unchanged; porphyritic augite and olivine.
42	Saranac	80 rods west of No. 40	2 ft. 4 in.	N. 70° E.	Gneiss	Diabase	Decomposed.
43	Saranac	....	....	....	Gneiss	....	Not a dike, but basic gabbro, sheared.
91	Saranac	By Cold brook, near its mouth.	1 ft.	S. 25° E.	Gneiss	Diabase	Has two small branches of 2 in. and 6 in. respectively; much decomposed.
106	Saranac	Just east of south end of Redford bridge	1 ft.	S. 80° E. (?)	Gneiss	Diabase	Porphyritic augite.
107	Beekmantown.	Close to No. 103	(?)	(?)	Gneiss	Bostonite	Flow structure poor. Contains magnetite and considerable green hornblende.

Series VI. There has not been sufficient time at my command to bestow on the Pleistocene deposits the attention they deserve. They are widespread throughout the county, often in sufficient force to completely obscure the underlying geology over considerable areas. They were, in part, formed by glaciers and the streams to which they gave rise; in part, in the body of standing water which occupied the Champlain valley just after the retreat of the ice, and which had, at first, a level much above that of the present lake, when it was probably fresh water, while later it was an arm of the sea.

Glacial deposits. Away from the lake, the county is covered with a heavy deposit of till. Over the high plain it is widely extended and largely masks the irregularity of its pre-glacial surface. In the hilly tract it is mainly confined to the valleys, though often prominent on the gentle northern slopes of the ridges. Sections show it to be mostly very stony and very sandy, as might be expected from the wide expanse of Potsdam country over which the ice moved.

Moraines have been noted at various points, but any attempt at mapping them would be premature. Much of the surface of the high plain is insufficiently drained, abounding in swamps, some of very large extent. Rough, jagged boulders, mainly of Potsdam sandstone, are widespread over the surface, often forming veritable trains, and being exceedingly numerous. Some of these Potsdam boulder trains extend well into the gneiss country.

Glacial striae have been observed at many points. They are commonly well preserved on the palaeozoic rocks, but none have been noted on the older rocks, although these are often well polished and smoothed. Along the lake their direction is approximately that of its trend, those observed varying from S. 15° E. to S. 15° W. and those on the high plain have the same general direction. As the hills are neared and entered, however, the general direction is to the southwest, corresponding to the general trend of the ridges and valleys.

A magnificent, long, esker-like ridge, which well merits description,* occurs in the county. It is found in the low strip, only two or three miles back from the lake, and forms a topographic feature of sufficient prominence to be clearly brought out by the twenty-foot contours of the new maps. First recognizable in Beekmantown township about two miles south of Ingraham post office, it runs north in a curve to that point, then bears to the west of north through Chazy. In the central part of that township its course is

*Mr. S. P. Baldwin has noted the presence of this ridge. American Geologist, March, 1894, p. 177.

interrupted by a wide marsh, and by protruding ledges of rock, but after an interval of a mile it again appears and runs north to the Chazy-Champlain line, finally disappearing one-half mile beyond that line. It rises, in general, about thirty feet above the ordinary level and the base has a width of a quarter of a mile. Its surface is 120 feet above the level of lake Champlain. It does not exhibit its entire mass, as its base is buried in Champlain clay. Assuming that the disconnected portions are parts of a single ridge, as seems highly probable, its entire length is ten miles. No good sections are exposed. A three-foot cut in it, two and one-third miles southwest of Chazy village, frequently shows somewhat rounded boulders mostly of Potsdam sandstone, a few of which reached one foot in diameter, embedded in a matrix of coarse, brown sand. No signs of stratification were visible, but the opening was not a very recent one.

Champlain deposits. The term "Champlain," as here used, merely serves to discriminate the deposits formed under water in the Champlain basin, from those formed upon the land. During and after the retreat of the ice, the glacial deposits on the low strip were covered by deposits laid down in the marginal portions of the body of water that occupied the basin at that time, the present lake being its shrunken remnant. The mountain streams brought down vast quantities of sand, building up large deltas at their mouths, and of mud, which was deposited farther out and also along shore between the deltas. As the water level fell from time to time, the sand deposits were pushed farther out and formed at lower levels, covering up the clays of the preceding stages. During much of this time the Champlain basin was occupied by an arm of the sea, and the marine clays and sands are fossiliferous. The fossils can be collected in abundance at several points in the county. The sand delta deposits formed by the Saranac, Ausable, Little Ausable and Salmon rivers are very widespread in the eastern part of the county. At the higher levels they are confined to their respective valleys, but lower down they become confluent. Much of the eastern portions of Ausable, Peru, Schuyler Falls and Plattsburgh townships is covered by a wide, dreary expanse of sand, often bare, sometimes with a sparse covering of coarse grass with huckleberries and stunted pines, and which is dreary and monotonous in the extreme. Dunes are quite frequent, especially where the sand has been trenched by the present streams.

Some of the evidence collected indicates that at first the water level was at a greater altitude than has heretofore been recognized. Both in the Saranac and Ausable valleys, the sands have been found to run up to the height of 1,000 feet, and some of them are in such situations that they can not possibly be regarded as river gravels and sands. This matter needs further investigation.

METAMORPHISM OF THE PRE-CAMBRIAN ROCKS.

After the intrusion of the gabbro, and prior to the commencement of Potsdam deposition, the region was subjected to intense dynamic metamorphism. The precise results produced would vary with the physical and chemical properties of the rocks concerned, but, broadly speaking, they consisted in the foliation of the rocks and the granulation of their contents, with or without subsequent recrystallization. The gneisses were granulated and subjected to a stretching process, by means of which the foliation and some, at least, of the banding was produced; rocks like the gabbro dikes being drawn out like the rest, and made to appear like an integral part of the series. While some of the gneiss is characterized by a cataclastic structure, other portions of it seem to have been completely recrystallized, and the different minerals seem for the most part to have formed at the same time, few, if any of them, showing idiomorphic boundaries against the rest. That this recrystallization was not the final result of the metamorphism, is shown by the frequent pronounced undulatory extinction shown by the component minerals of such rocks.

The anorthosites and gabbros were granulated and stretched in the same manner as the gneisses, though apparently being more resistant to the latter process. In the less feldspathic anorthosites, foliation was thus produced, giving them their gneissoid aspect, and in them more or less recrystallization took place with the formation of minerals foreign to the parent rock, by the reactions of the various constituents on one another, much garnet, hornblende and biotite thereby resulting. The stages of the process of granulation can be studied to as great advantage in the Clinton county anorthosites as in the Canadian examples so exhaustively described by Dr. F. D. Adams.

The basic gabbros seem to have been characterized originally by an ophitic structure, but as a rule they are more thoroughly and finely granulated than the anorthosites. They are often of such fine grain, and their boundaries against the enclosing rocks are so sharp that the resemblance to dikes is very striking. Reaction rims are a prominent feature in these rocks. They almost always contain hypersthene, which is not common in the anorthosites and less basic gabbros. In many cases the rock seems to have undergone complete recrystallization, and when this is the case a considerable amount of untwinned feldspar is present.

These basic gabbros vary in grain down to very finely granular varieties, which are identical in character with the "shear-zone" rock from Avalanche lake, described by Kemp.* A regular series can be made out from rocks with ophitic structure down to these finely granular varieties. It seems to the writer that these shear-zone rocks must have been originally of the basic, ophitic type, and then they are often found in this much granulated condition because less resistant than the massive anorthosites to the forces acting on the rock. Where such bands are present they would represent lines of weakness. But their different mineralogic composition is not regarded as resulting from such action, but as largely a primary difference.

These gabbros may be regarded as basic segregations from the anorthosite magma, or they may represent a period of igneous activity subsequent to the anorthosites. They certainly have a much wider distribution. So far as the writer is aware, data are lacking at present by means of which either of these propositions may be demonstrated at the expense of the other. Later observations by both Professor Kemp and the writer, clearly show that these ophitic gabbros are younger than the anorthosites.

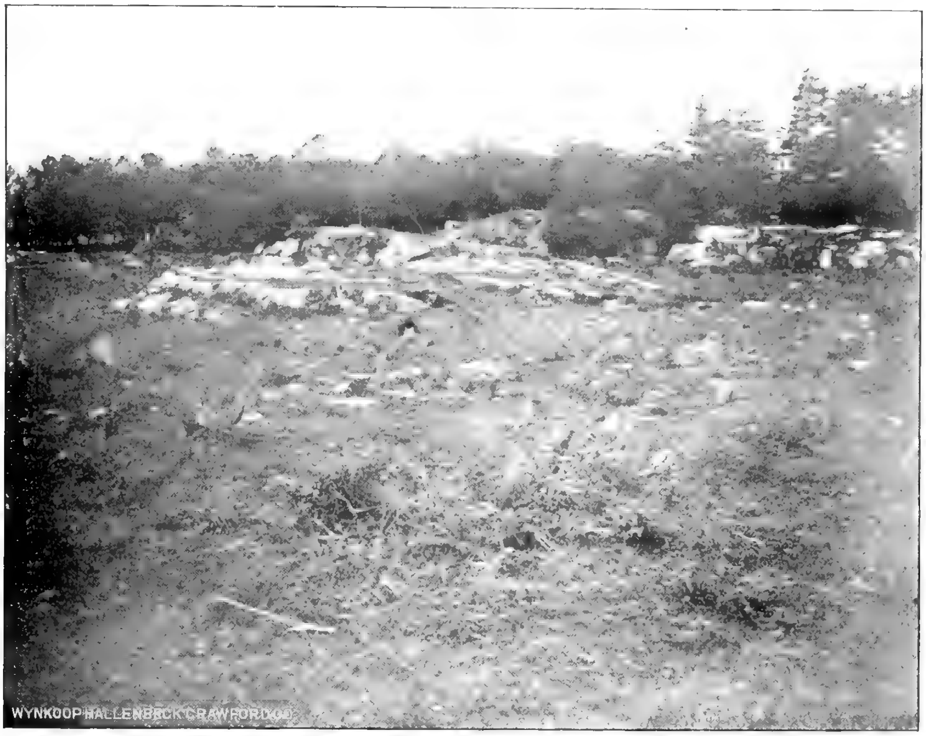
If the writer is correct in his belief that the diabases are of Pre-Cambrian age, they must have followed the metamorphism of the rocks, as they are not affected by it.

POST-ORDOVICIAN DISTURBANCE.

After the deposition of the Palaeozoic rocks, came the period of the Green mountain uplift in Vermont, and its effects were felt on the western side of lake Champlain. Though but a comparatively few miles west of the district in western Vermont characterized by sharp folds and thrust faults, the effects shown here are apparently limited to normal faulting, accompanied by a very trivial amount of folding. The dip of the Palaeozoic rocks is but slight, seldom reaching ten degrees, and more commonly not over five degrees, and is prevailingly to the north. Higher dips do occur, but are invariably local and in almost every observed instance can be demonstrated to be due to proximity to a fault. Very low folds are often to be made out, but can hardly be considered as constituting a prominent structural feature. Furthermore, there seems to be no system in their presence or arangement. They trend and pitch in various directions. Faults however abound, ranging from

* American Journal of Science, Vol. XLIV., pp. 109-114.

PLATE IV



Anorthosite on Halleck's Hill; showing the well glaciated surface,

PLATE V

Nearer view of the same.

insignificant breaks, to great dislocations which have a throw of 2,000 feet, and possibly more, and which can be traced for several miles. The possibility of the presence of thrust faults has been constantly borne in mind, but the evidence for their existence has not been forthcoming. In the majority of cases the hade of the fault is not to be made out, but it is at least high. Some can be demonstrated to be normal faults. By them the palaeozoic rocks are chopped up into a series of small blocks, and they are so prevalent that whenever the rocks are concealed much uncertainty necessarily prevails as to what is beneath. It may, however, be laid down as a general proposition that, in passing eastward from the Pre-Cambrian rocks toward the lake, progressively younger rocks are met with. The exceptions to this in the county are but few. The greater breaks have a northeast and southwest, or a north and south trend, while the smaller ones range at some angle to these, and so far as observed do not pass across them.

The Pre-Cambrian rocks have necessarily suffered also from the disturbances of this period, but in them the fractures are often difficult to locate, nor is it possible to definitely distinguish them from possible earlier faults. The topography often implies faults of great magnitude, but is wholly silent as to their date. Kemp has written of the frequent faulting of the ore-beds. Along contacts, too, decisive evidence of faulting is often forthcoming. The dikes are often faulted, the shift at the surface varying from a few inches only up to the complete disappearance of the dike on one side of the break. These faulted dikes give us the only evidence of faults which can, with certainty, be ascribed to the later period.

TOWNSHIP GEOLOGY.

The more prominent features of the local geology in the various townships will now be considered. The townships, in alphabetical order, are as follows:

Clinton.

The geology of this township is of no special interest. The Potsdam sandstone is the surface rock throughout, and the exposures are few and meagre. The eastern half of the township is swampy and heavily wooded. The central and western parts are higher and quite largely cleared of timber, but are deeply covered with till.

Mooers.

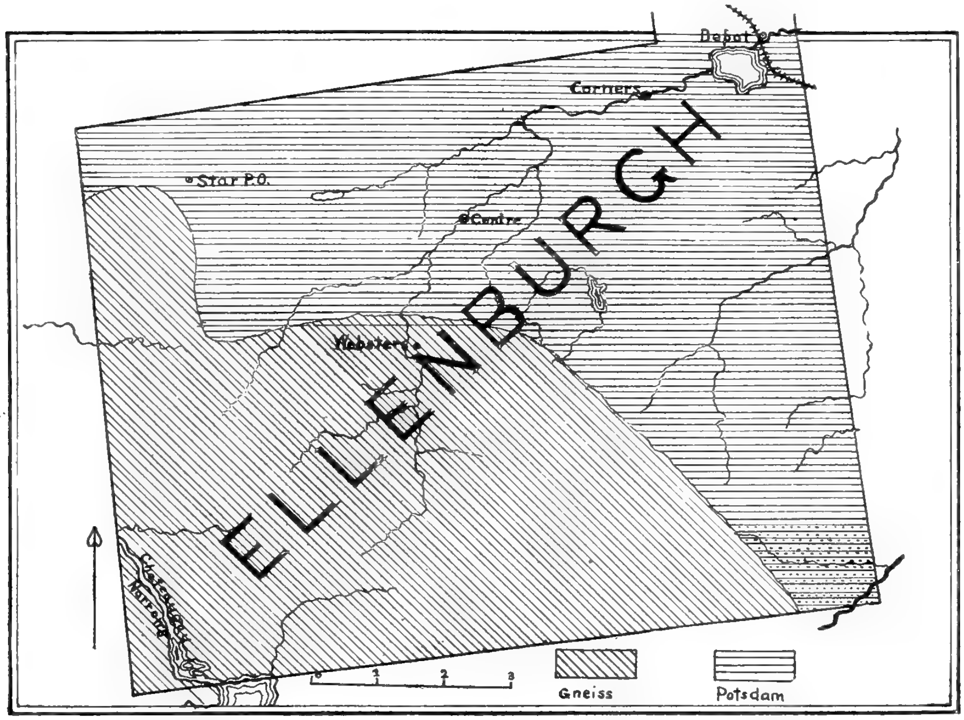
In this township, also, the Potsdam is everywhere the surface rock, but the exposures are better, more frequent, and somewhat more varied in character than in Clinton. Both townships form part of the high plain which slopes north from the Adirondack foot-hills. The dips are chiefly to the northwest, but the presence of slight folds is indicated by the occasional occurrence of southeasterly dips. North of Mooers village occurs a series of interesting passage beds to the Calciferous, with a breadth of outcrop at the Canada line of nearly three miles. They are cut off sharply on the west, their place being taken by ordinary Potsdam, thus indicating a fault as they dip to the northwest. They consist of rapidly alternating layers of white or buff, well indurated sandstone, and dark bluish grey dolomites, which are often sandy, the sandstones predominating. The dolomite layers, when forming the surface, have a peculiar habit of weathering, which may also be frequently observed in the dolomites of the Calciferous. Solution takes place rapidly along two sets of planes, approximately at right angles, until the entire thickness of the bed is eaten through (these dolomitic layers here have no great thickness, seldom more than a foot), so that it is converted into a regular series of disconnected blocks, of rounded outline, which project above the meagre soil and present a very curious and striking appearance.

If the Potsdam sandstone runs across the township without having its apparent thickness increased by faulting, the minimum thickness that can be assigned to it is 1,500 feet, with the summit not reached, and the base not even closely approached.

The township is quite heavily drift-covered. Along the streams in its eastern half, considerable sand is exposed, but nothing at all comparable to the great accumulations of the Saranac and the Ausable rivers. At Thorn's Corners, two miles west of Mooers village, the Great Chazy river shows Potsdam sandstone in the stream bed, and over it on the bank an excellent section, twenty-five feet in height, the upper ten feet consisting of coarse, cross-bedded gravels, overlying a stony and rather sandy till.

Ellenburgh.

Series I. The gneisses enter Ellenburgh from the south as three north-easterly trending ridges. Ellenburgh mountain on the east, Panther mountain in the centre, and on the west the less conspicuous ridge which forms Sanborn's hill and West hill. The ridges are separated by wide drift-filled valleys, in which occasional rounded and glaciated knobs of gneiss protrude above the surface. The Ellenburgh mountain gneiss, and that in the valley to the west of it, is the ordinary red, microperthitic gneiss of the Adirondacks, very acidic, poorly foliated, and cut by numerous veins of coarse pegmatite



and quartz. The pronounced red color of much of the rock is found to be due to the infiltration of hematite between the grains and into the cleavage cracks of the feldspar.

The gneiss of Panther mountain and West hill is highly acidic and much of it looks like a red granite, and contains nothing besides microperthitic orthoclase and quartz. In the more gneissoid exposures a monoclinic pyroxene of strong green color creeps in. Very basic bands are not very numerous and are, so far as observed, hornblende-plagioclase gneisses, generally having this same green pyroxene in addition. The magnetite grains which occur in these gneisses are often surrounded by rims of titantite, indicating that they are titaniferous, and this is frequently the case in these gneisses throughout the whole region.

The facility with which gabbro grades into diorite has been shown by several observers. These hornblende gneisses of the Adirondacks seem also to grade into gabbro-gneisses whose igneous origin and relationship with the greater gabbro masses are regarded as certain, and it is quite probable that the hornblende-gneisses will prove to be merely a phase of them.

Series II and *III* are not known to occur in the township, though it is quite likely that basic gabbros may be found in the gneisses.

Series IV. All the northeastern half of the township is occupied by the Potsdam sandstone, with prevailing dips of from 5° to 10° to the N. W. The striking feature of the Ellenburgh Potsdam is its coarseness, even at considerable distances from the gneiss, so that heavy conglomerates here range through a thickness of 200 feet or more. A quarter of a mile west of Star post office, and 200 yards south of the road, the Potsdam is found within fifteen yards of the gneiss, a slight depression with no rocks exposed lying between. The Potsdam is not as coarse as might be expected so close to the contact, no coarser in fact than is the larger part of the formation in the township. This, together with the somewhat abnormal dip of the sandstone at this place, gives rise to the suspicion of a north and south fault here (the Potsdam lies to the east of the gneiss), and such a fault would explain the sudden shoot to the north which the gneiss takes along this line.

In addition to the prevailing coarseness, much of the rock is very feldspathic, as is the case throughout the county in the basal Potsdam. The less coarse, rapidly disintegrating, hematitic beds which frequently accompany the conglomerates make, however, little show in this township. But there is often a rapid alternation of coarse and finer beds, giving a thin-bedded character to much of the coarse rock.

In the extreme northeast the conglomerates are left behind, and the rock consists almost wholly of quartz sand. Yet even here certain horizons are very pebbly. A very interesting exposure of the sort occurs in the bed of the English river at Ellenburgh depot. The dip here is slight and the surface of a single layer is exposed over many square yards. The rock is a coarse, even-grained grit but is set with numerous pebbles of white quartz, sometimes over two inches in diameter. The horizon is well above the base and affords a good instance of the coarse character which the rock holds throughout. In addition to the quartz pebbles three larger rounded masses of *sandstone*, from four to six inches in diameter, were also observed embedded in the layer, as well as two smaller pebbles of the same character.

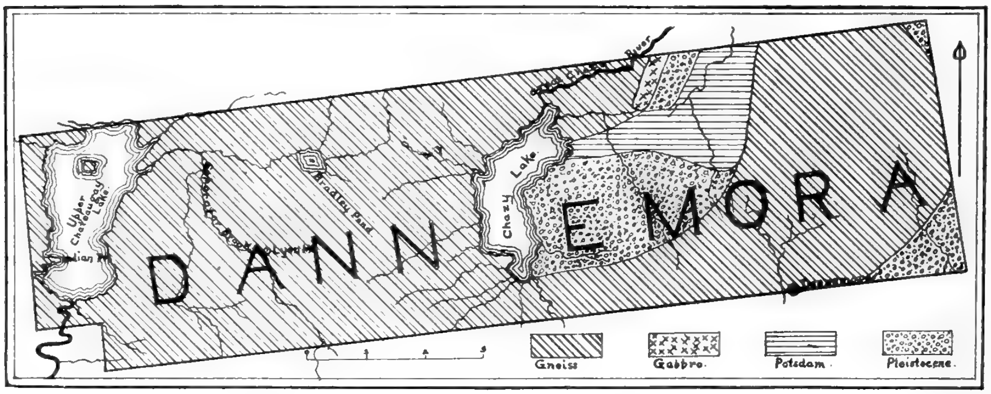
Series V. Of the eleven dikes found in the township only three call for any comment. Two miles from Webster's mill, on the road west, an enormous bostonite dike is exposed just north of the road. It is fully thirty feet in width, has a dark reddish hue, and contains much porphyritic orthoclase, the crystals ranging up to one inch in length. Besides furnishing a magnificent example of these dikes, it is also of interest for its indication of the wide distribution of the bostonites. Just south of this dike, by the roadside, is a dike of diabase (No. 96), two feet wide, which furnishes quite fresh material, and is noteworthy for the strong pleochroism of its porphyritic augite. One-fourth of a mile southwest of Star post office is a diabase dike (No. 102), which furnishes the largest feldspar phenocrysts observed in any diabase in the county. They are numerous, occur up to an inch in length, breaking with lustrous cleavage faces which beautifully show the twinning and complicated intergrowths of the crystals. The feldspar is close to labradorite.

Series VI. The township lies beyond the reach of the Champlain deposits. It has the usual heavy glacial deposits filling the valleys. A long, massive, esker-like ridge forms a conspicuous feature near Ellenburgh depot. It lies right athwart the valley of the English river and has saved the railroad company the trouble of constructing a trestle, or embankment across the valley. It has thrown the river out of its pre-glacial course and must have dammed the valley for a brief time. The river has cut but a narrow trench through it at its north end down to the level of the Potsdam in the stream bed. The summit of the esker rises nearly to the level of the valley walls, the valley being here quite wide and the sides of gentle slope. The length of the esker is not known, but its width is fully one-quarter of a mile. No good sections were seen, but a small cut at the base showed a coarse sand matrix in which pebbles were set, these being somewhat rounded and reaching no great size.

Dannemora.

This township has a more typical Adirondack character than any other in the county, with the exception of Black Brook. The massive ridge of Lyon mountain lies largely in it, though the summit is just over the border in Saranac. The two largest lakes in the county, Chazy and Upper Chateaugay lakes, lie, the former wholly, and the latter mainly, within its borders, and the latter is, furthermore, a quite typical Adirondack lake.

Series I. The gneisses constitute the larger part of the township, the massive ridge of Dannemora mountain occupying the eastern portion, Mount Lyon in the centre, and the range of hills which extends into Ellenburgh as Ellenburgh mountain on the west. Much of the gneiss is of the ordinary acid, microperthitic variety, with the ever present bands of basic hornblende gneiss. On Dannemora mountain, along with the red gneiss, is a white gneiss streaked with black, which contains a quite pleochroic green monoclinic pyroxene and much titanite. At Lyon mountain village, the ore-bearing



gneisses are also pyroxenic. They are well foliated, red gneisses, made up of quartz, orthoclase, plagioclase, green pyroxene, deep orange titanite, a little hornblende and magnetite. The pyroxene is strongly pleochroic, like that at Dannemora, a being greenish-yellow, b and c green. The presence of so much titanite in the rocks enclosing the magnetite deposits is interesting. It never appears as rims round the magnetite, as it does in some of the hornblende gneisses.

Series II. Not present in the township so far as known.

Series III. A single small knoll of basic gabbro occurs nearly a mile east of the lower end of Chazy lake, with gneiss in close proximity on the west, and Potsdam on the east, while the gneiss of Dannemora mountain is only two miles away eastward, so that this gabbro is undoubtedly to be classed with the smaller masses which occur interbanded with the gneisses. The rock is somewhat gneissoid, but readily identifiable in the field as gabbro. It is not completely granulated, but of the ophitic type, showing large individuals of labradorite and nearly colorless monoclinic pyroxene of diallagic habit, both crammed full of intrusions. The interspaces are of granular structure, containing plagioclase and some unstriated feldspar, neither with inclusions; augite, also without inclusions, hypersthene, hornblende, biotite and magnetite. This granular portion has evidently not resulted from the mere granulation of the original rock, but is almost wholly due to recrystallization. Reaction rims of biotite and hornblende around magnetite are excellently shown. Garnet seems to be absent. Throughout the county it is not so characteristic of the basic gabbros as of the anorthosites, though frequently present in them. Aside from this exposure no rocks of this series have been seen in the township.

Series IV. A tongue of Potsdam sandstone runs into Dannemora, occupying the depression between Dannemora and Ellenburgh mountains, and traceable to Chazy lake, at the Chazy Lake House. Though hemmed in between the gneisses, no coarse conglomerate has been seen, and most of the rock is the red, hematitic, easily decomposing arkose. The best exposures are in Steep Bank brook, two miles north of Dannemora village, and here at an altitude of 1,500 feet, the greatest elevation known to be reached by this rock in the county.

Series V. Forty-one dikes have been found in Dannemora township. Kemp has noted eleven which cut the ore-body in the Chateaugay mine at Lyon mountain, and five more have been described by Eakle from Upper Chateaugay lake. The remainder have been found by the writer. Along the west shore of Upper Chateaugay lake, and along the road north from Dannemora over the mountain, are notable exhibitions of dikes. Four of them are of bostonite, the rest are diabases. Only two of them need further notice here.

Dike No. 46, west of the lower end of Chazy lake is of the bostonite type, but abnormal. It is dark brown to black in color, non-porphyritic, and rather coarse for this rock, with the trachytic structure not well marked. It is almost wholly made up of rather large orthoclases, which are packed full of inclusions of green hornblende and biotite. The two minerals have precisely the same color, so that in many cases it is impossible to distinguish them from one another, but both are present. There are also some larger, irregularly bounded green hornblendes which seem secondary after a nearly colorless monoclinic pyroxene, two cores of which remain in the slide surrounded by the hornblende, which is of the uralite type. It is a curious rock, and if classed with the bostonites, must run very low in silica for that type. Just what was its original condition, is not clear.

Dike No. 66, from Upper Chateaugay lake, is a typical olivine diabase, in which even the olivine is surprisingly fresh. The pyroxene is of lilac color, with quite strong pleochroism, a yellow, b and c lilac. Its phenocrysts are full of inclusions and markedly zonal. In the ground-mass is considerable brown hornblende and some biotite, so that the rock grades toward the camptonites.

Series VI. The Chazy lake valley has some features which suggest a fault valley, but the lake is held in place by heavy drift deposits at both ends. There are also heavy drift deposits at the upper end of Upper Chateaugay lake. Bradley pond is but a remnant of a somewhat larger body of water in a wide valley where the drift is unusually heavy, and whose surface is strewn with multitudinous loose blocks of Potsdam. Three miles north of the pond, in Ellenburgh, a watershed is formed by an accumulation of hills of modified drift, sand and gravel with surface blocks of Potsdam, which stretches across the valley from side to side.

Saranac.

Series I. Except for the southeastern portion, known locally as Hardscrabble, the entire township is occupied by the gneissic series. The most accessible exposures are those found along the Saranac river, from Saranac hollow westward, the most notable being the section in the gorge below the High falls. Excellent and repeated exposures are also found along True brook. The gneisses in the township are for the most part of the ordinary red, microperthitic variety, with the usual variations in the amount of ferro-magnesian silicates present, and also with the customary bands of basic gneisses, both the hornblende gneisses and the gabbroic gneisses occurring. Along the North Branch of the Saranac, from Petersburgh westward to Cold brook, are microcline and plagioclase gneisses which closely resemble those in Black Brook township already described.

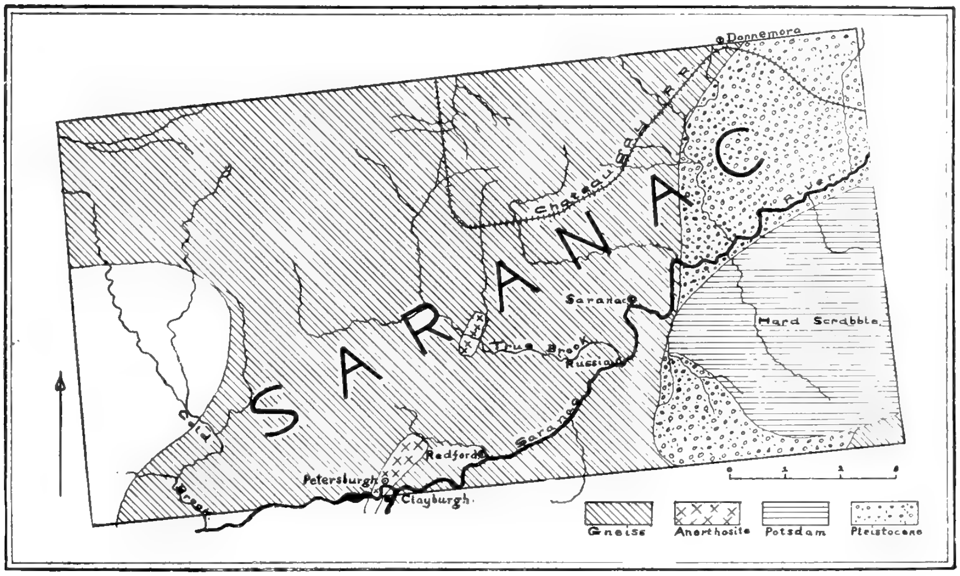
Just east of Russia, north of the road, is a strip of brecciated gneiss, like that described by Kemp from Hammondville and elsewhere in Essex county,* the gneiss being in angular fragments of varying size cemented together by a mixture of chloritic and other decomposition products. The breccia has no great lateral extent and is cut by dike No. 33.

Along True brook, in Lot 35, just above the old mill dams, are scanty exposures of the only rock at all resembling quartzite which has been seen in the county. Unfortunately the exposures are isolated, no others having

* Report of New York State Geologist for 1893, Vol. I., p. 456.

been noted within half a mile to the east, while westward from this point the valley expands, and all rocks are heavily buried in drift. Gneissic ridges are within a mile both to the north and the south, but the rocks accompanying the quartzites in the valley are nowhere exposed. Megascopically, much of the rock is white and granular, with occasional small red garnets showing, and, but for the latter, looking quite like some parts of the Potsdam. Other portions are coarser, showing both quartz and orthoclase, the latter predominating, and with an arrangement of the quartz in leaves, resembling, in that respect, the Canadian rocks which Dr. Adams calls "leaf gneisses."*

Under the microscope, the rock is seen to be mainly composed of microcline and quartz, with some orthoclase, a little plagioclase, and occa-



sional garnets, the whole with a rather finely granular structure. A few larger individuals give the impression that the rock has been granulated, but it is not certain. In one of the two slides made, are found occasional individuals of a nearly colorless mineral, whose parallel extinction, high interference colors, small axial angle, and positive character are indicative of sillimanite, though it is irregularly bounded and somewhat broken and crushed. Its presence is of interest, as the mineral is quite characteristic of certain schists closely associated with the limestones, and may perhaps indicate the presence of the limestone series here concealed by the drift in the valley.

* American Journal of Science, Vol. L., p. 62.

Series III. At Petersburgh, showing well just north of the road, is one of the largest of the basic gabbro bands that has been met with in the county. Measured across the strike the exposure is fifty yards wide, and the full width is not shown, but within a few yards distance, on both sides, ordinary red gneiss comes in. A few yards south of the river at Petersburgh bridge, is a small exposure of similar gabbro, and half way between Russia and Redford, is another with red gneiss close at hand. On the True brook road, just before reaching the fourth bridge (the road crosses the Brook several times), is still another, which looks like an enormous dike ten yards wide, enclosed in the gneiss.

These four gabbros are all alike in mineralogic composition, being made up of augite, hypersthene, hornblende, biotite, magnetite, plagioclase (some untwinned) and apatite. Unlike most of the gabbro of the region, they totally lack garnet. The gabbro south of the river at Petersburgh has the ophitic structure, with the large characteristic feldspars and augites, which always occur when that structure is preserved. The others are all granular, and have suffered recrystallization; that between Russia and Redford having the very finely granular structure of the "shear-zone" rocks. The Petersburgh exposures are readily recognizable in the field as gabbros, while that on True brook more resembles the hornblende gneisses.

Series IV. The Hardscrabble district, a rather elevated plain between the Saranac and Salmon rivers, which lies partly in southeastern Saranac, is occupied by the Potsdam sandstone, but the heavy drift renders it impossible to accurately map its southern, western and northern boundaries. The exposures seldom show more than the upper surface. The rock is thin-bedded for the most part, commonly buff, but with some red layers; is coarse and gritty, but seldom pebbly, and most of it disintegrates quite rapidly, few well indurated layers showing.

Series V. Thirteen dikes have been found in the township, most of which are decomposed diabases. No. 41, just west of the third bridge over True brook, is a typical olivine diabase, with large olivine and augite phenocrysts, the latter of a light rose color and slight pleochroism. The rock is quite fresh, much of the olivine being perfectly sound.

No. 32 is the only bostonite met with. It cuts the gneiss just east of Saranac village, and is a non-porphyritic, dark red rock, which contains a considerable amount of green biotite and of magnetite.

Series VI. The sand deposits of the Saranac valley run up the river to beyond Redford, and are very conspicuous at that point, where they have an altitude of about 1,000 feet. One mile southwest of Dannemora, at about the same elevation, is a considerable accumulation of sand with streaks of gravel, perched on the valley side about 400 feet above the river, and sand at about the same level shows at several points between. Both here and in the Ausable valley, these delta deposits of the old lake seem to run higher than heretofore recognized.

Black Brook.

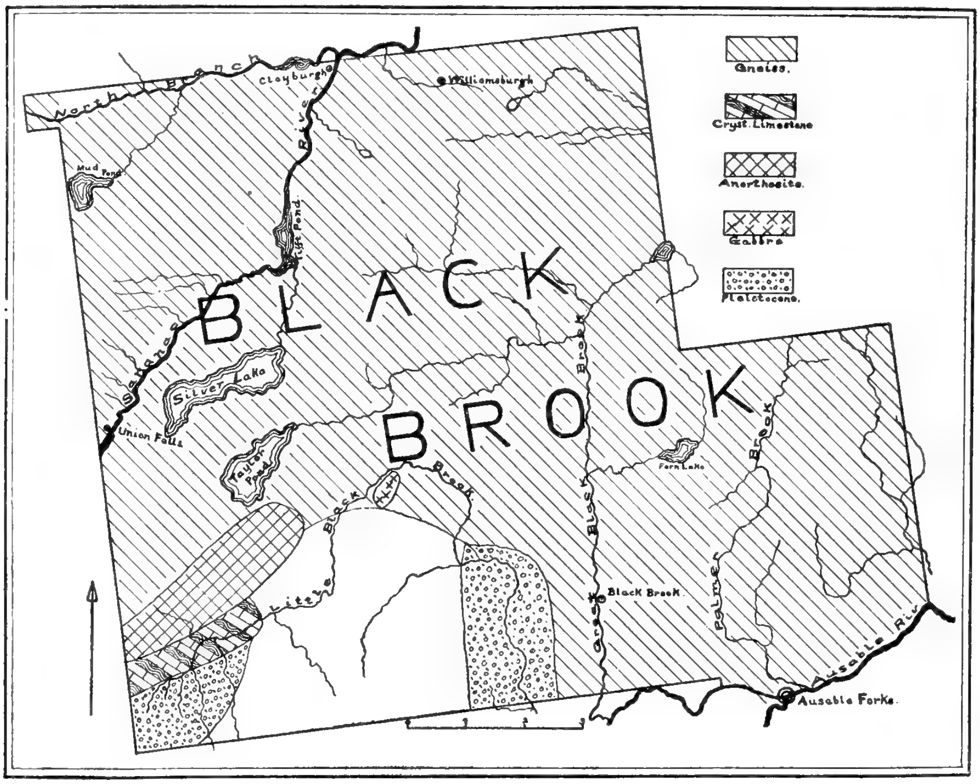
This is the largest township in the county, and lies in the southwestern corner, adjoining Franklin county on the west and Essex on the south. Its western half is wild, and much of it is quite inaccessible. The valleys are wide with few exposures, and the ridges are difficult of access, forest clad, and with their northern slopes heavily drift covered. Hence it is extremely difficult to find outcrops in sufficient number to permit of accurate mapping.

Series I. With the exception of the extreme southwest, the entire township is occupied by gneissic rocks which, for the present, must all be classed together. There is comparatively little of the ordinary microperthitic gneiss. Such is found on the northern border, and on Palmer hill at the east. But even on Palmer hill and along the river at Ausable Forks there is much microcline gneiss, and much of the gneiss contains abundant green monoclinic pyroxene. This association of pyroxenic gneiss with the Palmer hill magnetite deposits is of interest in view of the like association at Mineville, as reported by Kemp.* The same also occurs at Lyon mountain. In some of the Palmer hill gneisses there are titanite rims around the magnetites, a curious circumstance considering their juxtaposition to the ore-bodies. These gneisses are well shown along the railroad just east of Ausable Forks. In these exposures is a sheared strip, three inches wide, in a coarse pegmatitic band, which consists wholly of slickensided chloritic material. Just east of the Forks is a heavy band of basic gneiss, which is hard and firm, and contains, in addition to hornblende, plagioclase, biotite and magnetite, much hypersthene but no monoclinic pyroxene. It is the only rock of the kind seen in the county. The peculiar microcline gneisses, which have been described on a previous page, are widespread in the central part of the township, and the ponderous east and west ridge known as Silver Lake mountain, is wholly composed of them.

At Union Falls, the river drops twenty feet over gneiss and passes north eastward in a gorge, exposing an excellent section in which the very variable

* Report New York State Geologist for 1893, Part I., p. 441

character of the gneiss, as exhibited in the township, is well shown. The main portion is a well foliated rock of microperthitic microcline and orthoclase, with quartz and a variable, but commonly considerable amount of hornblende, biotite and magnetite. Much basic hornblende gneiss is interbanded with it. A mile and a half a little east of north of the Falls, in a field a few rods back from the road, is a considerable exposure of a brown gneiss which contains an orthorhombic pyroxene of too slight pleochroism and too weak double refraction for hypersthene, and which is probably enstatite. It is the only occurrence of this mineral yet noted in the county.



A short distance to the east is a well foliated microperthitic gneiss holding numerous garnets, a mineral which, as a rule, is quite rare in the gneisses. Gneiss is well exposed for several miles along the valley of Great Black brook, the best exposures being at Black Brook village. This gneiss is, for the most part, a well-foliated plagioclase gneiss, containing also orthoclase, some quartz and a considerable amount of hornblende, biotite and magnetite.

The long ridge called Leggett mountain, which lies in the extreme southwest and extends into Wilmington, Essex county, shows frequent exposures of red and lilac-grey microcline gneiss at its northeastern extremity. Along with these, is a small outcrop of basic gabbro of the type that occurs interbanded with the gneisses. Exposures elsewhere on the ridge were very difficult of access and were not reached, but it was thought probable that the whole was of gneiss. However, Professor Kemp reports gabbro from the ridge just over the border in Wilmington, and the place where the gneiss ceases and gives way to gabbro must be left for future determination.

Series II. Not far from the Franklin line, in the valley between Catamount and Leggett mountains through which Little Black brook meanders, occur the only exposures of the limestone series which have been found in the county. But three exposures were found, and the extent eastward is uncertain, but the belt passes westward into Franklin county, good exposures occurring around Franklin Falls.

About two miles east of the Franklin line, and lying close up against the side of Catamount mountain, a massive limestone occurs in which a considerable opening has been made and the rock burned for lime. The limestone is coarsely crystalline and much of it quite pure, but other parts contain much green pyroxene, sometimes in great bunches making up the larger part of the rock, sometimes more evenly scattered through the mass. In places graphite and phlogopite occur, but in no great quantity. Locally there is considerable titanite, and there is one finely crystalline, narrow band composed about equally of titanite, pyroxene and calcite. A few small, slender green apatites were noted, but are not common. The breast in the limestone is about twenty feet high and 150 feet long. Not far distant, farther up the ridge, basic gabbro crops out.

By the roadside, some fifty rods south of the limestone, is a small outcrop of a crumbling, rusty gneiss, consisting of a nearly colorless monoclinic pyroxene and microperthitic orthoclase. In addition it contains some sillimanite, titanite and magnetite, quite a little pyrite, and large scales of graphite along the planes of foliation. Associated with it is a band of basic hornblende-plagioclase gneiss. These gneisses are like those associated with the limestone elsewhere and belong to this series. No other outcrop of such gneiss has been seen in the county.

Series III. The massive, northeastwardly trending ridge of Catamount mountain is composed of gabbro, and is probably a prolongation of the area over the border which makes up the Whiteface mountain mass. The two are separated by a wide, drift-filled depression which is probably occupied by the limestone series. The Catamount ridge is suddenly cut off on the southwest, at right angles to the trend of the ridge, and presents in that direction a quite precipitous face which looks like a fault scarp. Such faces are characteristic of most of the ridges of the county and produce the same impression on the observer as do those of Essex county, which Kemp regards as of the block-tilted type.

The Catamount gabbro is of the anorthosite variety, and so thoroughly granulated that large cleavage faces are seldom visible in the hand specimen. Hence the prevailing color is white, the ferro-magnesian silicates not being in large amount and always concentrated along planes, so that the rock is quite gneissoid. Garnet is present, but not so prominent as in much of the anorthosite. The thin section shows monoclinic pyroxene, hornblende and magnetite.

Not far above the limestone quarry, basic gabbro outcrops, but is so poorly shown that it is impossible to ascertain its extent. It is composed of augite, hypersthene, hornblende, biotite, garnet, magnetite and labradorite. It seems to have been originally of the ophitic type as it contains some of the diallage like augite, full of inclusions, which characterize that type. None of the original idiomorphic feldspar remains, however, and most of the rock seems to have undergone recrystallization. None of the minerals have idiomorphic boundaries except the biotite, which does not appear as reaction rims round the magnetite, but in thin plates distributed through the rock. In fact there is no sign of reaction rims of any kind in the rock. In addition to the above the same gabbroic gneisses are found interbanded with the other gneisses of Series I that are found so commonly in the other townships.

Series IV. No Palaeozoic rocks are to be found in the township although the Potsdam sandstone almost reaches it on the north and east.

Series V. Thirteen dikes have been noted in the township, all of which are diabases. Three of the very narrow ones approach augite-camptonite by the augite of the ground-mass becoming idiomorphic. Nos. 84 and 86 are very typical diabases, furnishing quite fresh material.

Series VI. The higher level of the sand deposits of the Ausable river runs up the river some distance above Ausable Forks, at that point rising some little distance above the river level. Just west of the Forks on the road to Black Brook an excellent section, twelve feet in height, is exposed, which is as follows, from the top downward:

1. Soil.
2. Coarse yellow sand with a few boulders, ... 2 feet
3. Fine white sand with no boulders, ... 3 "
4. Stiff, blue, jointed clay, weathering white, . . . 1 "

5. Sandy, laminated clay, somewhat undulating, . . 0 feet 9 inches.

6. Laminated, clayey sand, much folded and contorted, 1 foot.

7. Alternating thin bands of sand and clay with occasional rounded boulders, to the base of the section, with a six-inch clay seam in its upper part, which unites with the upper jointed clay, No. 4, at the west end of the section, but one hundred feet away is three feet below it. At the east end everything is cut off by the sudden downward dip of the upper yellow sand. The white sand, No. 3, contains thin streaks of fine gravel and occasional small clay nodules, and becomes very gravelly at the east end of the cut. The whole seems clearly a shore deposit in standing water.

Ausable.

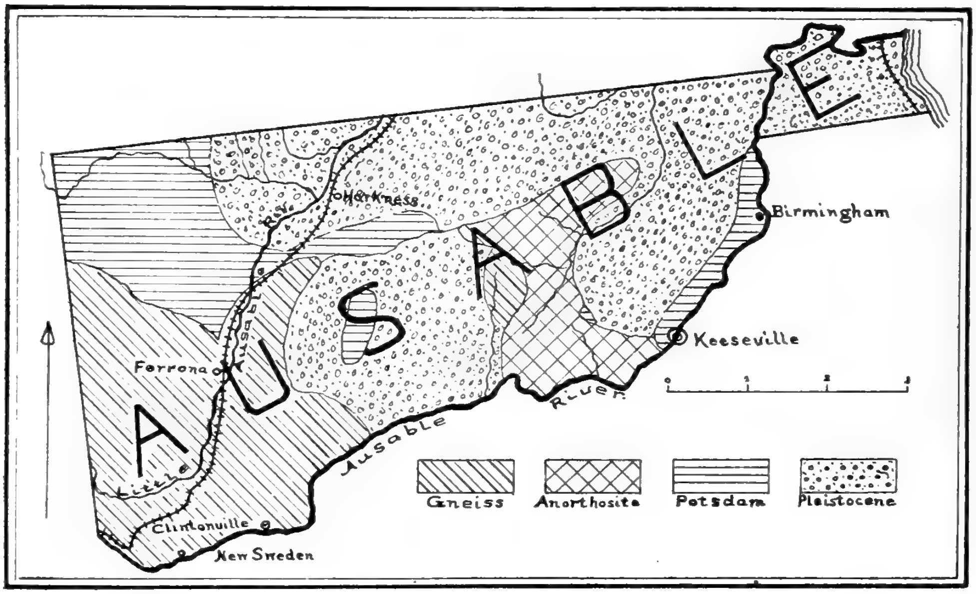
This is the smallest of the townships, and lies in the southeast, with the Ausable river forming its southern boundary except at the extreme east, where a narrow strip of low sandy land belonging to the modern delta of the river is included in the county.

Series I. The gneisses cross the river into the county at Clintonville and continue thence northeastward about half-way across the township, when they are overlapped and indented by the Potsdam, their line of outcrop swerving to the west and then to the northwest. The wide gneissic hill in the western part of the township is known as Arnold hill, and is topographically an extension of Palmer hill in Black Brook. The Little Ausable river cuts through it in a narrow, steep-sided valley, apparently due to a fault, with the gneiss showing grandly on the east side. At Clintonville and northeastward from it, are also excellent exposures. Then follows a drift filled depression a mile in width, beyond which the gneiss again crops out in two low hills, round which the gabbro sweeps in a semi-circle.

The exposures are, for the most part, of ordinary microperthitic gneiss, with some plagioclase gneiss toward the north, and with the usual bands of hornblende gneiss. On Arnold hill are important ore-bodies. About one mile southwest of Harkness station and near the railroad, is a strip of no great width which resembles a dike and is probably a sheared strip. It is a finely granular black rock, made up of plagioclase, orthoclase, hornblende, biotite and magnetite, hence with the mineralogy of the hornblende gneisses.

Series III. Lying east of the gneisses, and forming the rather low elevation known as Halleck's hill, is an area of anorthosite. It has a breadth of one mile and a half where it crosses the river from Chesterfield, and gradually decreases in width going north till the last of it runs under cover two miles north of Keeseville.

The district furnishes the most typical anorthosite to be found in the county. While the rock is much granulated, some of it wholly so, there is still much of it that shows partially unbroken crystals of labradorite that reach, on occasion, a very considerable size, being found up to three inches in length. A considerable part of the rock is almost wholly feldspathic, the ferro-magnesian minerals occurring only in very small amount. The less feldspathic portions of the rock are the most completely granulated, and have a prevailing gneissic habit. In these varieties garnet is very abundant, often



imparting a reddish tint to the rock. In them reaction rims are also a feature, and a considerable amount of recrystallization has taken place. Openings have been made in the more feldspathic portions of the rock in the vicinity of Keeseville, and some of it put on the market under the name of "Keeseville granite." It makes a very handsome stone, the large, blue-grey labradorite crystals surrounded by a lighter colored granulated zone giving a very pretty effect; but no tests of its crushing strength have been made, so far as the writer is aware. It seems quite resistant to weathering.

In several places in this anorthosite area are found bands of basic gabbro. When finely granular, as is commonly the case with the thinner bands, they look like dikes. The larger masses are often less changed and show the rude ophitic structure already described. The larger feldspars often show beautiful pressure effects, the crystals not only being broken but frequently bent. In one slide is a well-twinned crystal, about seven millimetres long, in which the gradual variation in extinction from one end of the crystal to the other amounts to 25°, showing a bending to that amount, yet with no apparent breakage of the crystal.

The contacts between these basic bands and the anorthosite are often as sharp and clear as intrusive contacts, so that slides may readily be prepared consisting half of one and half of the other.

As has been already stated, these basic gabbros are so absolutely like the basic gabbroic bands found in the gneisses, that there can be no question as to the identity of the two. Neither in the hand specimen nor in thin section can they be distinguished from each other. Both the granular and the ophitic phases occur in both situations. It would seem most probable that they are to be regarded as basic segregations from the main anorthosite intrusion, which have been stretched out into bands parallel with the foliation of the enclosing rock as a result of dynamic metamorphism. Such segregation would take place mostly toward the periphery of the mass, and such portions as were squeezed out into cracks in the enclosing rocks would be mainly of this type. But on the other hand the frequent sharp boundaries between the basic gabbro and the anorthosite, with no sign of gradation into each other, and the much wider distribution of the gabbro, can not but give rise to the suspicion that, at least in part, the gabbro intrusion may have been subsequent to that of the anorthosite.*

A massive band of basic gabbro which is found in the anorthosite at a point a little over a mile west of Keeseville, just north of the river road, is interesting as showing a gradation toward diorite. Monoclinic pyroxene and garnet are found in the rock but are very subordinate to the hornblende, which shows great development, while hypersthene is absent. A hint of this is given in the appearance of the rock, which is more schistose than the normal gabbro. The main interest attaching to the occurrence is from its possible bearing on the origin of the hornblende gneisses of the gneiss series, which the rock much resembles.

Two miles west of Keeseville, on the river bank, is a knob of gabbro which is interesting as indicating a transition to gneiss. It is of brown color, finely granular, and contains quite a little quartz and microperthitic

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* Later work by both Professor Kemp and the writer demonstrates that much, if not all of the basic gabbro is of later date than the anorthosite, as indicated here at Keeseville.

orthoclase in addition to the ordinary gabbro minerals, plagioclase, hornblende, augite, garnet and apatite. It is the most westerly of the gabbro outcrops, but two miles of barren ground intervene between it and the Clintonville gneisses.

Series IV. The only Palaeozoic rocks exposed in the township are of Potsdam sandstone. The magnificent exhibition of this rock in the Ausable chasm has been mentioned by many observers, and has been carefully measured by Mr. Walcott.* Except for this river section, all the Potsdam in the eastern part of the township is deeply buried by sand. The rock exposed at Keeseville and in the chasm is quite homogeneous, of white, grey or yellow brown color, and the fossils indicate that it is the upper portion of the formation that is here shown. This, together with the lack of red beds and conglomerates as the gabbro is approached, gives rise to the suspicion of a fault contact. It is about on a line, also, with a fault which runs through Peru and Plattsburgh, close to the lake shore.

A very interesting exposure of Potsdam on the west side of the supposed fault is worthy of description. The locality is not quite a mile west of Keeseville, not far west of the race track, and a few hundred yards southeast of School No. 5. Nestling in an indentation in the eastern face of the gabbro, is a small mass of peculiar, very coarse conglomerate, capped by very red, thin-bedded layers of feldspathic sandstone of the ordinary basal type. The conglomerate carries very numerous, well-rounded quartz pebbles of a reddish lilac tint, ranging in size up to two inches in diameter. With these are occasional smaller fragments of orthoclase and a few dark colored pebbles of decomposed rock, apparently of diabase. In streaks magnetite is present in very large quantity, in well rounded grains. The coarsely granular matrix looks black when fresh, but on weathering becomes mottled with blotches of green chloritic material, which gives the predominant color to the rock. In thin section, grains of quartz, microperthitic orthoclase, magnetite, titanite and microcline, named in order of abundance, are seen to constitute the matrix, and are set in a green chloritic-like cement, whose exact nature is not clear. The coarseness of the conglomerate is astonishing when we remember that it is composed entirely of gneissic debris, yet is in contact with anorthosite, the nearest exposures of gneiss being one mile and a half away.

In the northern and western parts of the township considerable Potsdam is exposed. It is, for the most part, a hard, flinty sandstone of buff color,

* Bulletin 81, United States Geological Survey, pp. 343-344. The boss of granite mentioned by Mr. Walcott, on the river bank above Keeseville, is of gabbro.

though on the north flank of Arnold hill, in the vicinity of the gneiss, coarse conglomerates occur. In the central part of the town it runs down in a curious way between two gneiss ridges. There is here a drift-filled valley, a mile or more in width, which runs clear across the township, and was apparently the track of a pre-glacial stream. Along the Ausable it intervenes between the Clintonville gneiss and the gabbro to the eastward, but further north, gneiss ridges form both walls. At the north end, the Potsdam-gneiss contact is found near Mr. Harkness's house. The well on the premises, close by the house, penetrated hornblende gneiss at a depth of a few feet, while only five rods to the northwest, flinty Potsdam was reached in a cistern. One mile and a half to the southward, are two old openings in Potsdam sandstone, known as Mace's quarry. The rock is ordinary hard, massive, buff sandstone. Less than a mile away on each side, are massive gneiss ridges, and we have here apparently a pre-Potsdam as well as a pre-glacial valley. It is unfortunate that the drift covering does not permit us to determine how far up this valley the Potsdam runs, but there seems no reason why it may not run clear to the Ausable river. It recalls the patches of Potsdam described by Kemp from Essex county.*

Series VI. The northern slopes of Arnold hill are covered with till, and the surface is plentifully besprinkled with boulders. The till covering ranges throughout the gneissic area, but elsewhere in the township everything of the sort is hidden from sight beneath the universal mantle of sand. This surrounds Halleck hill on the east and north, running clear to the lake shore and well into Peru. It extends up the Ausable valley beyond the limits of the township, and at Clintonville and New Sweden is heavily banked up against the gneisses, is bare and much drifted about by the winds. It also extends throughout the valley of the Little Ausable, even in its narrow upper reaches, great drifts of it lying around and against the protruding bosses of gneiss.

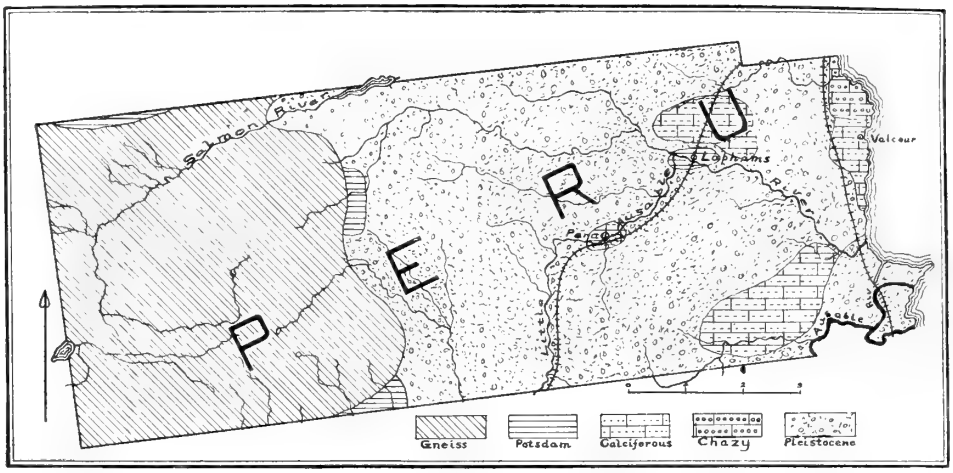
Peru.

The western third of Peru township is hilly, and occupied by the gneisses. A plain of till, with a breadth of one mile and a half, borders the hills on the east. Then there is a drop of fifty to one hundred feet, to the level of a sand plain, which has a breadth of from three to four miles. For the last three miles to the lake, rock ledges protrude frequently through the

* Report of New York State Geologist for 1893, Vol. I., pp. 454–458.

Champlain clays and sands, but from thence westward to the hills everything is concealed by the drift and sand.

Series I. Three northeasterly trending gneissic ridges rise in the western third of the township. The most northerly of these is a narrow ridge known as Burnt hill, which rises rather abruptly from the Salmon river valley, but whose summit is only a little above the level of a plain of Potsdam sandstone, which overlaps it on the north. In the central-west is the wide, massive ridge of Terry mountain, and to the south is a somewhat disconnected ridge coming in from Black Brook, the most easterly summit of which is called Mt. Etna. The larger part of the gneiss is of the ordinary microperthitic variety. A quite prominent gneiss on Mt. Etna is a quartz plagioclase gneiss, with some microcline and orthoclase, and with hornblende, biotite and magne-



tite present in considerable amount, so that the rock is well foliated. The Burnt hill gneiss contains much microcline, that mineral often constituting more than fifty per cent. of the rock.

Series II and *III* do not appear in the township.

Series IV. Potsdam sandstone. Though the Potsdam must occupy much of the central part of the township, the exposures, with one exception, are close to the gneiss, poor, and possess no special interest. At Lapham's mills the Little Ausable is in a new channel, and about thirty feet of Potsdam is there exposed, all rather coarse, some of it red, but mostly buff or brown in color. The dip is to the southwest, and rocks of Calciferous age surround it on all sides. That in the river bed at Peru, one mile to the southwest, has the same dip, while the exposures to the north and east dip to the northeast, and a fault must lie between them and the Potsdam, this fault being probably along the summit of a low fold.

Calciferous sandrock. Rocks of Calciferous age apparently form the surface over most of the eastern third of the township, although no certainty can be reached upon this point, due to the scarcity of exposures. The outcrops are small and isolated, and generally give no clew to their horizon in the Calciferous, being for the most part of the iron-grey dolomite which constitutes such a large part of the formation. Just north of Lapham's, are meagre outcrops of very sandy dolomites, which weather to deep ferruginous, sandy, brown crusts, and seem to belong to Division D, of Brainard and Seely.

Along the lake shore, both north and south of Valcour, rocks of this age outcrop for a distance of a mile or more. The major part of the rock is a hard grey dolomite, full of seams and balls of calcite, and in some layers quite fossiliferous. Interstratified with them are thin bands of limestone, more abundant toward the top. Here limestone is also found in irregular lenses, which are full of fragmentary fossils, looking as if they had been worn on a beach. An *Ophileta*-like form also occurs, and is the only species found entire. The rocks lie in a series of low east and west folds, with a slight fall of the whole toward the north. They are well toward the top of the Calciferous, and are followed a short distance to the north, apparently conformably, by the lower Chazy. The whole mass is penetrated by irregular slaty seams.

Chazy limestone. From Valcour northward along the lake shore, rocks of Chazy age outcrop in a belt about half a mile wide, abruptly terminating on the west along a fault line, the Bluff Point fault. The exposures are rather infrequent, and the district needs detailed study, but everything seen seems referable to the lower part of Division A, of the Chazy. On Mr. Day's land two quarries have been opened in the rock, one near his house and one by the lake. In the upper quarry especially, the rock is quite fossiliferous, and good collections can be made. A large *Nautilus* is conspicuous among the fossils. Mr. Day has an excellent *Lituites* obtained from the quarry. Trilobite fragments abound, mainly of *Illænus* and *Harpes*, and several species of brachiopods are present, *Orthis costalis* being the most common form. The locality is one of considerable palaeontologic interest.

Series V. Eight dikes have been found in Peru, of which six are diabases, and call for no special mention. The other two cut the Chazy limestone, near the lake shore, and are of interest on account of the rarity of dikes in the county outside of the pre-Cambrian rocks.

No. 2, in the field just south of the Day quarry, is a typical camptonite, the only one so far found in the county. It may be traced clear to the lake shore, a distance of some 600 yards. Unfortunately it does not furnish very fresh material.

No. 3 lies one-fourth of a mile south of the other, and is a beautiful monchiquite. Material may be obtained in which even the olivine is quite fresh. The strike of this dike would carry it over to the southern part of Valcour Island, and it may be the same dike as the one found there by Brainard and Seely. As far as can be told from the description, the two are quite similar. But in so disturbed a region such identifications are extremely hazardous.

Schuyler Falls.

There is little of interest in the geology of this township. The extreme eastern edge of the Burnt hill gneiss comes into the southwestern corner from Peru. With this exception the only rock exposed in the township is the Potsdam sandstone, though it is reasonably certain that the Calciferous is also present in the east, obscured by the heavy sand. The western part of the township is occupied by Potsdam, lying at a tolerably high level, and continuous on the west with the Hardscrabble Potsdam in Saranac. The gorge of the Saranac river, at Cadyville, is cut in the eastern edge of this plateau, and exposes an excellent section. The old channel of the river lies to the northward and is filled to the brim with drift. Along the Salmon river the rock is well exposed at Schuyler Falls village, and less well at Norrisville. In the exposures is much red rock, and some that is tolerably coarse, but whether low or high up in the formation does not appear.

Series VI. All the eastern half of the township is heavily covered with sand, the level ranging from 300 to 400 feet altitude. Occasional cuts show the clay below. Further to the west the prevailing cover is still sand, though at higher level, and becoming more and more confined to the vicinity of the river. Along the Chateaugay railroad the sand shows grandly, much of it being bare and forming dune-like ridges. Cuts in the river bank at Morrisonville show an esker-like deposit of coarse sand and gravel, with small somewhat rounded boulders. Its summit lacks a few feet of reaching the level of the sand plain, so that its presence would be unsuspected were it not for the river channel.* A precisely similar section is shown along the Salmon river just west of Schuyler Falls, which may represent a prolongation of the same deposit.

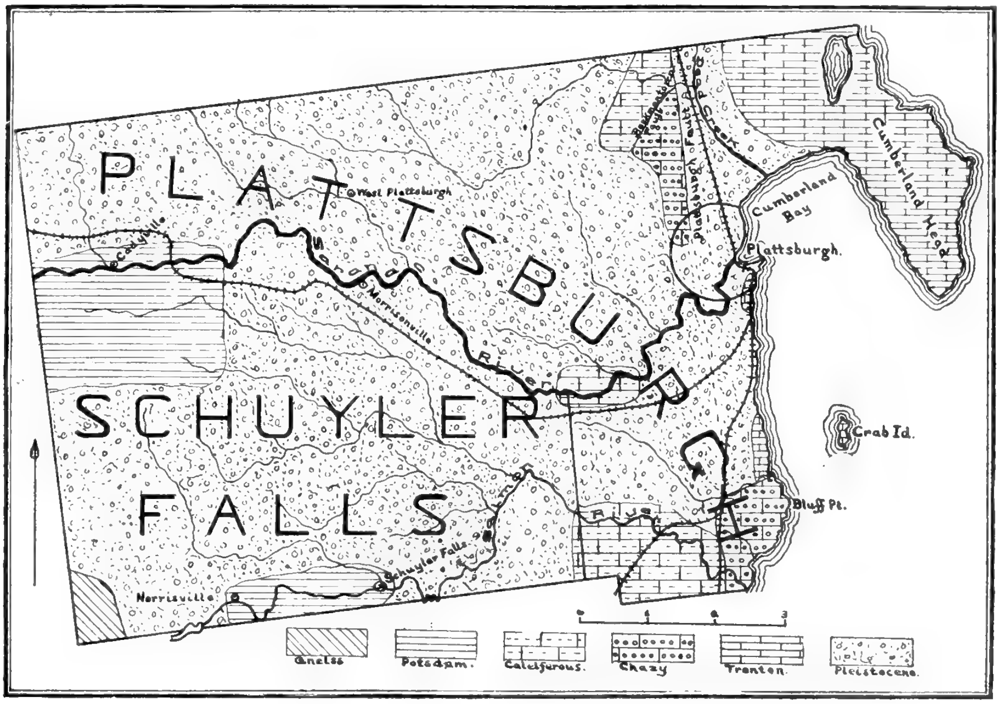
* This esker (?) is noted by Mr. Baldwin in *American Geologist*, March, 1894, page 177.

Plattsburgh.

No pre-Cambrian rocks occur in Plattsburgh.

Series IV. Potsdam sandstone. Except for the river exposures at Cadyville just alluded to, the Potsdam does not outcrop in the township. In fact, with this exception there is not an outcrop of any kind in the western three-fourths of Plattsburgh. This wide belt must be underlaid in part by rocks of Potsdam, in part by those of Calciferous age; but where the boundary between them may lie is purely a matter of assumption.

Calciferous sandrock. By the Salmon river, at the bridge two miles above the mouth, several ledges of a hard, dark blue, somewhat calcareous



dolomite are exposed. By the road south of the river a grey dolomite, with seams and spheroids of calcite, is shown. Though no fossils were found, the lithology of these outcrops puts them in the Calciferous, probably well toward the top.

At the pulp mill on the Saranac, three and one-half miles southwest of Plattsburgh, the river is out of its old channel for a short distance, and exposes a vertical section of some fifty feet, showing heavy, dark blue-grey dolomites, which hold spheroids of calcite, and weather to a yellow color, interstratified with dark calcarous slates. No fossils were found, and no other exposures are near, to aid in determining the horizon, which is regarded as Calciferous, though with some hesitation, it being possible that the rock belongs at the base of the Chazy.

Along the road to Beekmantown Corners, north of Plattsburgh, a long ridge of rock of Calciferous age is exposed, mainly of a flinty, grey dolomite in massive beds lying nearly horizontal. In the bed of Kennon brook, nearly to the Beekmantown line is a considerable exposure, exhibiting some twenty feet of rock, the lower part consisting of dark blue, sparkling dolomites mingled with lighter colored, more sandy beds and thin layers of white, hard sandstone, while above are massive iron-grey dolomites. These beds are well down in the Calciferous, higher layers coming in above them in Beekmantown.

Chazy limestone. The Chazy is excellently exposed on, and southward from Bluff Point, and also north of Plattsburgh, where it lies just to the east of the Calciferous exposures described above.

Brainard and Seeley have written briefly of the Bluff Point exposures.* The point is a conspicuous topographic feature, rising sharply to an altitude of 170 feet above the lake, and being the only high ground along the shore in the entire county. It is a fault block with a resistant stratum at its summit. Nearly the whole of the middle Chazy and about one hundred feet of the lower division are well exposed. By following along the ridge southward from the point, into Peru, nearly the whole lower division may be brought into the section. The whole series is characteristically fossiliferous. Along the lake shore at the boat landing, the beds shown are well up in the *Maclurea* division, are much jointed, and contain abundantly a large strophomenoid form, much like *R. alternata*, of the Trenton, for which it was taken until the discovery of *Maclurea* threw doubt upon the identification. Several other species may also be collected there.

Just south of Bluff Point is a large quarry, worked in a layer of the lower division in which the crinoidal fragments have a red color. Much stone has been, and is being taken out, which, when polished, makes a beautiful and striking marble.

The Chazy north of Plattsburgh is in a much faulted district, and has been mapped in detail. At the normal school, beds of lower Chazy age are exposed, which crop out again going north, and are then succeeded, just beyond the race track, by the lower *Maclurea* beds. These continue along the road for a distance of nearly a mile, with a sinuous strike. They consist mainly of massive, nearly black limestones, and are largely quarried. With

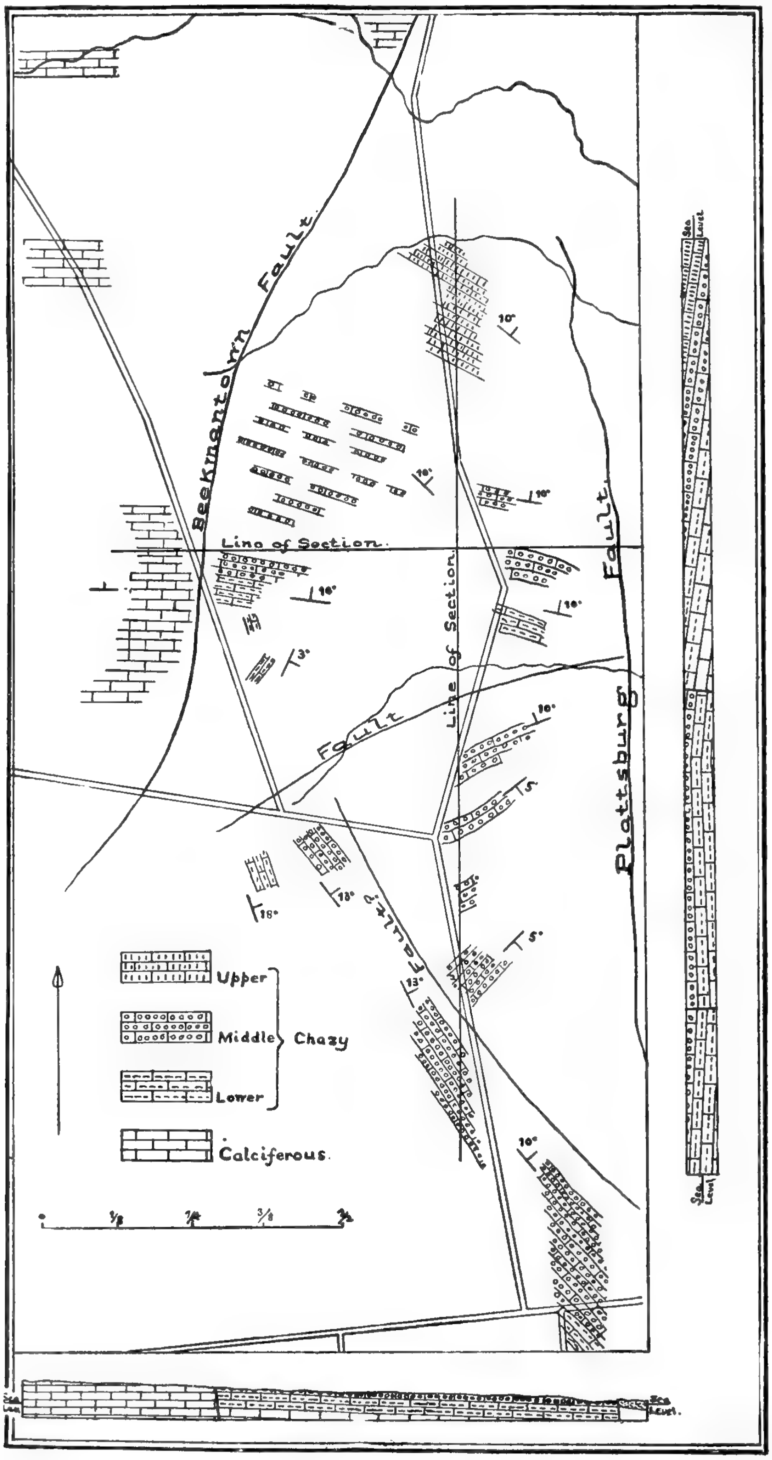
* Bulletin Geological Society of America, Vol. II., p. 295.

these are thin-bedded, rather shaly bands, with an abundant brachiopod fauna. Just beyond the three corners, a little over a mile north of Plattsburgh, is an east and west fault, bringing up again the upper beds of the lower division on the north side. This is followed at once by the *Maclurea* beds again, and thence northward the entire *Maclurea* division and a large part of the upper Chazy appear within the space of a mile, the latter well exposed and abundantly fossiliferous. The final exposures are less than half a mile from the Beekmantown line, and are succeeded, in the direction of dip, just across that line by massive dolomites of Calciferous age. If the section of the Chazy here be combined with the Bluff Point section, a nearly complete exhibit of that formation is obtained.

Trenton limestone. The best exposures of the Trenton to be found in the county are in this township, but the base, the Black River limestone, is nowhere exposed. Along the lake shore, just south of Bluff Point, and extending for a third of a mile, are beds of Trenton age. They are separated from the Bluff Point Chazy by an east and west fault, with a throw to the north of about 200 feet. A small stream occupies the fault line. The section exposes some 100 feet of the Trenton. At the south end the dip is steep, the beds being tipped up along the fault. The rock is, for the most part, a black slaty limestone with lighter colored limestone bands toward the base, which contain the brachiopod fauna characterizing the lower 100 feet of the Trenton in Chazy township. The upper two-thirds of the section is quite barren of fossils, occasional trilobite fragments occurring. Similar beds are found in the same position on Crab island, which lies one mile to the eastward. The section there has already been briefly described. The island is structurally a low anticlinal fold, pitching to the north about five degrees. The upper 100 feet of rock exposed there, carrying a lamellibranch fauna, is shown nowhere else in the county.

On Cumberland head, and thence northward into Beekmantown, are the slaty exposures already described. They are younger than any of the Crab island Trenton, and separated from that by an unknown vertical interval. Just south of the breakwater at Plattsburgh, similar slates are exposed on the shore, in which no fossils have been found, but in which thorough search should be made, as they may be found to partially fill this gap. Lithologically they resemble the Cumberland head series much more than they do the ordinary Trenton.

Faults in Series IV. The whole Palaeozoic series is greatly faulted. Though much remains to be done in working out the faults, especially the minor ones, the greater breaks stand out prominently, and deserve mention. The Bluff Point Chazy is cut off sharply on the west by a north and south



fault of considerable extent and magnitude. In southern Plattsburgh, however, no rock shows to the west of the fault line. It may be traced to the south into Peru, and well to the north also. We may call it the "Plattsburgh fault." Just north of Bluff Point, the east and west fault, already described, runs out to meet it. The throw of this, which may be called the "Bluff Point fault," is to the north, and an approximation to its amount may be had. The entire upper division of the Chazy, 200 feet thick on Valcour island, fifty to 100 feet of the middle division, and fifty to 150 feet of the Trenton are missing, so that the vertical displacement is from 300 to 400 feet. North of this fault, the Plattsburgh fault is not traceable for nearly four miles, on account of the total lack of exposures, but north of Plattsburgh city, on the prolongation of the fault line, is a displacement which is thought to be the same. Here the Chazy exposures on the west side are sharply cut off at an angle with their strike. To the east no rock is exposed for a distance of one mile and a half, when the Cumberland head slates come in. Though the fault line is strongly marked wherever shown, no data are available for determining the amount of displacement. The throw is to the east, and must be large.

Three-fourths of a mile to the west is another great fault, very well shown, which brings up the Calciferous against the Chazy. The horizon in the Calciferous has not been determined, but is apparently well down, so that the entire lower division of the Chazy, over 300 feet thick, and probably a much greater amount of the Calciferous, are faulted out, the throw again being to the east. This fault may be named the "Beekmantown fault." It has a more easterly trend than the Plattsburgh fault, so that the two appear to effect a junction on the Beekmantown line, shutting out the Chazy altogether, and bringing the Calciferous and Cumberland head series into contact in southern Beekmantown. The displacement here, therefore, must be very great, as the entire Chazy, all the ordinary Trenton, and an unknown amount of the Calciferous are missing, and 1,500 feet would be a very moderate estimate of its amount.

These three, together with the cross-fault in the Chazy beds between the Plattsburgh and Beekmantown faults, are the main faults in the township. Small faults occur on Cumberland head, and the slaty cleavage there developed in the whole series would probably be represented by a considerable fault, were the beds more rigid. No doubt other faults occur, but the paucity of outcrops renders their discovery and decipherment nearly impossible.

Series V. Only two dikes have been found in the township, but they are of interest as, together with the South Hero dikes described by Kemp, they are the most northerly of the post-Utica basic dikes known along the lake Champlain meridian.

Dike No. 1 is exposed by the roadside on the road south from Plattsburgh, a few yards beyond the point where it rises from the sand plain on to the Bluff Point limestone exposures. It is a quite typical monchiquite, with very abundant olivine phenocrysts, often perfectly fresh, which speck the dense black rock with white spots. Occasional small porphyritic augites also occur. The dike being so narrow, the ground-mass is very dense throughout, and consists of small, slender augites, magnetite and sparse brown hornblendes set in an apparent glassy base, most, if not all of which has a very weak double refraction, and thorough investigation may show the presence of analcite.

Dike No. 4 cuts the Trenton north of Bluff Point, and is near the south end of the section. It is largely made up of a nearly colorless augite, which occurs in two generations, phenocrysts, however, being only occasional. Olivine is present,. but rare, and can not be regarded as an essential constituent. Hornblende is absent except for a few green, uralitic crystals of secondary origin. Magnetite is present in considerable amount, and there is also a notable quantity of biotite in the ground-mass, some of which is certainly primary. The rock contains numerous round white spots, giving it an amygdaloidal appearance. In the centre of the dike is a strip six inches wide which is clearly marked off from the rest, runs the whole length of the dike, and gives the impression of a second dike cutting the first. The rock is of the same character, however, though the white spots are less abundant than in the main dike. Under the microscope these white spheroids are seen to be formed of a colorless, isotropic mineral, which by means of a gypsum plate, is seen to be optically anomalous, in that it shows faint double refraction. The mineral seems to be analcite. Some of the spheroids contain also calcite crystals. Inclusions of biotite, apatite and hornblende, of rather large size, occur in the analcite. The spheroids are not sharply bounded, but grade into the rock. Considerable analcite is also present in the ground-mass of the rock.*

Dike No. 19, from Crab island, is quite similar. It is made up of augite, biotite and magnetite, with glassy base, but it lacks the analcite spheroids, and instead is amygdaloidal, the cavities being filled with calcite and zeolites other than analcite. It has numerous and large porphyritic augites.

* Since the above was transmitted for publication, the article published by Professor L. V. Pirsson "On the Monchiquite or Analcite Group of Igneous Rocks" has appeared (Journal of Geology, Vol IV., p. 679). Pirsson shows the presence of analcite to be a feature of these rocks. The analcite in Dike No. 4 seems to be primary.

Series VI. The widespread sand deposits of the Saranac, form here, as in Schuyler Falls, the most conspicuous feature of the Pleistocene deposits. Away from the river in the northwestern part of the town, heavy morainic deposits come in above the level of the sand plain.

Beekmantown.

Series I to III. The only Pre-Cambrian outcrop in Beekmantown is found on Rand's hill, a wide northeast and southwest ridge running from western Beekmantown into southern Altona. On the east and south, a heavy mantle of drift covers the flanks of the hill, concealing the extent of the rocks in those directions. The ridge is made up, for the most part, of anorthosite which is flanked on both sides by gneiss. On the east is a microperthitic gneiss of brown color, which contains both green monoclinic pyroxene and hornblende. On the west the only gneisses shown are basic, very schistose hornblende gneisses, both with and without pyroxene.

The main interest attaching to the anorthosite here is due, in the first place, to its distance from the main body of that rock; and, in the second place, from the information it gives regarding the character of the surface on which the Potsdam was deposited. At the present time the hill is entirely surrounded by Potsdam, with the possible exception of a strip half a mile wide. The summit has an elevation of 1,500 feet, while the Potsdam on the west side runs up to 1,400 feet, and we are certainly justified in assuming that at one time the whole hill must have been covered by the sandstone, quite probably to a considerable depth.

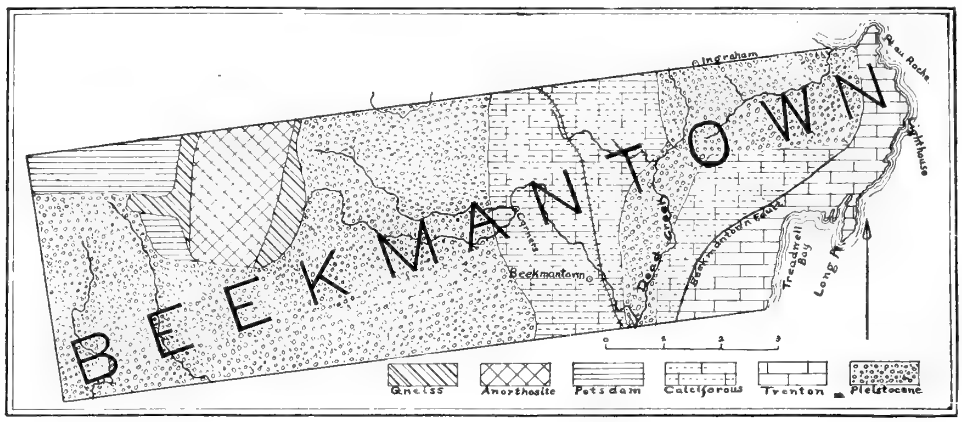
The exposures of the anorthosite in Beekmantown are by no means as good as in Altona, and the rock will be described in the report on that township. Those in Beekmantown are of quite typical anorthosite, but the rock is not fresh.

Series IV. Potsdam sandstone. The only outcrops of this rock seen in the township are along the road over Rand hill, and closely adjoin the anorthosite on the west. The exposures are tolerably frequent, but very poor and the only rock seen is of the red, feldspathic, easily disintegrating variety. Except for a gap one-half mile wide, occupied by hornblende gneisses, the Potsdam exposures are practically continuous along the west side of the anorthosites, and the road is reddened throughout the larger part of its length, by the degraded rock. No conglomerates were seen.

East of Rand hill, the very heavy drift-covering completely hides all rock from view till the Calciferous exposures in the central part of the town are reached. To the south, too, everything is concealed. Much of this covered territory must be occupied by the Potsdam.

Calciferous sandrock. This formation is better shown as a whole in Beekmantown than anywhere else in the county. In the central portion of the town, within a radius of two miles from Beekmantown Corners, are many exposures, the aggregate thickness of which must be very great. One mile north of Beekmantown station, is the fossiliferous locality which has been described by Professor Whitfield,* where beautiful Ophiletas may be obtained in abundance. The other exposures are of very sandy grey dolomites, sometimes passing into nearly pure white sandstone. All the Calciferous here seems to belong to Divisions C and D, of Brainard and Seely.†

Southward from Beekmantown village, a well marked ridge of Calciferous dolomites runs southward, and is continuous with the Calciferous



that lies west of the Beekmantown fault in Plattsburgh. The best exposures are at the Poor-house. The fault passes into this township, but its course has not been definitely traced.

Exposures along the Lake. Cumberland Head Series. The black slaty limestones of this series extend into the township from Plattsburgh, and are exposed along the shore of Treadwell bay and thence westward for a mile. The exposures form a series of narrow, sharp ridges, the topography resulting rather from the slaty cleavage than from the dip of the rocks. The fossils are the same as on Cumberland head.

On the shore at Long point and to the northward, are similar rocks. They have so far furnished no fossils, and require further study, but are classed with the preceding provisionally, on account of the lithologic and

* Bulletin American Museum Natural History, Vol. III., p. 2.
† Bulletin American Museum Natural History, Vol. II., p. 48.

topographic similarity. They lie well to the eastward of the Treadwell bay exposures, as though shifted by a fault. If that be not the case, they are at a higher horizon.

Rocks of Uncertain Age. Closely adjoining these Cumberland head slates on the west, are hard, grey dolomites, which form occasional knolls protruding above the general surface. In one of the exposures, limestone bands occur, which are full of fossil fragments, and similar to the bands described from the upper Calciferous in Peru, just north of Valcour. These rocks would be unhesitatingly classed as Calciferous, were it not for their position. It seems certain that they must belong to that group, and they are so represented on the map. Yet they are separated from the main exposures of the Calciferous in central Beekmantown by a wide valley in which no exposures occur, while the topography gives no indication of a fault between them and rocks close at hand on the east, which lie at least 1,500, and probably 2,000 or more feet higher in the section. This may be the line of the Beekmantown fault. It is at least certain that throughout this territory the entire Chazy is faulted out.

Along the lake shore, from the extreme end of Point au Roches, southward to the lighthouse, are pretty continuous exposures of blue and black limestones, at times somewhat slaty, but ordinarily massive. They are very barren of fossils, holding *Leperditia* in some layers but little else, so far as found. The top layer at the Point is charged with marcasite and contains *Leperditia* and a *Holopea*-like gasteropod, abundantly. The section has considerable thickness; just how much, remains to be determined, but one hundred feet is a very modest estimate. The writer is unable at present to indicate the precise stratigraphic position of these rocks. Mr. Van Ingen writes that the *Leperditia* layer at the Point recalls the basal bed of the Black River limestone on Button Bay island, and is disposed to correlate it with that, and to regard all the rest as of Chazy age. While this is quite probably the proper interpretation, the entire lack (or apparent lack) of the fossils which elsewhere in the county abound in most of the upper Chazy, is an objection to it. The rock closely resembles some beds found in the upper Chazy, but they nowhere exhibit anything like the thickness shown here. It is therefore thought that we may here have beds of Trenton age not met with elsewhere in the county, occupying a position either just above, or just below the Cumberland head series, and they are provisionally indicated as such on the map. If they are of Chazy age there must be a considerable fault between them and the Trenton slaty limestones north of Long point.

Such indecisive results are presented very apologetically. The scarcity of fossils and the lack of time for work of the detailed character necessary are accountable therefor.

Series V. The eight dikes found in Beekmantown, are all on Rand hill, cutting the Pre-Cambrian rocks. The proportion of bostonites is greater than usual, six of the dikes being of that type. These show well the very considerable variation which such rocks present. Dikes Nos. 28 and 29 are of dense, hard red rock of aphanitic, stony look, almost entirely devoid of phenocrysts, and with very small content of ferro-magnesian silicates. Nos. 27 and 107 have a peculiar schistose appearance in the hand specimen, as if they had been subjected to shear, but the appearance is entirely lost in the thin section, which appears quite normal. They contain a larger proportion of dark silicates than the first two. No. 27 has also abundant orthoclase phenocrysts of unusual purplish color, which is due to the filling of the cleavage cracks by hematite.

Nos. 31 and 103 are nearly black rocks, likely to be taken for diabases in the field unless carefully inspected, but in the slide are quite like the others except for the presence of a much greater amount of hornblende and biotite. These occur mainly as inclusions in the orthoclase, and the trachytic structure is not well defined.

Series VI. Rand hill is so heavily banked with glacial deposits on the east, south and west, that all rock is obscured by them for a distance of at least two miles in these directions, and commonly for more. The surface is everywhere strewn with loose irregular blocks of Potsdam sandstone. These accumulations may be morainic in origin, as suggested by Mr. Baldwin,* but no opportunity was afforded for closely investigating them.

Altona.

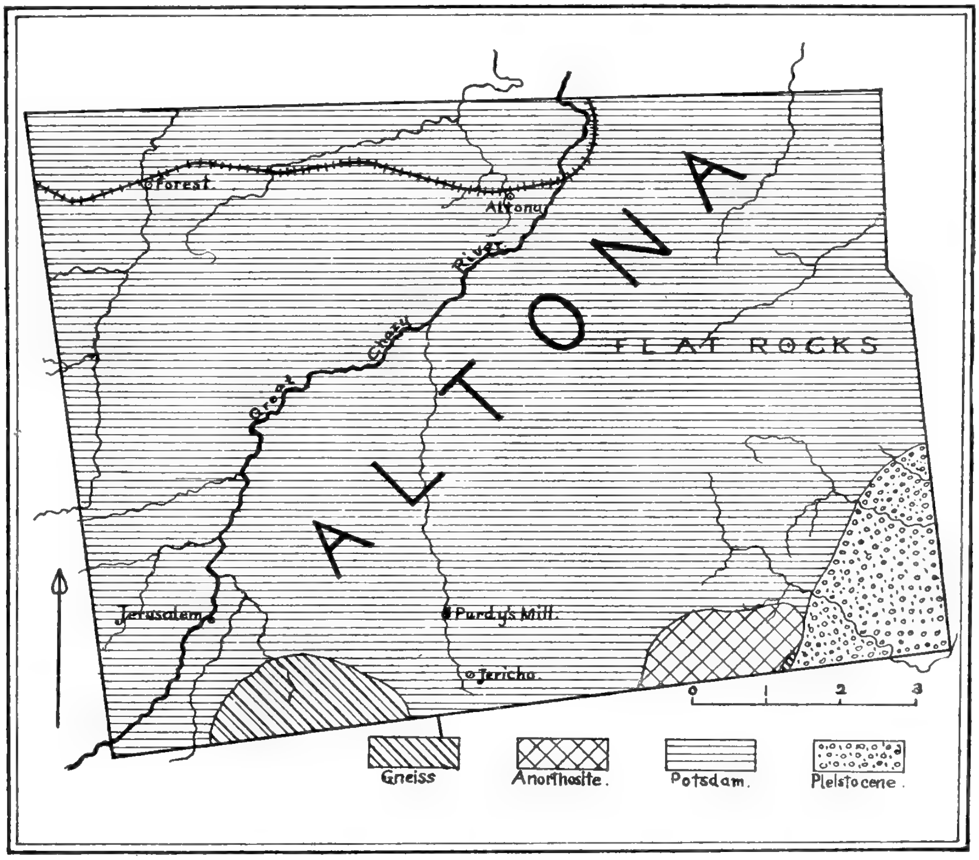
Series I. Gneiss of the ordinary microperthitic variety is exposed on the eastern side of Rand hill. Its contact with the anorthosite is shown along the turnpike (old military road) and exhibits a transition zone, a few feet in width, of a rock of intermediate mineralogic constitution. This transition rock has cataclastic structure and shows a dike-like dark band which proves to be a sheared strip, consisting of a finely granular aggregate of quartz, microperthitic orthoclase, augite, garnet, and a little plagioclase. The garnet is certainly secondary, and much of the rock has undergone recrystallization.

* American Geologist, Vol. XIII., p. 181.

The north end of the Dannemora mountain gneissic ridge projects into the southwestern part of the township, the rock being the pyroxenic gneiss usual on that ridge.

Series III. Anorthosite forms the main part of Rand hill here, as in Beekmantown. Excellent exposures may be seen along the turnpike and thence southward up the hill. The surface rock is fresher than in Beekmantown, probably due to the more energetic action of the ice-sheet on the northern slopes of the hill.

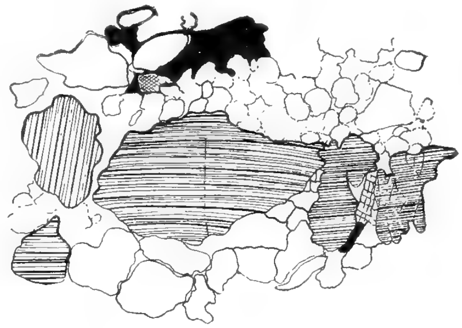
As here shown, the rock is less completely granulated than the Keeseville rock, in much of which no large fragments remain. Here none of it has



undergone complete granulation and much of it is quite coarse, so that the large labradorites, instead of the granular portions, give the main color to the rock.

Garnet is very abundant, much more so than in the Keeseville rock, so that frequently the granular matrix which surrounds the labradorite individuals has a very pronounced dark red tinge. Some portions of the rock consist entirely of garnet and labradorite. Generally, however, augite and magnetite are also present and hornblende is common. Hypersthene has not been observed here, nor in any of the anorthosite in the county. As was to be expected from the less complete granulation, but little of the rock is foliated, the basic minerals occurring in clumps rather than in streaks.

A short distance up the hill from the turnpike, a well foliated gabbro outcrops. Owing to the tangle of brush and the thin soil covering, its extent could not be determined, but it is not great. It is less basic than the ophitic gabbros, and lacks that structure; neither have the uncrushed labradorites the abundant inclusions which characterize those of the ophitic gabbro. Besides the labradorite the rock contains much garnet and magnetite, considerable apatite, and what was probably augite now wholly passed into chlorite. Granulation is not complete. The labradorite crystals which have partially escaped this process, show beautiful polysynthetic twinning, and exhibit most notably effects of the dynamic action other than the granulation. Not only are they broken and the fragments displaced, but nearly all are bent, the bending being most clearly brought out by means of the oft-repeated twinning, as shown in the accompanying figure drawn with the camera lucida.



Broken and bent labradorite crystal from gabbro on Rand hill, Altona. The surrounding granular material is almost wholly labradorite.

Series IV. With the exception of the small areas just noted, the Potsdam sandstone is the surface rock throughout the township. Moreover, here is by far the most impressive display of this rock to be seen in the county, if not in the state. Extending north from Rand hill is a plateau of nearly horizontal Potsdam sandstone, running up to heights of 1,100, 1,200, and even 1,500 feet, and stretching away northward with an average fall in level of from seventy-five to one hundred feet per mile. For the most part it is very bare of debris, and on the steeper slopes the naked ledges of stone rise in a series of gigantic steps, as if they had been swept bare of debris by powerful currents. The district goes under the name of the "Flat rocks." It is rather deeply incised by the Great Chazy river but otherwise is not deeply dissected by erosion, appearing as a base level of tolerably recent elevation. Rand hill is a monadnock rising above this level.

It is very difficult to get any trustworthy conception of the thickness of the Potsdam as here exposed. The rock lies in a series of slight north and south folds, with such a slight dip, that it is no easy matter to determine the amount of pitch. The pitch is quite certainly to the north, and somewhat in excess of the fall of the surface in the same direction. The floor on which the rock was laid down also falls to the north, and at a greater rate than the dip of the rock.

Heavy basal conglomerates, such as those in Ellenburgh, make but little show in Altona, very possibly because of the lack of exposures in the vicinity of the crystallines, though this can not be the whole reason. Several outcrops of small extent, but occurring within a few yards of anorthosite or gneiss, are found on Rand hill, and are all of red, feldspathic, easily degraded type, with no sign of conglomerates. Away from the crystallines the rock presents its usual variations in color, size of grain, and degree of induration.

Series V. The most impressive display of dikes to be seen in the county is exhibited along the turnpike where it passes over the northeastern edge of Rand hill. The anorthosite here is seamed with dikes, some of which are very large and complex, branching repeatedly and covering considerable territory. These vary so much from place to place that measurements five yards apart would give wholly different results, but the complexity is well illustrated by the following careful measurement of a portion of Dike No. 8, made along the surface in a north and south direction. Commencing at the south is

1. Anorthosite,		
2. Diabase,	8 ft. 1 in.	
3. Anorthosite,	11 " 9 "	
4. Diabase,	0 " 9 "	
5. Anorthosite,	16 " 2 "	
6. Diabase,	23 " 8 "	enclosing three small horses of anorthosite.
7. Anorthosite,	91 " 4 "	
8. Diabase,	1 " 10 "	
9. Anorthosite,	2 " 0 "	
10. Diabase,	1 " 7 "	
11. Anorthosite,	15 " 0 "	
12. Diabase,	4 " 0 "	
13. Anorthosite,		

The sub-divisions of this dike bear in all directions, re-uniting and forking again, so that several of the anorthosite members of the section represent enormous horses in the diabase.

Fourteen dikes have been found here within an area of less than a square mile, and if all the branches were counted separately this number would be trebled. The heavy second-growth on Rand hill undoubtedly conceals many more. The only two of these dikes that call for any especial mention are the two bostonites.* No. 7 is of the red, aphanitic type, with numerous small porphyritic orthoclases showing. It contains a little magnetite and chlorite, and the flow structure of the ground-mass is well marked. No. 9 represents the other extreme of these rocks. It is coarser, the whole appearing holocrystalline to the eye. It is much darker in shade, due to a large biotite content. Both orthoclase and biotite occur in two generations, the orthoclase phenocrysts reaching a length of over one centimeter. The ground-mass is quite coarse, and contains apatite and augite in addition to the orthoclase and biotite. Quartz has not been recognized; if present it is only sparingly so. This is the only dike of this type so far noted in the region which has phenocrysts of a ferro-magnesian mineral, and the great abundance of the biotite in this dike is quite unusual.

Chazy.

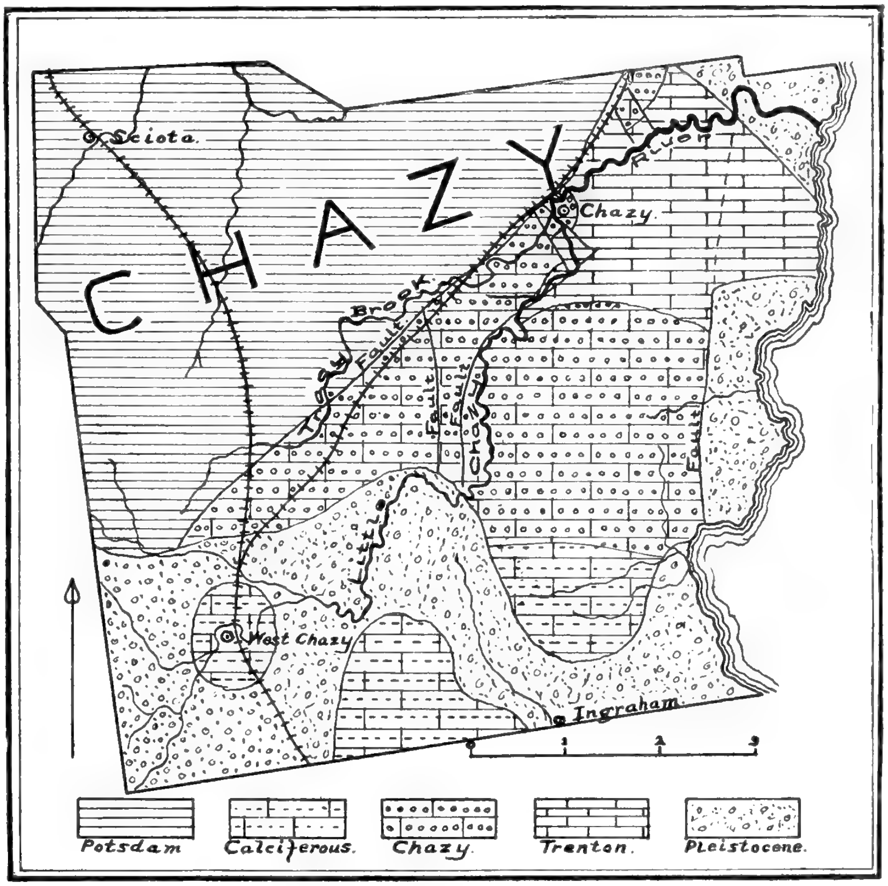
No Pre-Cambrian rocks appear in Chazy township.

Series IV. Potsdam sandstone. The Potsdam occupies the northwestern half of the township. That on the extreme west belongs to the high plain and pertains to the basal part of the formation. That on the low grounds, on the contrary, is toward the summit, the passage beds to the Calciferous appearing just over the border in Champlain township. A great fault separates the high level from the lower Potsdam, and another great fault lies between the Potsdam and the Ordovician limestones to the east of it. Most of the rock is of the ordinary character, and calls for no comment. A curious black layer, several feet thick, is exposed in a railroad cut just north of Chazy depot. While mainly a quartz rock, occasional grains of orthoclase, microcline, plagioclase, hornblende and magnetite occur, and large zircon grains are a feature. The quartz is full of minute black inclusions, and there is also a black cement of uncertain nature to which the color of the rock is due.

* Trachytes would be a better term as that is what the rock is, and no useful purpose is served by the use of the other so far as the writer can see. It is used here merely to make the nomenclature conform to that already in use in the region.

Calciferous sandrock. This formation, which is so widespread in Beekmantown, just to the south, makes but little display in Chazy, appearing only in the extreme south, where the upper beds are shown, soon to be followed toward the north by the Chazy. The exposures are poor and possess little interest.

Chazy limestone. Here is the type locality of the Chazy, and nearly the whole of the formation is exceedingly well shown. In the near vicinity of



Chazy village it has been carefully sectioned and mapped by Brainard and Seely. For convenience of reference their section is here reproduced.*

MEASUREMENTS AT CHAZY IN ASCENDING ORDER.

Group A.

1. Iron-grey, fine grained dolomitic limestone, in beds one or two feet in thickness, weathering drab with fine yellowish streaks at right angles to plane of bedding, containing *Orthis costalis* and crinoidal fragments, ... 110 ft.

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* American Geologist, November, 1888, p. 324.

2. Tolerably fine limestone, filled with fragments of crinoids, containing *Orthis* and *Strophomena*,	20 ft.
3. Measures concealed,	40 "
4. Impure limestone, filled at bottom with *Orthis*, thin-bedded when long exposed to weather, the upper six feet abounding in crinoidal fragments,	30 "
5. Fine-grained, massive limestone containing *Scalites angulatus*, *Raphistoma* and fragments of trilobites,	25 "
6. Impure limestone abounding in *Orthis*,	10 "
7. Measures concealed,	25 "
8. Massive grey limestone, largely made up of crinoidal remains, having red spots in a stratum about ten feet from the top; abounding with gasteropods near the middle,	50 "
	310 ft.

Group B.

1. Thick-bedded, nodular, dark-colored limestone, containing *Maclurea magna*,	50 ft.
2. Massive, pure limestone, grey, fine-grained, often oölitic, abounding in crinoidal remains and *Stenopora fibrosa*,	20 "
3. Massive, bluish-black, tolerably pure, nodular limestone, containing *Maclurea magna* and masses of black chert,	45 "
4. Similar to No. 3, but containing in addition to *Maclurea*, various species of *Orthoceras* and large masses of *Stromatocerium*,	90 "
5. Less massive limestones, quite impure, and often disintegrating into nodules as though shaly,	60 "
	265 ft.

Group C.

1. Dark, iron-grey dolomite, weathering yellowish,	1 ft.
2. Blue, compact, fine-grained, pure limestone, containing fine lines of calcite,	6 "
3. Dove-colored, compact, brittle, perfectly pure limestone, containing small nodules of calcite,	5 "
4. Iron-grey dolomite,	$3\frac{1}{2}$ "
5. Like No. 3, only containing larger calcite nodules,	$4\frac{1}{2}$ "
6. Dark-grey, fine grained, compact limestone, somewhat impure, having a mottled aspect when weathered, containing undetermined species of *Murchisonia* and *Orthoceras*,	2 "

7. Iron-grey dolomite,	1 ft.
8. Blackish, impure limestone, abounding in *Rhynchonella plena*,	36½ "
9. Grey, massive, coarsely granular limestone, mostly made up of crinoidal fragments, which are sometimes red, containing *Rhynchonella*,	26½ "
10. Same as No. 8,	32 "
11. Measures concealed,	7 "
12. Tough, impure dolomite,	8 "
13. Measures concealed,	24 "
	157 ft.
Total thickness of A, B and C	732 ft.

In the southern part of the township the lower division of the Chazy is widely exposed, especially toward the west, but it is much disturbed there, and no section has been seen as good as that quoted. Running due south from Chazy village, and lying just to the east of the territory included in their map, is a long section of slight dip, extending unbroken from the Calciferous up into the basal Trenton, though much of the upper and lower divisions of the Chazy are not well exposed. It is the only section in the county, except the one on Valcour Island, which shows the entire Chazy, but it is not well adapted for a determination of the thickness on account of the slight dip.

Some layers of the Chazy were formerly quarried in the township for building stone, but the industry has lapsed, probably because of the better quality of stone obtainable from Isle la Motte.

Black River limestone. Nowhere else in the county has this rock been found well exposed, but it is admirably shown around Chazy village, and is quarried and burned for lime on a large scale. It is a compact, ringing, massive black limestone, much of it with conchoidal fracture, and has a thickness of thirty feet. It is quite fossiliferous in some layers. A bed twenty feet from the base contains a large *Maclurea* and masses of *Stromatocerium*, much like the Chazy forms, so that when this layer alone is exposed, it is no easy matter to distinguish the two. *Columnaria* is confined to one or two layers just beneath the *Maclurea* bed. Beneath the beds are rather barren, but hold *Asaphus gigas* and lamellibranchs identical with Trenton forms. At the base is a *Leperditia* layer, and the whole rests on a massive, brittle, dove-colored limestone, with conchoidal fracture, which forms the summit of the Chazy, and is missing from Brainard and Seely's section. The rock is very like No. 3 of Division C, of that section.

Trenton limestone. North and east from Chazy village, the lower portion of the Trenton is found exposed, a thickness of about 150 feet being shown. The best section is that in the Little Chazy river, just east of the village, where the dip is high, so that within a short interval, a considerable thickness of the rock is exposed. Alternating beds of black, rather slaty limestone, and more crystalline beds of lighter color, which are full of brachiopods, make up the section. They are in all respects similar to the lower beds on Crab island and in Plattsburgh, but here in Chazy is the only locality found in the county where the Black river and Chazy limestones may be seen in place below them.

Faults. Owing to the better and more frequent exposures, the faults which have dislocated the Palaeozoic rocks are more readily worked out in detail in Chazy than elsewhere in the county. They have already been discussed by the writer, in so far as the stage of the work would permit.* The past season's work in company with Messrs. Van Ingen and White corrected inaccuracies in two instances, and later on some other errors were found.

The most conspicuous and important break shown in the vicinity, is the great fault running across the township from southwest to northeast, and on into Champlain township. It will be called the Tracy brook fault, as the entire course of that stream lies along the fault line. Along its course through Chazy the entire Calciferous is blotted out, the various members of the Chazy and even of the Black river being brought down against the Potsdam. The entire throw is not far from 2,000 feet.

The downthrow block on the east of this fault is much shattered, and consists of a series of small blocks caused by cross faults. The dip is steep, ten degrees or more, and the amount of throw is ordinarily to be determined with ease by the surface shift of the Black river limestone, which forms the most convenient horizon for this purpose. Seven of these cross faults have been identified in a distance of three miles, and doubtless others will be disclosed, as detailed mapping is extended southward. This shattered zone is terminated eastward by another fault, which closely follows the course of the Little Chazy river, and may therefore be called the Little Chazy fault. But to the north and south it passes into drift-covered territory, beyond which it can not be traced. East of this fault is the long continuous section

* Bulletin Geological Society of America, Vol. VI, pp. 285-296.

of the entire Chazy, followed by the Black river and Trenton, which has already been noted. The structure is that of a low anticlinal with northerly pitch.

Still farther east, the Chazy beds are cut off abruptly by an apparent fault at right angles to the strike. No rock shows to the eastward but there is an abrupt fall in altitude of from sixty to eighty feet. This probably represents the northward prolongation of the Beekmantown fault, but has not yet been demonstrated as its equivalent.

Series V. No dikes have been found in the township.

Series VI. Besides the long esker already mentioned, nothing worthy of special description has been noted. The Champlain clays are found everywhere except on the extreme west.

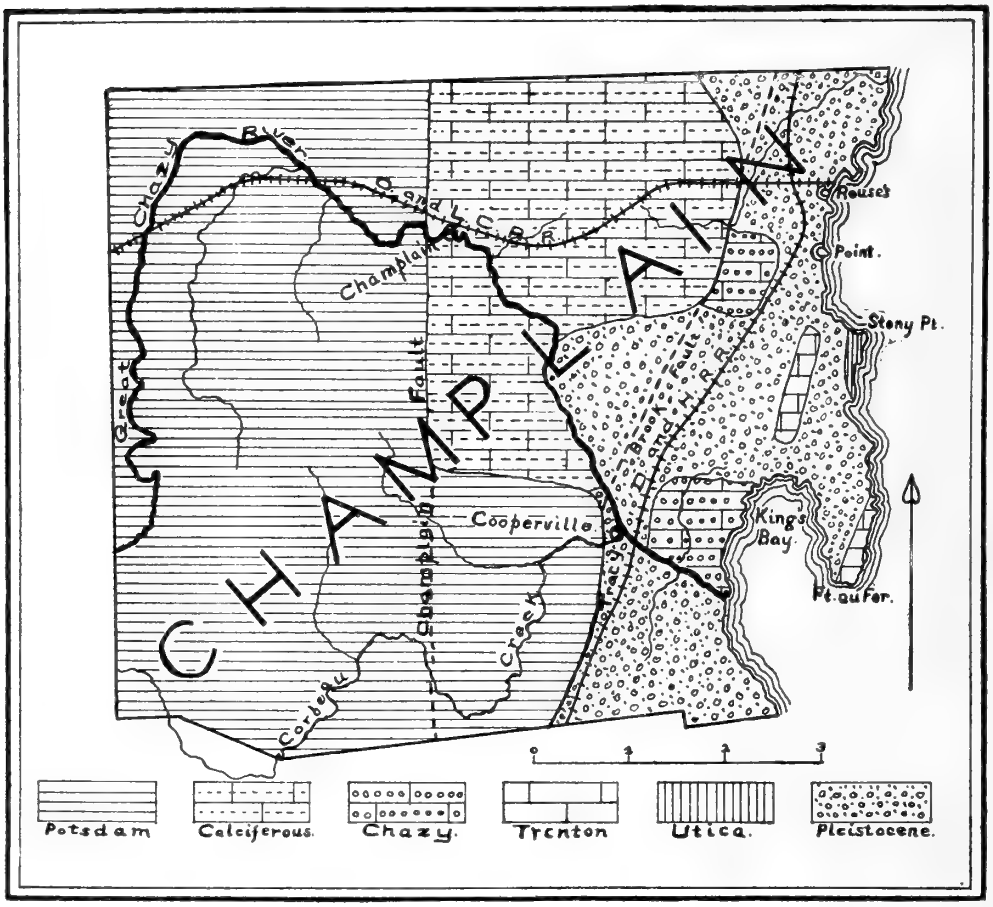
Champlain.

No pre-Cambrian rocks occur in Champlain.

Series IV. Potsdam sandstone. The Potsdam extends into Champlain from Chazy along the west side of the Tracy brook fault. It is exposed quite continuously along the fault line as far as Cooperville. From that point northward, dolomites appear interstratified with the sandstone, marking the passage beds to the Calciferous, and followed by the heavy grey dolomites of the Calciferous itself about a mile north of Cooperville. These continue to the Canada line, the whole with slight northerly dip.

This strip of Potsdam and Calciferous along the west side of the Tracy brook fault, has a width of from two to three miles, and is adjoined on the west by territory in which nothing but Potsdam is found clear to the Canada line, the dip being slightly to the north, as before. Not even the passage beds are seen on the west. There is clearly a fault here running the full length of the township in a nearly north and south direction, and throwing to the east. The amount of throw is purely conjectural as the horizon in the Potsdam on the west side is not known, but it has an undoubted minimum value of 250 to 300 feet. The name "Champlain fault," is suggested for it. Continued to the south into Chazy with the same trend, it would connect with the Tracy brook fault near Chazy village, the junction of the two furnishing an adequate explanation for the prominent ridge of Potsdam with abnormal dips which lies west of the Tracy brook fault north of Chazy village.

Calciferous sandrock. The Calciferous exposures in Champlain are limited to the zone between the Champlain and Tracy brook faults. As these diverge somewhat, the width of outcrop widens northward. In this zone meagre exposures are not infrequent, but do not suffice for the construction of a section. It seems, however, that only the lower division of the formation is represented. The rock is mainly a hard, massive, grey or iron-grey dolomite, but is often very sandy, and in some layers the sand predominates, and the color is lighter. The sand is mainly coarse, and often gives a pseudo-oölitic appearance to the rock. One mile and a half west of Rouse's Point, a



layer of coarse breccia is exposed, the ordinary grey dolomite containing numerous, rather angular pieces of finer grained, more sandy dolomite, of varying size up to four or five inches in length. These pebbles, if they may be so called, are clearly derived from the formation itself, being precisely like layers which occur just beneath the breccia at that point.

Chazy limestone. A portion of the Chazy is well exposed in the district from Cooperville eastward to King's bay. Nearly the entire *Maclurea* division and much of the lower division are well shown and very fossiliferous.

The average dip is ten degrees to the east, while the Potsdam, less than a mile to the westward, has a slight northerly dip, the Tracy brook fault lying between. What is known as the King's bay quarry, is here in the *Maclurea* beds, and formerly considerable stone was taken out here.

Three miles further north, and about two miles southwest of Rouse's Point, another ridge of Chazy limestone protrudes above the surface, and has been quarried somewhat. Only a few feet in thickness of the *Maclurea* beds are seen here. They have the same easterly dip as at King's bay, though steeper, while on the west are nearly horizontal beds of the lower Calciferous, marking the further extension of the Tracy brook fault.

Trenton limestone. The road south from Rouse's Point runs for two miles just east of a low rock ridge, covered only skin deep by soil. A small opening in the rock, about two miles south of the Point, discloses Black river limestone, striking with the ridge, and therefore probably forming the whole of it. The dip is in the same direction as is that of the Chazy, a mile to the westward, so that both probably lie in the same fault block. This is the only exposure of undoubted Trenton (inclusive of Black river) in the township known to the writer. Just to the east, and occupying the larger part of the peninsula north of King's bay, is a considerable marsh which marks a fault line, beyond which are exposures along the lake shore at Stony Point and Point au Fer. On Stony Point is the Utica slate, as already described. At Point au Fer is a rocky cliff, extending several rods along shore, and exposing from fifty to one hundred feet of rock, the lower portion consisting of dark blue, somewhat slaty limestone, much jointed and with the cracks commonly filled with calcite; while the upper part is well laminated and quite argillaceous, splitting into thin, even slabs, and weathering to a light color. No fossils were found here, and the stratigraphic position of the beds is doubtful in so far that it is uncertain whether they belong below or above the Utica horizon. They are certainly not older than the Trenton, and are provisionally mapped as of that age.

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

(GEOLOGICAL MAP.)

PRELIMINARY REPORT ON THE GEOLOGY OF ESSEX COUNTY.

JAMES HALL,
State Geologist.

J. F. KEMP,
Assistant.

1895.

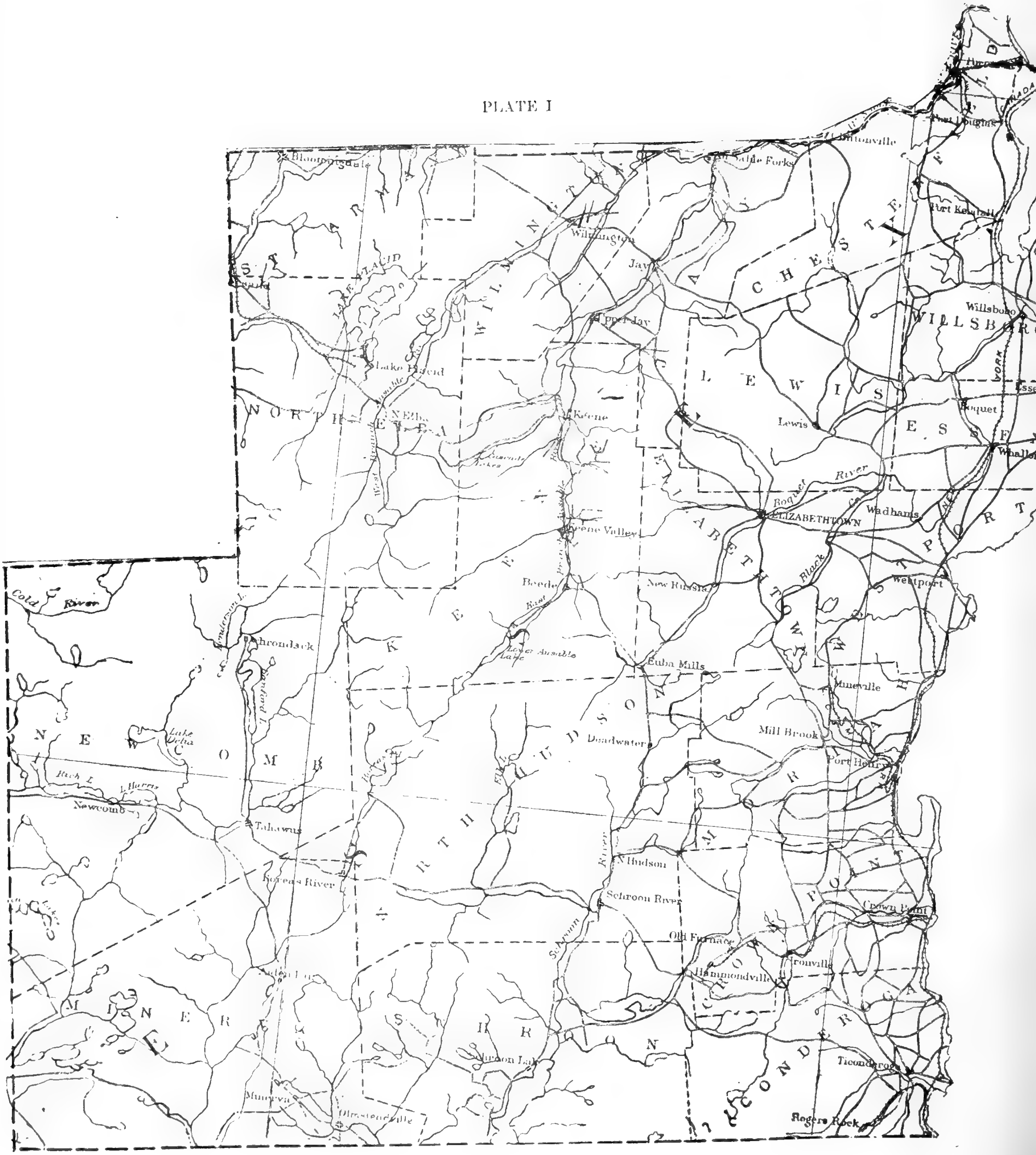
James Hall, *State Geologist*,

Sir:—I submit herewith a continuation of my previous report upon the geology of Essex county, and with it geologic township maps which almost complete the survey of this county. Small areas still remain in the extreme northwest and on the southwest which, on account of their wild nature and inaccessibility, I have not yet been able to reach with the time and means at command.

Very respectfully yours,

J. F. KEMP.

PLATE I



MAP OF ESSEX COUNTY.

Preliminary Report on the Geology of Essex County.

By J. F. Kemp.

(Continued from the Report of the State Geologist for the Year 1893, pp. 433–472.)

The field work for the accompanying report was done in September, 1894, and September, 1895. In the former month a trip was made from Port Henry across North Hudson and Newcomb townships and into the old iron mining settlement at lake Sandford at the expense of the Geological Department of Columbia University. In September, 1895, the field expenses were borne by the State. Almost indispensable aid has been afforded by the topographic maps of the United States Geological Survey, so far as prepared or available, but the western townships have not yet been mapped in this way, or at least have been drawn only along their eastern borders, and the lack of an accurate location of water courses and boundaries has been felt in these districts. Acknowledgments are due to Mr. Herbert M. Wilson, of that Survey, for his courteous and prompt supply of advance sheets.

The same series of signs and the same provisional nomenclature that was used in my former report has been continued in this one, and to those introductory pages, 444–451, reference may be made for their full elucidation. For the sake of clearness, however, a brief outline of the several divisions is here repeated. The additional observations have corroborated these previously published generalities, but it is doubtful if a sharp stratigraphic distinction can be drawn between Series I and II. It seems increasingly probable that the crystalline limestones may prove to be but phases, perhaps several times repeated of Series I, but they are lithologically distinct and peculiar. They are noticeably more abundant to the south and southwest. In this connection results to be obtained in mapping Warren county are to be awaited with interest.

Series I. Gneisses usually with both orthoclase and quartz. Varieties with hornblende, biotite, pyroxene, and with almost no dark silicate. are met. Plagioclase is usually present and may be the only feldspar. The exposures vary in color from very light grey, almost white, to dark grey or even to red. The lamination may be conspicuous or may almost fail.

Series II. Crystalline limestones, ophicalcites, black hornblendic-pyroxenic schists and thinly laminated garnetiferous gneisses.

Series III. Rocks of the gabbro family, ranging from aggregates of pure labradorite through varieties with increasing amounts of dark silicates to basic olivine-gabbro. The varieties rich in feldspar are called anorthosites, following the Canadian practice. They shade from perfectly massive varieties into others strongly gneissoid.

Series IV. Palaeozoic sediments, viz., sandstone, limestone and shale, of which the Potsdam of the Cambrian is the oldest and the Utica shale of the lower Silurian is the latest.

Series V. Trap dikes and porphyries.

Series VI. The glacial and post-glacial gravels, sands and clays.

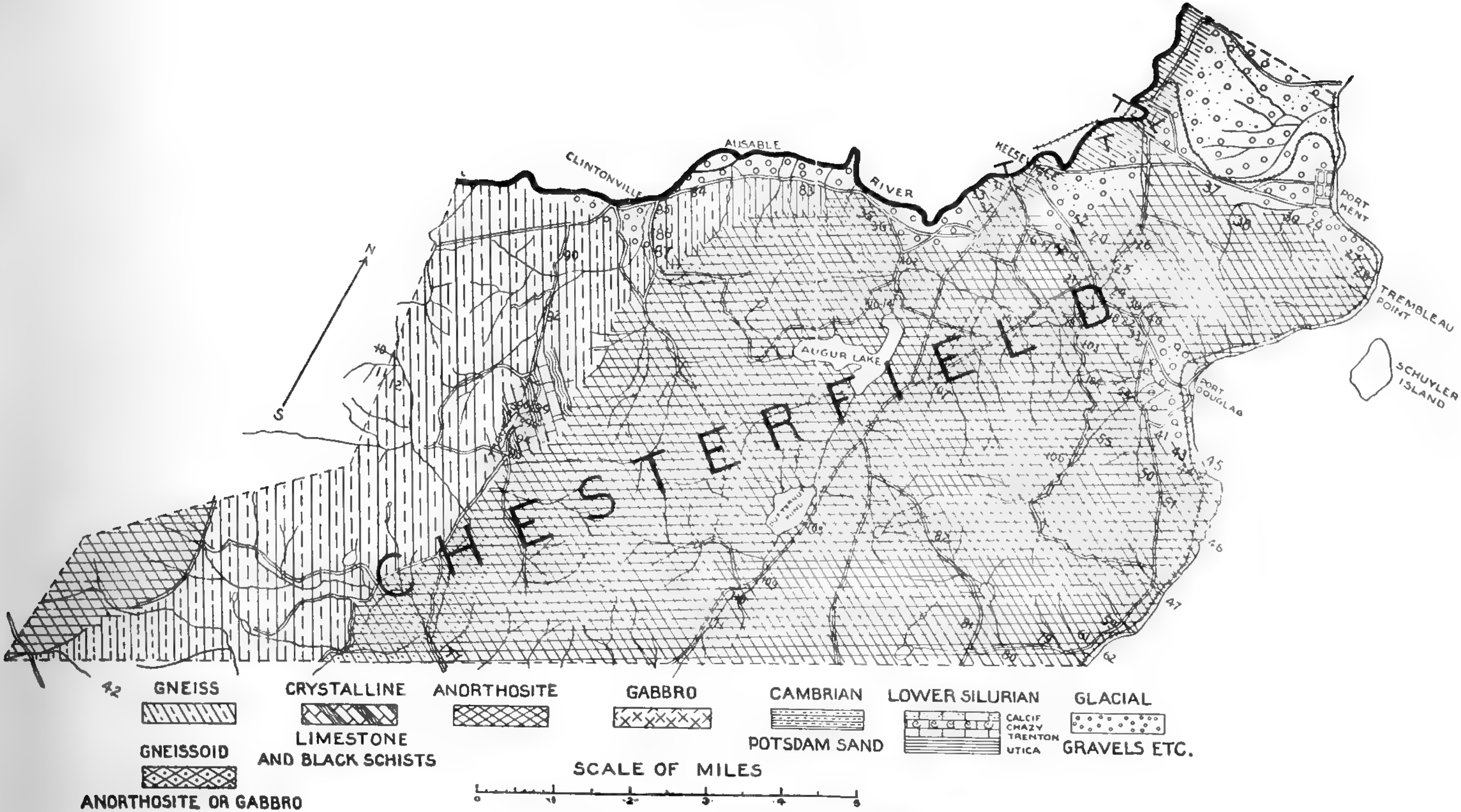
In the subsequent descriptions a topographic sketch is first given of the town, and then the several series are taken up in the above order. The iron ores or other economic products conclude the local notes. The townships are described in general from north to south, as follows:

Chesterfield.

In my previous report, a map and description of Chesterfield were given on page 463. The map was based on the county atlas, as the Willsboro sheet of the United States Geological Survey had not at that time appeared. I was misled into thinking that the western line of the town lay just beyond the valley in which is Trout pond, but the new maps, especially the Ausable sheet of the United States Geological Survey, and field work along the border from Jay, have shown that another valley and brook lie in the interval and that the gneisses extend across this western boundary, as far to the east as Clintonville, embracing on the south the little crystalline limestone area, and projecting into Jay.

The rocks on the south are puzzling gneissoid types, but after a trip across the southwestern corner of Chesterfield to Bluff mountain, in Lewis township, and observations on the trend of the ranges, I am led to redraw Chesterfield as in the accompanying newer copy herewith submitted This also has the drainage correctly drawn and in much greater detail.

PLATE II



GEOLOGIC MAP OF CHESTERFIELD TOWNSHIP.

The western border of Chesterfield is a very wild, rough and mountainous district, and needs more detailed study to make the delineations of the formations of other than a general character.

Series I. On entering Chesterfield from Jay, the area of rich quartzose, feldspathic gneiss that is extensively developed in the northwestern part of the latter town, runs across the border. I went up over Bald mountain, and collected specimens 11 and 12. In thin section they exhibit quartz and microperthitic feldspar, with the dark silicates in No. 12 only represented by decomposition products. The quartz is especially rich and is rolled out in lenticular masses.

On the north side of Bald mountain, is the wild gulch called the "Gulf," and south, still further, and on the east side of Black mountain, is another ravine scarcely inferior. Plumbago prospects are reported in the "Gulf," from which I saw samples that would suggest the probable presence of crystalline limestones as well; but from pressure of time and the necessity of traversing the southern side of the county to get the broader geologic features of that section recorded, I was unable to fully explore the region.

The gneiss extends south from Chesterfield into Lewis township, and at No. 42 (of the Jay map) appears in the high, rough ridge of Bluff mountain, and at No. 43 in the outlying spur of Jay mountain on the south. Both of these specimens, in thin section, show much quartz, with which, in No. 42, is strongly microperthitic untwinned feldspar, and a few shreds of nearly opaque hornblende. In No. 43, quartz is in excess. With it occurs much augite, some scapolite, and almost no plagioclase. Regarding the other series of rocks, no new facts have been noted.

Jay.

Jay is a very irregularly shaped township, as the map indicates. Its greatest length is about thirteen miles from north to south, and except in the narrow extension into the wild mountainous country in the southeast, it averages about six miles from east to west. The greater part of it lies in a valley along the east branch of the Ausable river. The valley is open and broad on the north, where the surrounding hills are two to three miles apart, but on the south they close in decidedly and, at the line with Keene, the valley is narrow. The altitude of the river varies from 550 feet A. T., at Ausable Forks to about 700 at the Keene line. Except along the main stream of the Ausable river on the northeast, the border line with Chesterfield is a very wild and mountainous strip; Bald mountain is 2,139 feet A. T., but less than a mile south of its summit the Gulf runs east and west like a gash, and at less than 1,000 feet above sea level. The northerly spur of Black mountain, at a short distance from the south side of the Gulf, is 2,100 feet. Without careful study I regard this as one of the faulted valleys to which reference was made in my former report, p. 439. The main summit of Black mountain is 2,160 feet. It is separated by another wild gorge from an unnamed peak southwest of it that attains at its summit 2,632 feet of altitude. Still further south is Jay mountain, 3,287 feet in the town itself, and 3,601 feet just across the line in Lewis township. At the extreme south the northerly spurs of Hurricane mountain reach an altitude of over 3,500 feet. About three miles southeast of Ausable Forks, a knob-like hill called Haystack rises to an altitude of 1,338 feet. From the west its outline well justifies its name. The western town line runs along near the summits of several rather large hills of anorthosite which are separated by cross valleys. The northerly one, Clark mountain, is 1,577 feet, the next one south called Hamlin mountain, is 2,122 feet, then follows Bassett at about 1,900 feet, and Ebenezer at about 2,000 feet. Southwest of the town is the huge mass of the Sentinel range, and just inside the southern line of the main portion of the town is Clements mountain, 2,540 feet. On the western side of the southern extension, the contours on the slopes of Big Crow mountain range from 2,000 to 3,300 feet. It is evident from this outline that the easily accessible portions of the valley quickly rise to the decidedly elevated and wild ranges of mountains, on the east and west, which are from 1,500 to 3,000 feet above it. In scenic attractions the valley is one of the loveliest in the mountains.

Series I. The gneisses constitute the northeastern corner for three miles or more south of the Ausable river. Their strike as shown on the map is variable, being north and south, northwest, northeast and even east and west when corrected for magnetic variation. On the east, the rock is a very coarsely laminated variety with very abundant lenticular masses of quartz up to two or three inches long, that lie between corresponding lenses of red feldspar.

In thin section the feldspar proves to be microperthitic orthoclase, or microcline in largest part. Dark silicates are subordinate, with hornblende the commonest one present, but biotite is also often seen. Nos. 5, 6, 9, 10, 11, 12 and 13 are of this character. Just across the bridge over the East Branch at Ausable Forks, a dark green gneiss outcrops in the bank at Nos. 1 and 2. It looks much like the rocks of Series III, but in thin section it is seen to

GEOLOGIC MAP OF JAY TOWNSHIP.

and a basic garnetiferous, gneissoid rock (No. 40) were in the same ledge and not over one foot apart. No. 41 is a gneissoid variety again. On my return from this trip into the mountains my horse ran away and spilled these specimens all along the highway, so that I lost them and cannot give the mineralogy more accurately for this reason. At Nos. 55 and 56, gneissoid anorthosites again appear that show in thin section the familiar crushed feldspar, and in this case a little hornblende and diallage. Away down in the southeast, gneissoid norites appear, that contain labradorite, hypersthene, emerald-green augite, hornblende and garnets. A little quartz also appears, and a tendency in the plagioclase to develop a microperthitic texture that resembles the rocks regarded as members of the typical gneisses. Intermediate varieties of this character are extremely difficult to satisfactorily place in stratigraphic relations, and lead one to concede great possibilities to metamorphism. The aspect of the rock, however, is clearly igneous and its relations are with Series III. Another extended stretch of gneissoid rocks is in the ridge on the east bank of the Branch above Upper Jay, and extending into Keene. Under the microscope, No. 35 exhibits brown hornblende, a little green pyroxene, more or less crushed labradorite and deep pink garnets. It is considered also to belong to Series III.

Two exposures of dark basic gabbros have been met in or near the town. One, No. 4, in the northeast, was not over twenty-five feet thick, in quartzose gneisses on each side. It is a typical gabbro like the one near the Cheever mine, at Port Henry. The second exposure is in the town or near its line in Lewis township, on the southeast. In the thick woods above Sprucemill creek, appears a large exposure of dark green olivine gabbro, No. 59. The familiar reaction veins between the feldspar and the ferro-magnesian silicates are present.

Series IV. The Palaeozoic sediments fail entirely in this town. The Potsdam sandstone to-day is not found much farther up the Ausable river than Keeseville, unless it is buried under the sands and gravels, but it is not improbable that it has had a more extended outcrop in earlier time.

Series V. No diabase or other related dikes, except the gabbro described under Series III above, were met.

Series VI. The great deposits of sand and gravel that were mentioned in my previous report, page 464, and that are especially well developed along the Ausable river, cover a goodly portion of the northern part of Jay. Especially on the flanks of Clark mountain and in the neighboring parts of Wilmington they spread out as stretches of sand, covered by a second growth of timber. Clay is found one mile and a half above Ausable Forks, on the East Branch, in a thick bed just west of the road. East and south of Haystack mountain, along the highway, are extended deposits of sand that remind one much more of the seashore than of the mountains. Now that the contour maps are available, these deserve careful study as illustrating the glacial and post-glacial history of the region.

Glacial striae are not lacking and are marked in several places on the map by large arrows. The pilot charts of lake Champlain give the magnetic meridian as 11° 45′ W. of the true north. The striae have been corrected for this by making the true strike 12° east of the recorded magnetic. Near the Forks they run nearly east and west (N. 92° E.). At Lower Jay they are N. 52° E., and again two miles east, N. 52° E. Southeast of Upper Jay, at No. 56, they are N. 12° E. The frequency of boulders of Potsdam sandstone well up in the mountains and south of the outcrops of this formation leads one to infer that there was movement from north to south even against the present slope. All around the mountains these boulders have often attracted observation in elevated and interior positions.

Concluding remarks. Much further detailed study is needed along the Jay-Chesterfield line in the stretch of mountains forming this wild and uninhabited strip. The writer appreciates that the delimitations of the formations given in the map are based on scattered observations, which future study may more or less modify, but as a general expression of the results of a reconnaissance, they are presented because they throw some light on a little known region.

Wilmington.

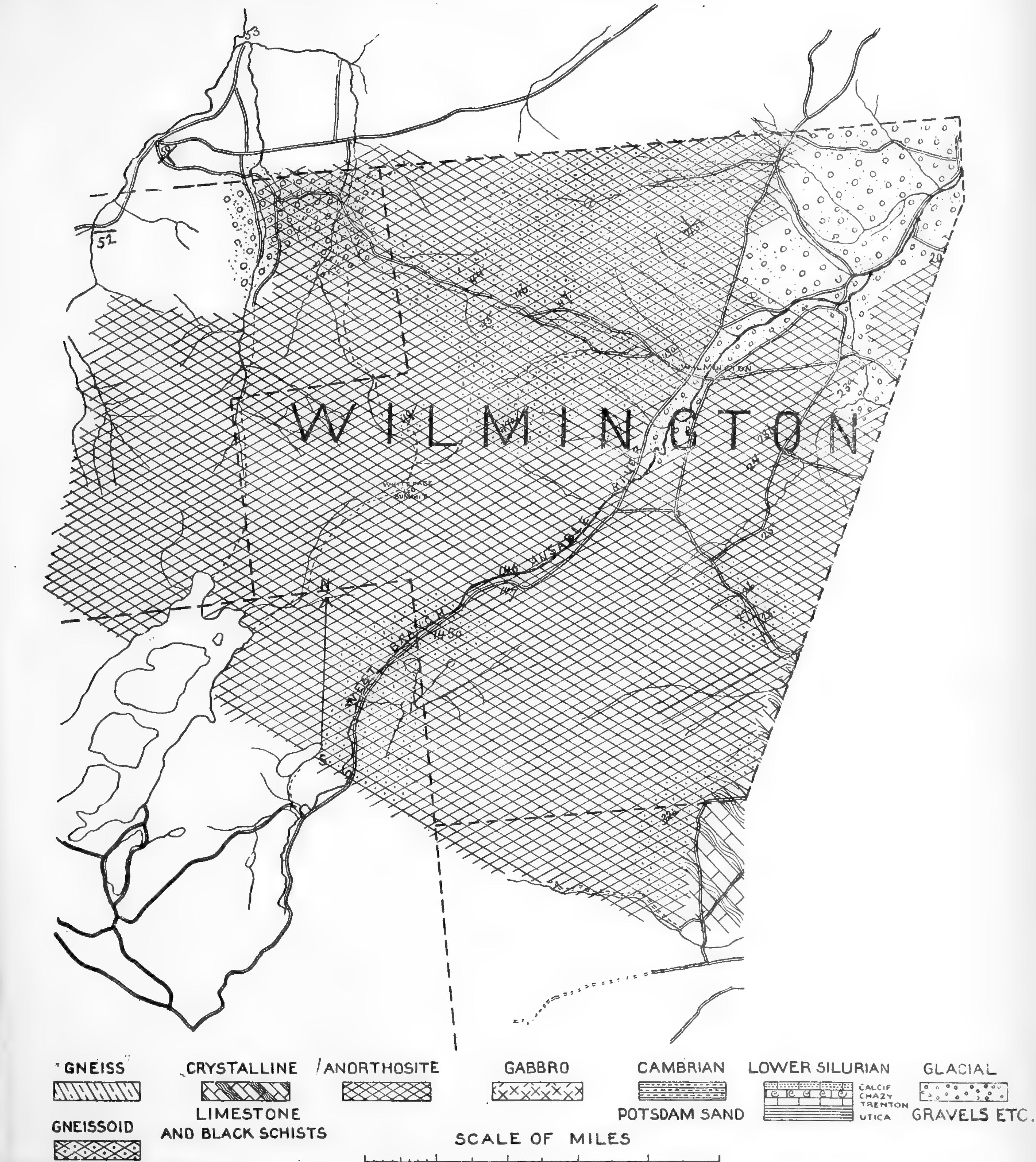
Topography. The topography of Wilmington is closely parallel to that of Jay. A broad valley at the northern boundary with a general altitude of 800 to 1,000 feet above the sea, narrows toward the south or rather southwest to a mere gulch. Where, as in Jay, we have the East Branch of the Ausable river, in Wilmington we have the West Branch, a very similar though somewhat smaller stream. In the eastern central portion there is also a marked side valley along a small tributary which, however, is closely parallel in direction with the main stream. The mountains that separate Wilmington on the east from Jay, viz., Clark, Hamlin, Bassett and Ebenezer have already been referred to under Jay. Between each pair there is a cross valley and road. The whole southern part of the town is occupied by the rugged and wild mass of Sentinel mountain, whose extension forms a notable ridge to the south. The highest point is 3,858 feet, but there are two or three others that are nearly as high.

The western part of the town is occupied by the noble peak of Whiteface mountain, whose isolated situation to the north of the other peaks of the first rank, makes it in many respects the most striking of all the Adirondacks. The view from its summit yields to that of no other in scope and grandeur. The summit is 4,872 feet above tide, so that Whiteface is, according to the maps of the United States Geological Survey the fifth in altitude of the Adirondacks. Marcy, 5,344 feet; McIntyre, 5,112 feet; Skylight, 4,920 feet, and Haystack, 4,918 feet, surpass it; Dix, 4,842 feet, Basin, 4,825 feet, and Gothic, 4,738 feet, follow in order; but after Marcy and McIntyre all the next five have insignificant differences. Whiteface was thought, for many years in the early part of this century, to be the highest of all. To the southwest it drops off abruptly to lake Placid, but to the northeast it is prolonged in a high ridge called Wilmington mountain, that reaches 3,500 feet. There is one pass at an altitude of 2,300 feet with a road running through it from Wilmington to Franklin Falls. The drainage from the western side of the range flows into the Saranac river.

Series I and *II*, with my interpretation of the gneissoid rocks, are lacking in the town, but I appreciate that the northerly extension of the Wilmington range may be, perhaps, with fuller study, in part, at least, classed as such. Professor Cushing has considered the extension over the town line as belonging to the gneisses. The mineralogy of the rocks gathered by me is given under the next topic. Series II may reach a short distance across the line on the southeast.

Series III. All along the easterly portion the rocks are green anorthosites or gabbro. No. 20 is a coarse pegmatite with pyrrhotite, and forms a limited occurrence in the other massive rocks. At No. 24 the usual anorthosite crops out, showing the familiar crushed structure. At No. 27 the rock becomes more basic and like the gabbros and at No. 28 a granulitic phase was met, much the same as those described in my former report, page 469, from the Weston iron mines near Keene. The mass of Sentinel mountain has only been traversed by me around its base on the northerly extension. In Keene, however, we have crossed it finding anorthosite all the way. On the northwest side too we have studied its foot along the West Branch. Though often gneissoid, it uniformly exhibits, so far as seen, the minerals of the gabbros.

PLATE IV



GEOLOGIC MAP OF WILMINGTON TOWNSHIP.

The ridge of Wilmington mountain in the northerly portion has been traversed at No. 43b. The rock is gneissoid with the usual minerals of the gabbros. In the pass at No. 44, the gneissoid structure also holds, and in thin section the rock shows labradorite, hypersthene, garnet and brown hornblende. At No. 46 it is chiefly labradorite.

The rock of Whiteface mountain is quite different from the usual types elsewhere in the mountains. It is a markedly white rock through which are distributed dark bunches of ferro-magnesian silicates up to half an inch or more across. It looks like a light granite. It is not strongly gneissoid, although faint lamination is distinctly visible. Under the microscope it exhibits plagioclase, brown hornblende, pale lavender augite, magnetite, presumably titaniferous, and titanite. Pegmatite veins, strongly quartzose run through it at the summit. The rock on the way up from Wilmington, at No. 47a, is strongly laminated, with a nearly north and south strike. On the trail down to French's, at No. 49, is a very gneissoid type, with a true strike of N. 25° E.

The rock under the microscope is chiefly untwinned but very coarsely microperthitic feldspar with an extinction on the cleavage, up to seven degrees, so that it appears to be orthoclase. The inclusions are spindle-shaped, but curve and are irregular. Their general alignment ranges up to twenty-five degrees with the line of extinction of the enclosing feldspar. The other minerals are diallage and a few shreds of quartz. The rock is very puzzling, exhibiting as it does the characters of both the gneisses and gabbros. Future and more thorough exploration may lead to the determination of some of this great ridge on its northwesterly side as belonging to the series of gneisses. It needs more exploration, but as it is a heavily wooded district and remote from settlements, it is less accessible than many other districts. I have provisionally colored it as belonging to Series III, as such is my opinion from observations thus far made. The same rock that forms the peak of Whiteface mountain extends well down to the shores of lake Placid, and further along the ridge to the northeast in the pass, the rocks, as already stated, have the mineralogy of the gabbros.

After leaving Station 49 no more actual outcrops were crossed by the trail which passes down through thick woods. All the boulders that were met, and some could not have been far from their parent ledges were gneissoid rocks of the mineralogy of the gabbros. But soon after leaving No. 49, the trail passed into St. Armand.

Series IV entirely fails in Wilmington.

Series V. At the High Falls of the West Branch, near the North Elba line, a trap dike of eight or nine feet in width becomes the directing agent of the stream and explains the deep and narrow gorge by its easy decay and erosion. Immediately associated with it is much coarser crystalline red granite, precisely similar to the association of the dike and granite at the falls and gorge near Keene Center, as described in my former report, p. 468. The granite is older than the dike, for inclusions of its red aggregates of quartz and orthoclase are frequent in the trap.

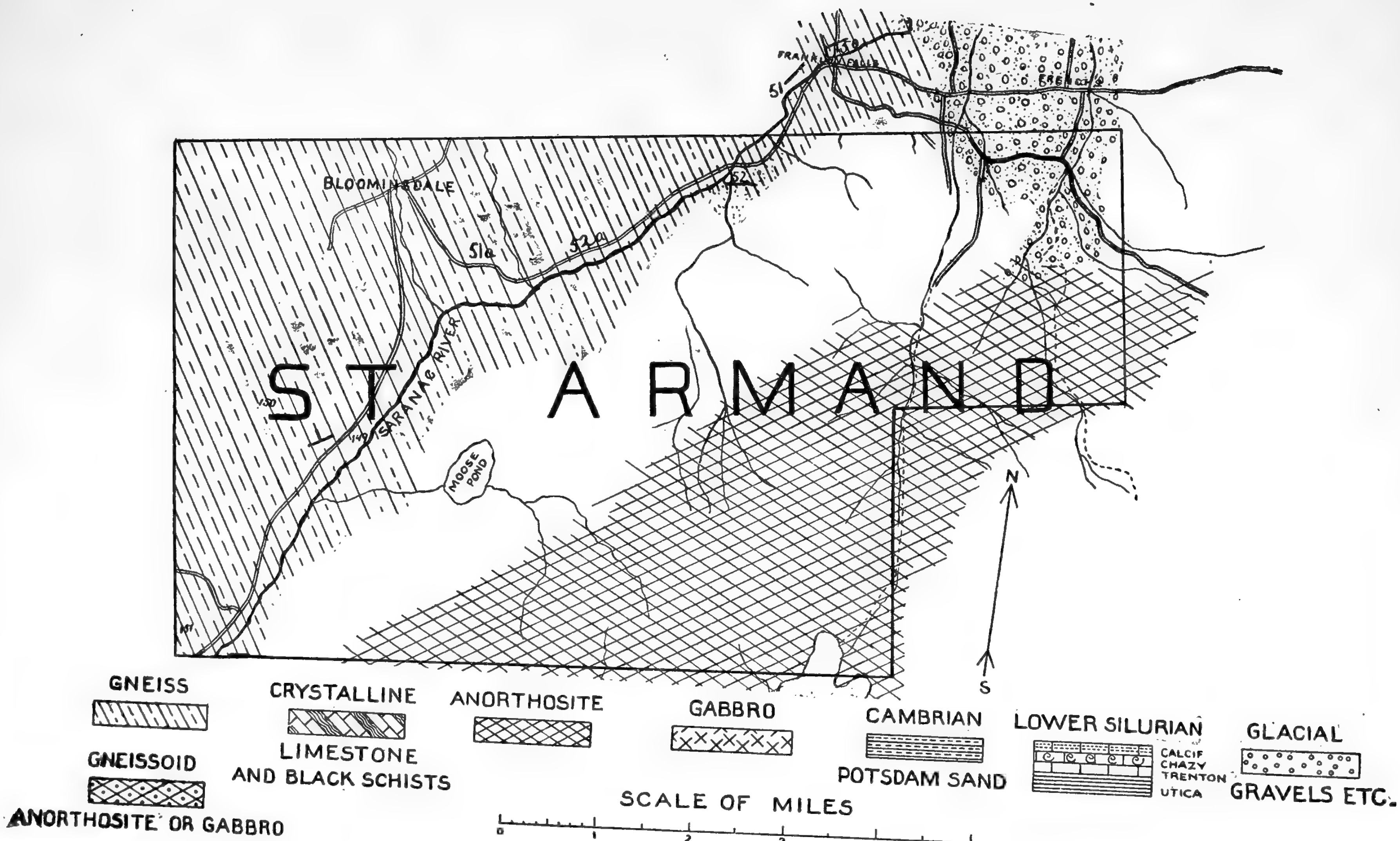
Series VI. The sands and gravels of the glacial and post-glacial times are strongly developed in the northeastern corner. They lie well up the valley of the West Branch. The most abundant by far are in the nature of water-sorted materials, fine sands and gravel.

Mines and Quarries. There is an abandoned prospect for iron ore just west of Wilmington, called the Weston mine. It was never a serious producer, but attracted attention in connection with the bloomery that formerly was operated in Wilmington village. The associations would indicate a titaniferous ore. The existence of a pegmatitic development of anorthosite with some pyrrhotite near the little post office of Hazleton, has been mentioned under No. 20. The samples shown me were only of mineralogic interest, although of course the general geologic relations in wall rocks of the gabbro family, suggests the presence of nickel and cobalt, but experience in the norian rocks of the Adirondacks and Canada to date has only developed titaniferous magnetites as the ores present.

St. Armand.

In my previous report a short sketch of the northwestern corner of this town was given and it was shown to be of the typical gneisses of Series I. In September, 1895, I was able to gather some further details, and have redrawn the old map so as to include them. Nevertheless, the lack of time and means, the rainy weather and the pressure I felt upon me to make a reconnaissance of the southern tier of towns of the county, prevented the trips into the wilderness along the southern boundary of the town that I expected to carry out. Since the field work of 1893, the lake Placid sheet of the United States Geological Survey has appeared and has rendered available a map of the eastern half.

Topography. St. Armand lies along the Saranac river, which cuts it on the diagonal. The northeastern corner is covered with sand and gravel and



GEOLOGIC MAP OF ST. ARMAND TOWNSHIP.

is of mild relief. Along the east and south there are the spurs of Mount Whiteface, and further west the ridge of Moose Pond mountain, all forming a practically unbroken wilderness. The mapping of this section is tentative and is based on the inference that the rocks in the edges of these ridges as met in North Elba on the south and Whiteface on the east continue toward the north, but where the line, if indeed it can be made out, between the rocks of Series I and Series III is to be drawn, must be investigated later. A high ridge bounds the Saranac river on the west, south of Bloomingdale, and another appears north of the river and east of this town.

Series I. At No. 51a there is a red orthoclase gneiss. At Nos. 52a and 52 the gneiss is dark green, and is the same as No. 2 of the Jay map. Under the microscope it exhibits microperthitic orthoclase, a little plagioclase, and some almost opaque hornblende. Zircons are also not lacking. At the bridge over the Saranac there is an excellent exposure (No. 52). Outside the township, in Franklin county, the gneiss rocks continue beyond Franklin Falls, and two miles down the river there is a goodly ledge of the familiar white, crystalline limestone, charged with pyroxenes, titanites, bunches of hornblende, pyroxene and quartz. The dark hornblendic schists that always accompany the limestone, are also well developed. All these indicate that the anorthosites and gabbros, so far as present, lie south of the Saranac river in this town, although we know that they exist near St. Regis lake to the west of the line of Essex county. The strike of the gneisses is mostly northeast, but east and west and northwest strikes are known.

Series II is not met within the limits of the town, although, as stated above under Series I, it does appear about three miles north of the line.

Series III. The area covered by these rocks is mapped on an inferential basis from observations on the prolongation of the ridges south and southeast. While actual study of the rocks *in situ* may modify this, I consider the inference as worthy of confidence in the present state of our knowledge.

Series IV is entirely lacking.

Series V. No dikes were noted in the town itself, but just over the border at Franklin Falls one appears in the side of the road near the hotel, with a northeast strike. It is a dark trap, presumably diabase.

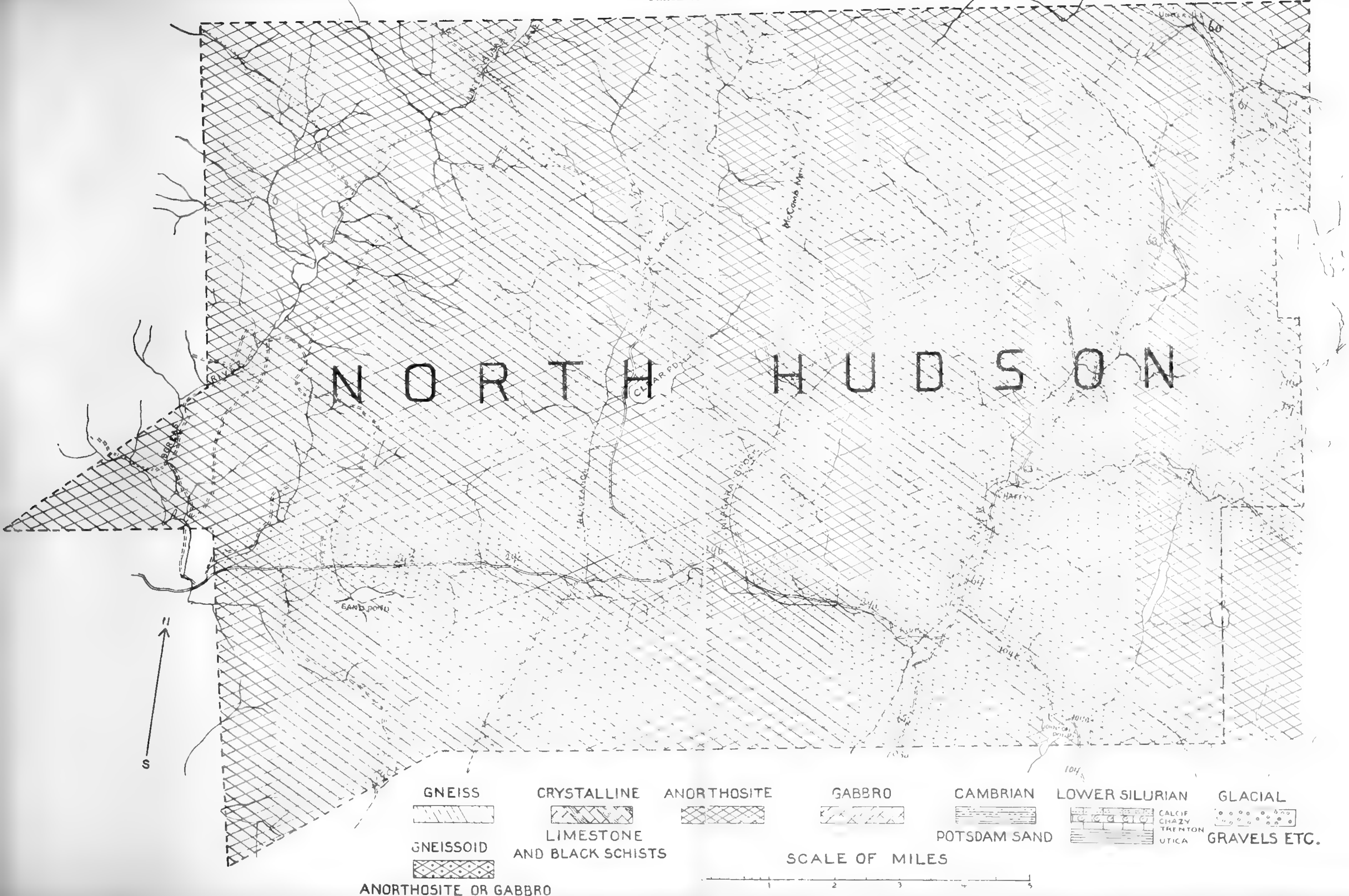
Series VI. The modified drift is widely spread in the less elevated districts. In the northeastern corner it covers several square miles so that no outcrops are available. Level meadows suggest at times former ponds or lakes, and the extended one near Bloomingdale station, outside the county, was referred to in my former report, page 472.

North Hudson.

Topography. North Hudson is one of the largest townships in the county. It lies just south of the principal peaks of the Adirondacks, but its line includes the summit of Mount Dix, 4,842 feet above tide, the sixth in altitude of the high peaks. McComb mountain reaches 4,425 feet but the others are all below 4,000, and only one approximates this. The ridges have a marked trend, a little east of north, and all the valleys and larger watercourses show the same characteristic. The town contains several large and fairly open valleys. On the northeast it is marked by rather low hills, 500 feet or so above the upper waters of Schroon river which, near Deadwater pond, are about one thousand feet above tide. The same character continues along the east border. The Schroon river flows with a rather sluggish current southwest across this portion, the total fall in twelve or fifteen miles being about 200 feet. The valley is a fairly open one, is filled in with sand, and the highway is nearly a dead level, often for long stretches. West of the Schroon river the country is much more rugged and elevated and is practically uninhabited except for the sparsely distributed houses along the road to Newcomb.

Immediately west of the Schroon river, Saunders mountain, Old Far and Little Far, Niagara mountain, Nippletop and Wyman hill make a considerable rampart, that is broken where the "Branch" comes in from the west to the Schroon river, making thus one of the few east and west streams of the region.

The next great ridge to the west containing Spotted mountain, McComb and Dix, is separated from the ridge just mentioned, chiefly by Niagara brook, which flows along the excessively steep westerly slope of Niagara mountain, taking its water exclusively from the west side of the valley. Further south comes in the "Blue Ridge," whose culmination is Hoffman mountain, just over the line in Schroon. West of McComb lies the valley of Elk lake, a wide and somewhat swampy one with the lake in the middle. It forms the source of the "Branch." West of this lies Boreas mountain, nearly 4,000 feet (3,815) at its culmination, which makes the watershed between the tributaries of the Schroon and the Boreas rivers, and between the Schroon river and the East Branch of the Ausable river. The headwaters of the Ausable and Boreas rivers are in another broad northeast and southwest valley that is marked by wet meadows and lakes. In the northwest corner of the town are Cheney Cobble mountain, 3,673 feet, and the slopes of Allen mountain, that culminate just over the border at 4,345 feet.



GEOLOGIC MAP OF NORTH HUDSON TOWNSHIP.

The Boreas river passes out of the southwest corner of the town into Minerva, with various minor tributaries heading in hills of moderate elevation.

Geology. So far as I have explored North Hudson, only the rocks of Series III have been met. I have crossed the northwestern corner, coming down from Marcy to the Upper Ausable lake. All the rock visible was anorthosite. In the northeast and east all the roads on the map have been traversed and the anorthosites, related gneissoid types and gabbros have alone been met, but it is quite possible that the gneisses of Series I may be present in the northeast corner. No. 60, near Underwood, is crushed anorthosite; No. 61 is massive gabbro; No. 63 is also massive but is very finely crystalline; No. 64, near Root's hotel, is typical crushed anorthosite. All along the highway that comes in at Chafey's from the east, is Series III, an extension of the great area that forms the prominent knob of Harris hill just over the border in Moriah, and Moose Pond mountain in Crown Point. The road that comes in to the main highway, just south of No. 64, from Johnson's pond, traverses anorthosite all the way. At No. 103a, where the highway along the Schroon river crosses the town line, there is an outcrop of dark typical gabbro.

On the highway that crosses the southern half of the town from Root's hotel to Newcomb, the rocks are anorthosites and gabbros more or less gneissoid. Gneissoid rocks of the same type are met on the town line where the trail in the southwest corner crosses the town line. I have reached that point coming up from the south in Schroon. The valleys in the interior of the town have not been visited, but as anorthosites and their related rocks are found on the north in Keene and to the northwest in Newcomb, it is unlikely that any other series will be met.*

Series I and *II* are lacking so far as we yet know.

Series III covers the town so far as our present knowledge goes. See above under Geology.

Series IV is lacking, but it is extremely probable that it formerly existed in the Schroon river valley, as a small outlier is still preserved at Schroon Lake post office.†

Series V. No dikes were observed, but they doubtless exist.

Series VI. The usual sands and gravels are present all along the Schroon river and at times form level stretches of noticeable extent. They are even abundant enough to be quite seriously drifted by the winds in one

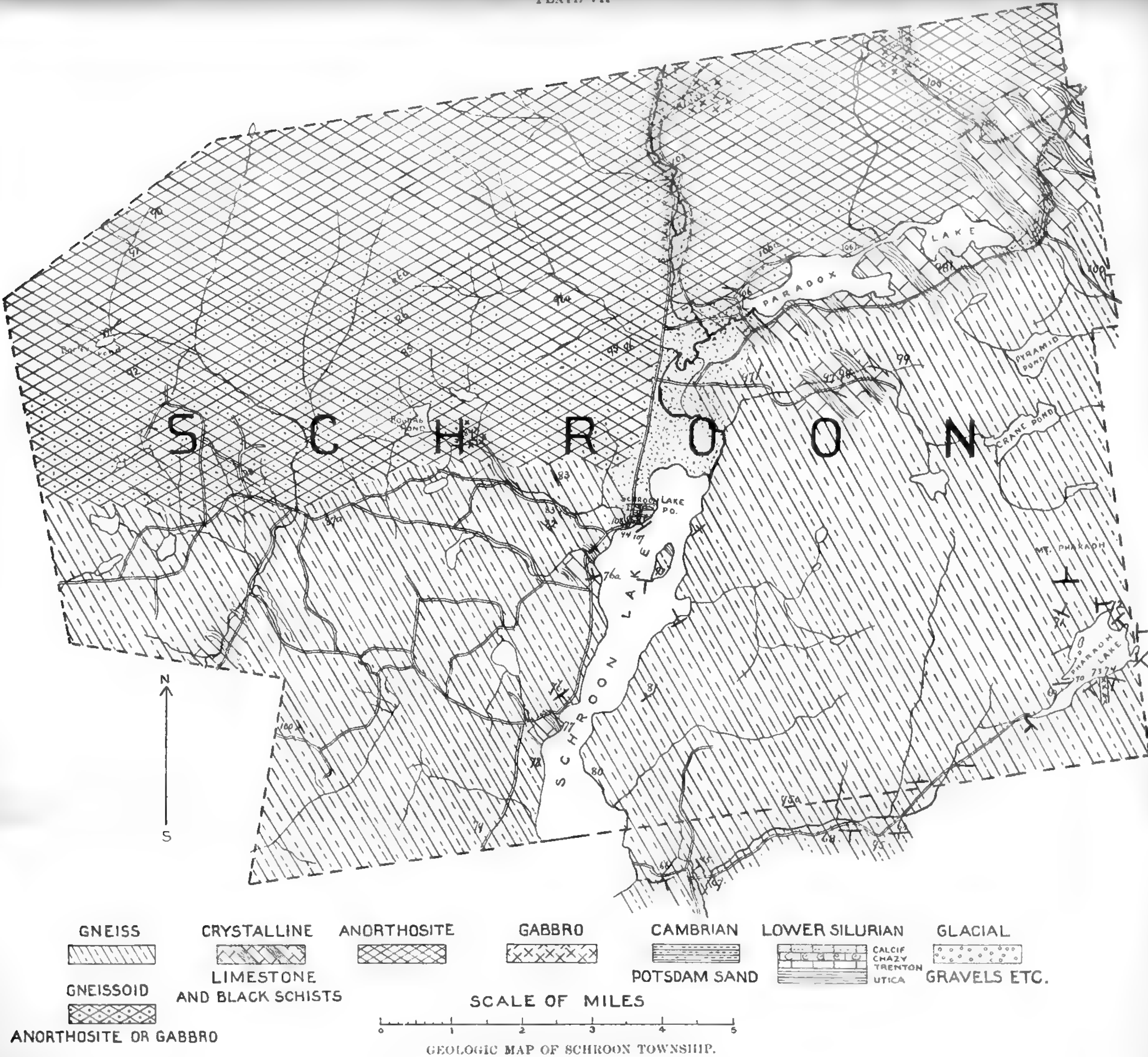
* They have since been thoroughly traversed, and only Series III has been found.

† A small area of Potsdam sandstone has been found in subsequent field-work, about a mile north of Chafey's.

or two localities. To what depth they fill the valley is uncertain, for the Schroon river has not excavated them to bed rock. Lakes or estuaries must have existed after or during the wane of the ice-sheet in order to have made possible the abundant deltas.

Schroon.

Topography. Schroon is a township lying along the southern limit of the high peaks and partaking both of their topography and of that of the more open country further south. It contains the northern half of Schroon lake and all of Paradox lake, the largest two in Essex county. The town is cut into two nearly equal portions along a north and south line by Schroon river and lake. The valley of Paradox lake, running east and west, cuts off the northern third of the eastern half. It is a region of moderate elevations formed by the outlying anorthosite spurs of the great Moose mountain ridge of Crown Point and North Hudson. The highest summits reach 1,700 feet. Paradox lake lies in an irregular east and west valley, with its surface 820 feet A. T. To the south is a wilderness of moderate hills with one very prominent peak, Pharaoh, 2,557 feet, that is the chief land mark of all this region. Lakes and swampy valleys lie in among the hills. Passing along the southern line the same topography continues to Schroon lake, which is 807 feet A. T. The altitudes therefore of Paradox and Schroon lakes differ but slightly, and in high water it is reported that Schroon lake rises so much faster than Paradox that the drainage is temporarily reversed—whence the name "Paradox." It is quite evident that they were one continuous body of water in recent times and that the Schroon river has built up an extensive sandy delta that has cut them apart. Its course over sands and gravels for ten miles or more to the north has furnished it with abundant sediment in the immediate geologic past. West of Schroon lake, the southern line cuts Green hill, which reaches the respectable altitude of 2,227 feet. Passing along the zig-zag boundary to the north and west, deep valleys and fairly high hills prevail. Near the northwest corner, Hayes mountain just west of Bailey pond is 2,822 feet. The northern boundary crosses a series of high ridges with a marked north and south trend and with narrow valleys or notches between. Washburn ridge culminates at 2,938 feet, Texas ridge at 3,212 feet, and Hoffman mountain, the nucleus of them all, at 3,715 feet, the highest in the township. This region extends as an unbroken wilderness until the valley of the Schroon is again met. The central part of the town is fairly open and quite generally settled. Beech hill



GEOLOGIC MAP OF SCHROON TOWNSHIP.

at 2,203 feet is the culminating point of the largest clump of hills, but farms extend almost to its summit. The drainage of the western part of the town is mainly through Trout brook into the Schroon river in Warren county to the south. The exceptional interest that attaches to the topographic relations of the Schroon lake basin are later commented on.

Geology. The northern portion of the town is formed by Series III, but almost all the remainder, except for outliers of gabbro, consists of the gneisses and crystalline limestones of Series I and II. A small but extremely significant remnant of Calciferous cherty limestone covers a few acres at Schroon Lake post office.

Series I. As shown by the map, the southern portion of the town to the extent of more than half its area is formed in largest part of gneisses. The gneisses vary somewhat among themselves, but a light colored, strongly-laminated one, shown by the microscope to consist of quartz, microperthitic orthoclase, prominent garnets and a little hornblende, is a very prominent type. It is the principal rock around Schroon lake, and in the country to the southeast around Mount Pharaoh and Pharaoh lake. Hornblendic varieties also appear that are darker than this one, and still different varieties as noted in the detailed itinerary that follows.

The valley of Paradox lake is bounded on the south by the limestones of Series II, but on the eastern border of the town, at Nos. 100 and 101, is the Schofield ore-body, whose walls are a massive gneiss, precisely like that which contains the ore at Hammondville. It is little else than plagioclase feldspar and quartz. A few magnetite grains appear, but the rock is a very pure aggregate of the two minerals mentioned, right up to the ore. The hills and ridges in this region are very generally gneiss, while the lower lying slopes and depressions are limestone. Along the highway to Crane pond, No. 97 is a coarse gneiss of interlaminated flat lenses of quartz and orthoclase, which have evidently been rolled out under dynamic stresses. In the slides, strained or crushed crystals are abundant. Very little hornblende is present. Along the east shore of Schroon lake, the rock is a coarse quartzose gneiss, at times with mica, again with hornblende, and often with garnets, while along the highway which lies in part in Warren county, it is much the same, and is the garnetiferous variety cited at the outset. The same rock makes up the mass of Mt. Pharaoh. A fine illustration of a brecciated gneiss was met at No. 69 on Pharaoh lake. This light garnetiferous gneiss leaves a strong impression on the observer that it is clastic in origin, although precise evidence is difficult to obtain.

The gneisses form the western lake shore, with intervals (Nos. 76a, 77). No. 78 is a light grey variety like that of the western shore, but No. 76 and 79 are darker, full of plagioclase, with brown hornblende, and in No. 76 diallage, so that the mineralogy suggests an altered igneous rock. The gneisses continue across the hills on the south. At No. 109, on the southwest, a quartz-hornblende-gneiss is met.

On the highway running west from Schroon lake post office, at No. 83, is a quartz-hornblende-gneiss, and at No. 82 a basic hornblendic variety. Outcrops are few along the road to the west, but the gneisses and limestones occur just over the border in Minerva, along this general line. Particular interest attaches to these relations because just to the north the spurs of Hoffman mountain begin to rise and shade from gneissoid gabbros into the massive anorthosites, so that the highway is not far from the boundary between the two.

Series II. The crystalline limestones are quite widespread and of considerable areal importance. As always, they favor the depressions. Along the south side of Paradox lake they are strongly developed. At No. 98b, is a high ledge with a good-sized cave extending into it. The limestones reach up into the valley to the northeastern portion of the town, and are prolonged into Crown Point, as shown on the map of that town already published. In the valley of Alder brook, that is the outlet of Crane pond, the limestones are abundant all along the highway, and with them are the usual black schists. The limestones appear again at Nos. 76a and 77, on the west shore of Schroon lake. They were not met elsewhere, although abundantly developed in Minerva.

The limestones are white, coarsely crystalline and graphitic. They seldom show any large cross-section, say twenty-five to fifty feet, without bunches and knobs of dark silicates, or scattered irregular bits of pyrrhotite, hornblende, pyroxene, flakes of phlogopite, etc.

Series III. The anorthosites and gabbros constitute the northern portion of the town and rather more than one-third of its area. They are prevailingly gneissoid, and as the areas of the gneisses of Series I are approached, they become very strongly so, almost to the extent of schistosity. This tends to decrease in the interior hills, and at No. 95 quite coarsely massive varieties are attainable. All over the adjacent areas on the south are huge boulders, often as large as a small house, of the light bluish anorthosite, that has come from the inner hills. At or near No. 87a, I paced one that was roughly oval, 30 x 20 feet, and that projected six feet above the turf, with an unknown extent below ground. Others often stand in full exposure, 10 x 20 feet in dimensions. The district is the most prolific in them of any traversed by me.

Along the highway in the northeast corner, gneissoid anorthosites are met at No. 103 and alternating with gabbros (No. 104) they continue along that road over to the valley of the Schroon. On the highway in the Schroon valley, massive gabbro is met at No. 103a, and massive anorthosite at No. 105. Gneissoid anorthosite forms the north shore of Paradox lake at No. 106a and No. 106b, but quartz gneiss outcrops at No. 106. On the west side of the road up the Schroon valley, the anorthosites are met in the hills and have gneissoid laminations more or less distinctly developed. In the foothills to the north of Rogers pond, thinly laminated basic gneisses, manifestly derived from gabbros, are first traversed and only yield to the more massive forms in the interior peaks. The region where Nos. 85, 86 and 86a appear is a very difficult one to cross, as there are no trails and as it has been recently burned over. On the northwest, gneissoid anorthosites again appear at No. 88, and over to the north of Bailey's pond, with varying accessions of dark silicates, they continue to the North Hudson line.

The exposures and float masses of the rocks of Series III in this town have given some of the most interesting data regarding the dynamic metamorphism of these rocks that have been met in the mountains. Perfectly massive varieties were collected, consisting of a coarse aggregate of green labradorite, with perhaps a stray hypersthene, augite or hornblende crystal and a garnet or two. Crushed rims around the crystals first manifest themselves and increase gradually until the rock consists of nucleal fragments embedded in a white pulp of comminuted feldspar. Such varieties I have called *pulp anorthosites*. Apparently these have resulted largely from crushing strains without much shearing. When the latter is superadded, the crushed materials are dragged out into the laminations of a gneiss, with the nucleal crystals left as lenticular "eyes" around which the laminae pass. Abundance of dark silicates accentuate the laminations, and the development of garnets makes them much more prominent. The formation of this latter mineral is a question deserving much careful study and chemical analysis. It is a remarkably common and characteristic mineral all through the mountains and is present in all the older rocks, but especially in those of Series III. It seems to result from the pyroxenic constituent and also to develop in purely feldspathic rocks, and in these it may be in fairly regular dodecahedra three-fourths of an inch in diameter. It is a deep rich red in the rocks of Series

III, but is notably paler in those of Series I and II. I expect to give the subject of its formation detailed investigation in the future, as opportunities occur.

In distinction from the more feldspathic members of Series III, of which special mention has been given above, often under the name anorthosite, attention should be directed to the dark basic gabbros and their metamorphism. Although the latter are best exhibited in Moriah township, on lake Champlain, just north of Port Henry, they are also, to a less degree, shown in Schroon. The dark gabbros often contain olivine, and are a plutonic rock, rich in pyroxene, brown hornblende, titaniferous magnetite, and a dark green plagioclase that tends to develop somewhat lath-shaped crystals and, in many specimens, to suggest the diabase type of texture. Excellent exposures occur along the highways on the northeast at Nos. 104 and 103a. The last named is a large ledge, perfectly fresh and extensively blasted out on account of the passage of the road. In the extreme southeast, on the shore of Pharaoh pond, is a dike twenty-five feet wide, of well-marked gabbro, far out from any visible parent mass, and in walls of light grey quartzose gneiss. Again, west of Schroon Lake post office, on the lane leading out toward Rogers pond, at No. 84, is a fine outcrop of coarse dark olivine gabbro.

These massive gabbros, when subjected to shearing stresses, develop dark hornblendic schists, and this change can be shown even in the limited exposure of the rather narrow dike on Pharaoh pond. The feldspar is crushed, and the dark silicates are dragged out into thin laminae. Even the massive types have seldom escaped the production of reaction rims of garnets that mark the boundaries between the feldspars and the dark silicates or ores, almost never allowing the former to come into actual contact with the latter. Hypersthene, brown hornblende and biotite also enter into the rims, especially where they surround magnetite, but garnet is much the commonest and most noticeable of them all.

Series IV. Much the most interesting and significant of all the exposures in Schroon township is that embracing a few acres of what I take to be the Calciferous formation. The rock is a grey, cherty limestone or dolomite. It extends along the shore on both sides of the steamboat dock at Schroon Lake post office, and has a total outcrop of about 400 yards. Rogers brook falls over a ledge of it and affords the best and most extended cross-section. The strike is by the magnetic compass N. 60° E., and the dip is 25° N. W. Referred to the true meridian this would be 10 to 12° more to the eastward. Roughly but carefully measured, the total thickness exposed above the lake water is about seventy-five feet. Streaks of chert run through the ledge, and coaly or asphaltic material appears in the cracks. Calcite pockets are not lacking but, although I searched carefully over the ledges, I was unable to find definite remains of organisms. Thin sections of the chert merely exhibit a brown, nearly isotropic base with numerous rhombohedra of calcite or dolomite scattered through it. A few opaque ones are apparently limonite residues after original siderite. This outcrop was noted by Charles E. Hall in his report on the Laurentian Iron-Ore mines of the Adirondacks (Thirty-second Annual Report New York State Cabinet, p. 139), who speaks of it as Chazy and as containing fossils. Fossils sufficiently well preserved would, of course, settle the stratigraphy at once, and I feel the greatest hesitation in speaking of the ledges as Calciferous in opposition to the earlier record. The resemblance is so close, however, to the cherty magnesian limestones that are undoubtedly Calciferous and non-fossiliferous on lake Champlain (as for instance just north of Port Henry, and again just north of Crown Point on the Delaware and Hudson railway), and the probability of Calciferous in this outlying district resting on Potsdam is so great, that I leave the determination as stated, being ready to recall it if the evidence of fossils should be against it.

The interest of the exposure lies in the fact that it is the remotest outlier yet found of the Palaeozoic sediments in the mountains. The nearest outcrop is the little area of Potsdam sandstone, distant at least ten miles in a direct line in the Putnam's pond valley of Ticonderoga which, however, drains north through Penfield's pond in Crown Point to lake Champlain. The actual divide at the head-waters is insignificant. Down the Schroon and Hudson valleys the nearest exposure recorded is at Hadley, about forty miles away. There is little doubt, however, that the Hadley tongue formerly set back up the Hudson and Schroon valleys, and that this little outlier is the only remnant, so far as we now know, that is left. Hadley is given by the railway (see Macfarlane's Geological Railway Guide, Second Edition, p. 118) at 606 feet, and Schroon lake has lately been determined by the United States Geological Survey at 807 feet, so that the rise is now about 200 feet. The interesting point is whether these modern valleys were depressions and embayments up which the oceans set in Cambrian and Ordovician time; or whether the early Palaeozoic strata spread all across the crystallines and have only been preserved in small in-faulted blocks, whose faulting is relatively modern.

The former has been the case with the lake Champlain basin and apparently with its arm up through Crown Point and Penfield's pond into western Ticonderoga, along the easterly branch of Putnam's brook (see map of Ticonderoga, Report of the State Geologist of New York for 1893, p. 452); with the lake George basin and its arm up through the Trout Brook valley in Ticonderoga (see last reference), and in the Hudson-Schroon valley, we have doubtless still preserved for us the old Cambrian-Ordovician topography. It is furthermore a curious fact that the strike of all these outliers is northeast, and the dip is also low to the northwest. It is remarkable that the same strike and dip hold good for the embayments of these rocks all along the west shore of lake Champlain, in Essex county, and notwithstanding the minor faulting we cannot well avoid inferring that there has been considerable tilting in which the county to the east and southeast has risen. The Green mountain upheaval may in part account for this, but the Schroon outlier is a long way into the Adirondacks to have felt its effects, when it produced such slight tilting along lake Champlain itself, only twenty miles away from the principal elevation. If we assume anticlinal folds instead of faults, it is extraordinary that the eastern limbs should be eroded while the western remain. Tilting in blocks with fault lines approximately parallel to the present valleys, is more likely to be the true explanation.*

It is also worthy of remark that the Schroon valley is a base-leveled one, or nearly so, except as concerns side tributaries. The Schroon itself is a very sluggish stream for a mountainous one, and the fall is very slight, as was noted above under North Hudson, from its source to Schroon lake. Such obstructions as it is now at work upon are chiefly glacial deposits. The great geologic age of the valley no doubt accounts for this sluggishness and the question may be raised if other slow streams, not evidently held in abeyance by glacial deposits, may not be explained in the same way.

Series V. Several dikes have been noted. The point on Pharaoh pond, where No. 70 is located, is well provided with them, as the accompanying sketch (Figure 1) shows. The laminations of the gneiss run straight across the strike of the dikes. The dikes have also proved an easier prey to the weathering effects than has the gneiss and the retreat of the shore along their lines has in part at least caused the points. The dikes cut pegmatite veins, and in one case a small dike cuts a larger one. The occurrence of these little scraps of igneous rock in doubly terminated fissures and running like veinlets

* Since the above was written, topographic maps of this area have been issued by the United States Geological Survey, and based on these, the writer has discussed this question at greater length in the "Bulletin of the Geological Society of America," Vol. VIII., p. 408, Plate 51.

all through the gneiss is remarkable. We can only infer that the intrusion of the larger ones extensively shattered the walls and that the molten trap oozed into every notable crevice. The rock is a diabase. The presence of the gabbro across the lake at No. 73 may be remarked, but I see no reason to connect the two. A very similar group of little dikes was also met west of Schroon Lake post office at No. 83. The accompanying sketch (Figure 2) illustrates their relations. The exposure was only a small one, eight or ten feet square, and the tiny dikes were faulted in an interesting way, as shown in the figure. The smallest of these was doubtless originally continuous.

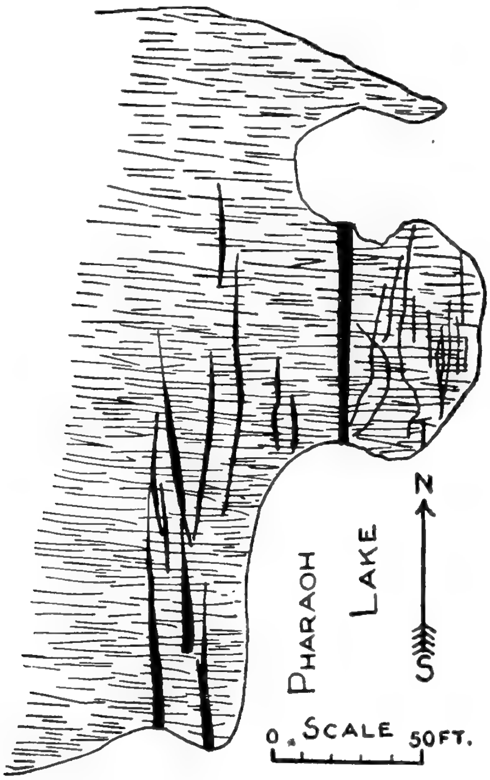


FIGURE 1.

Series VI. The glacial drift is very generally present, and, as already remarked under Series III, enormous boulders are of great abundance just south from the mountains. The town, however, seems to have been in the region of transportation rather than of deposition, and the hills of gravel, moraines, etc., that we meet farther south are lacking. Water-sorted sands of post-glacial times are present in the stream valleys. The hills are of rock so far as observed, and the boulders noted were doubtless stranded in the melting of the ice sheet while they were in transit. All the large boulders are anorthosites.

Mines There is only one ore-body in the township, so far as I learned, and that is the Schofield vein on the extreme east, at the line with Ticonderoga. There are two ore-beds in a ledge, fifty yards or so east of the highway, and about thirty feet above it. The lower and larger is about twenty inches thick, and the upper, a few feet above, is from two to twenty inches. Naturally this amount is not very serious, but in the earlier days of the

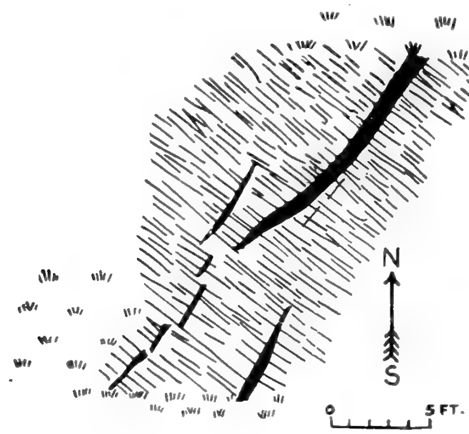


FIGURE 2.

bloomeries the lower vein was somewhat mined, and excavations thirty or forty feet down were made. The ore is probably much the same grade as that at Hammondville, as the wall rock is the same.

In his Bulletin on the Iron Ores of New York, Professor Smock speaks of another small mine on the north side of Paradox lake, but I learned no particulars about it.

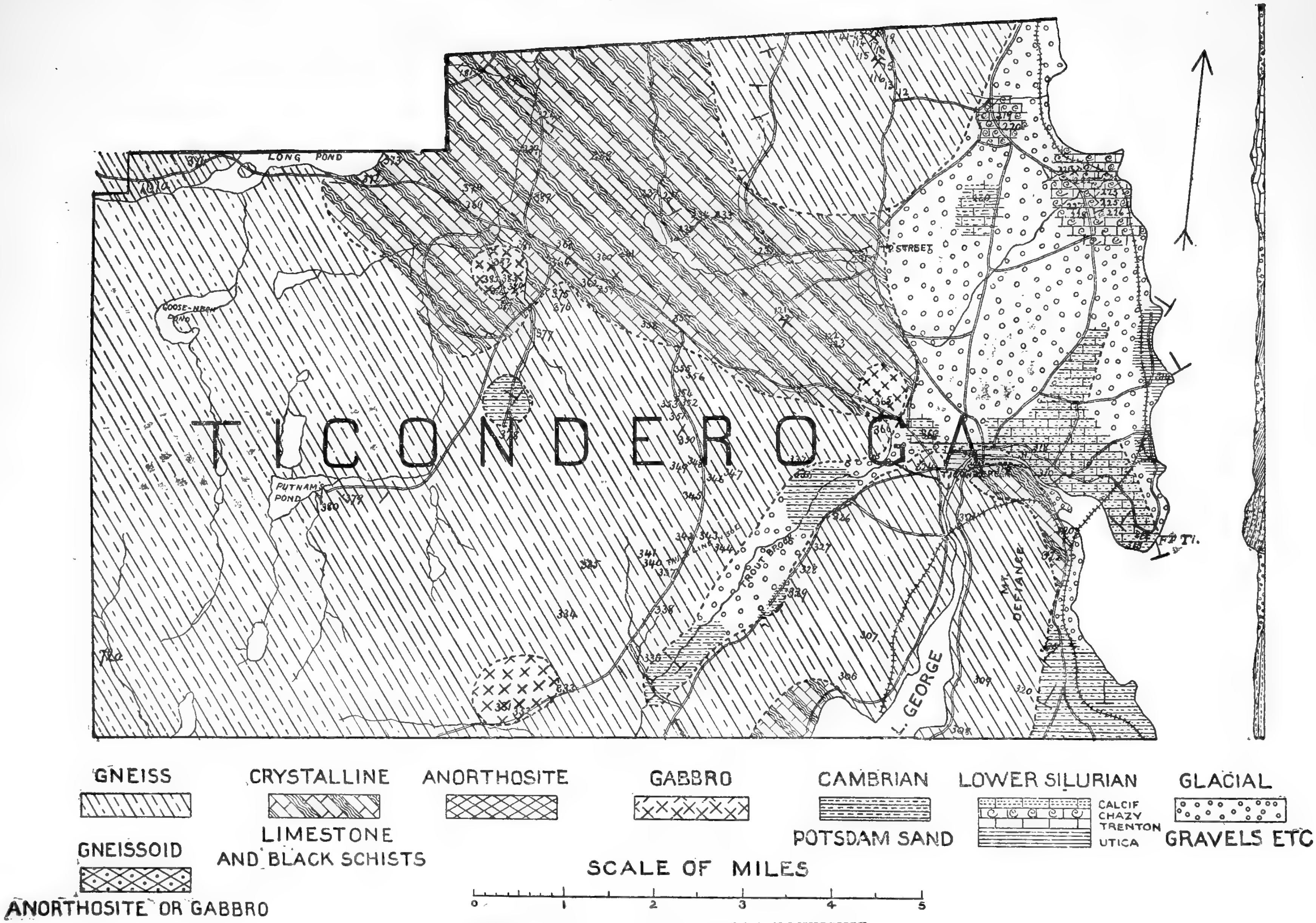
Ticonderoga.

In my previous report, p. 452, the map of Ticonderoga was left incomplete as regards its western edge. The observations that were gathered last season along the western line with Schroon, make it quite evident that the gneisses of Series I, with perhaps some limestones as yet unlocated and some minor intrusions of gabbro and trap dikes cover the area. The map has therefore been filled in on this basis, and appears here in completed form.

Minerva.

Topography. Minerva is a very large township, which is still but sparsely settled. While its elevations are of moderate character, no specially notable one being within the town lines, they are, in instances, extremely rugged and wild. Population is chiefly limited to the southeastern corner,

PLATE VIII



GEOLOGIC MAP OF TICONDEROGA TOWNSHIP.

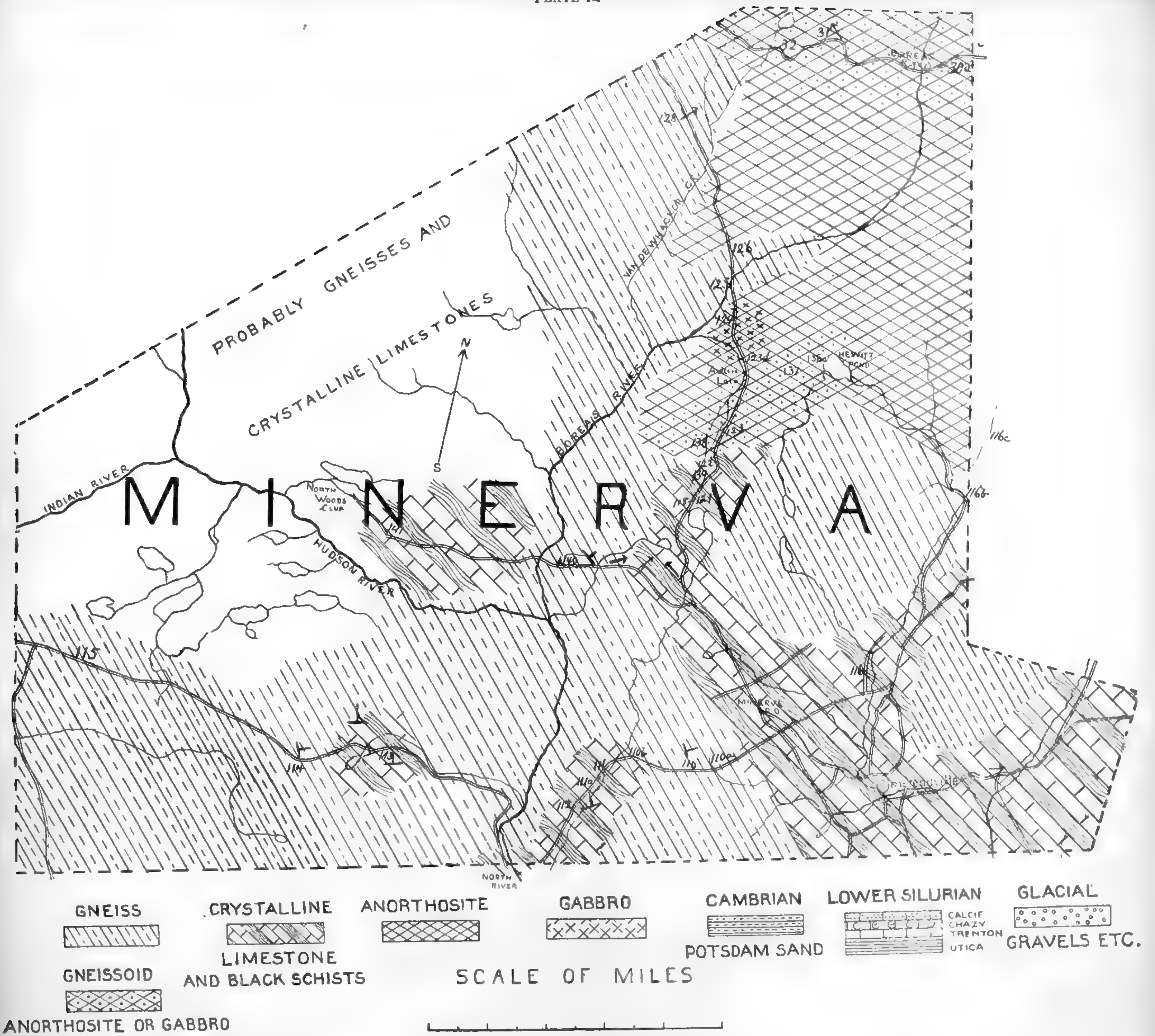
where Olmsteadville is situated. Scattered houses extend for a few miles along the highways, but to the north, after three or four miles, there are but a half dozen until one reaches Newcomb. The same is true of the southwest. On the northeast the Boreas river flows into and diagonally across the town. Where it enters, the river is about 1,700 feet above tide and the surrounding hills are 800 feet and less, higher. Passing southward along the eastern border, the summits reach 2,000 to 2,500, and as a maximum 2,850 feet. Right at the corner where the boundary bears away eastward, is Oliver hill, a very large knob of 2,477 feet. Minerva stream flows southward on the west of it and Trout brook on the east. A high ridge marks the southeastern boundary. The valley of Minerva stream is somewhat open and level near Olmsteadville, but along the southern boundary the hills are again of notable height, and rugged in the extreme. The valley of the Hudson cuts the northern town line near its middle point and is narrow, with steep, precipitous hills closing it in. The town of North River is just over the line in Warren county, and five miles still further down is North Creek, the nearest railway terminus. Along the highway to Blue Mountain lake for several miles after leaving the Hudson, the ridges are rocky, bare and rugged, but on the extreme west they die away in open and fairly level country where the lakes appear on the map. Along the northern border around to the starting point the hills come in again, but the country is a wilderness, broken only by the camp of the North Woods Club.

Geology. So far as present observations go, the town is chiefly formed by gneisses and crystalline limestones, of which the latter are especially abundant as compared with the other towns studied. On the northeast, gabbros and related gneissoid rocks appear, and the same are present along the eastern border, but the greater part of the town is south of the main outcrops of the anorthosites.

Series I and *II.* It is not feasible to sharply distinguish between these two at present (even should it ever be so), as observations have not been accumulated in sufficient amount. The valleys, naturally the places where the highways are located have, almost without exception, been excavated in the limestones. The intervening ridges are gneisses. So much of the town is difficult of access that observations are not yet recorded in great detail. On the central eastern border the gneisses are met at No. 116b, but south in the same valley near Irishtown the limestones appear. Along the road at No. 116c on the west side of the creek, I noted a pile of sulphurous magnetite said to have been derived from the hills to the westward. It reminded one of the Lee ore near Port Henry and the Vineyard openings on Buck mountain, in Ticonderoga. Near Olmsteadville and in the valleys to the eastward, limestones and the characteristic schists and gneisses that accompany them are frequent. The same statement holds true along the highway that runs west and then southwest to North River. At No. 110 is a light quartz gneiss, at No. 111 a white crystalline limestone, and in between are dark hornblendic schists and thinly laminated gneisses such as usually accompany the limestone. Quartz veins of inconspicuous character are often seen. At No. 112, in the creek bottom and on the east bank, is a fine outcrop of a thinly laminated, richly quartzose gneiss. Limestone appears near the town of North River in the east bank of the Hudson, and further up stream are cliffs of gneiss nearly 200 feet high. Along the highway to Blue Mountain lake, alternating exposures of gneiss and limestone are met to the town line, except just east of No. 115, where a gabbro excessively basic and somewhat schistose and rich in magnetite appears. From No. 113, for a mile or more, a superb fault scarp is on the north side of the road, where the dip and strike sign is located. It exposes a precipitous front of gneiss, and has a small prospect hole for garnet well up on its sides.

Passing now along the highway in the eastern central part of the town from Olmsteadville to Newcomb, the same alternations of gneisses and limestone exposures are met as far as No. 123, which is a mile or less south of Aiden Lair. Gneissoid rocks belonging to Series III then appear and extend off to the northeast beyond Hewitt pond and no doubt connect with the areas north of Bailey's pond in Schroon. They are described under the next series. At the crossing of the Boreas river, quartzose gneisses again crop out at Nos. 125 and 126, but gabbro and black hornblendic schists lie both south and north of them. Beyond Van de Whacker creek is No. 128, a coarse quartz-orthoclase gneiss, with the two minerals in lenses just as was noted for Schroon, No. 97, and Jay, No. 6, the latter from Haystack mountain.

Along the road that branches off to the North Woods Club near the middle of the town, black schists and gray gneisses are crossed as far as the Boreas river. Beyond its bridge, limestone of the usual graphitic white variety is the principal rock exposed. No. 141 was the last outcrop that I was able to reach, so that a great area in Minerva and Newcomb to the northwest remains unstudied, but I have little doubt, both from its abundant lakes and moderate hills, that it will all prove to contain the usual association of limestones, schists and gneisses.



GEOLOGIC MAP OF MINERVA TOWNSHIP.

The strikes and dips that were recorded are plotted on the map, but they display such variability that no general conclusions can be drawn from them. They will only be of value in close detailed study in which every outcrop is noted, so that step by step such structural details may be worked out as are possible.

Series III. Along the east and west highway in the extreme northeast corner of the town, gneissoid rocks rich in garnets and doubtless derived from moderately pyroxenic gabbros and norites, are the rule from Labier's at the town line until the line of Newcomb is nearly reached. The usual basic gabbro then appears and extends across into Newcomb, but near the highway outcrops do not occur with all desirable abundance. Gabbros or black gneisses and schists regarded as derived from them are found just south of Van de Whacker creek at the crossing of the highway from Minerva to Newcomb. I map them as belonging with the gabbros, although from their general metamorphism, the interpretation is not thoroughly established. South of the Boreas river, gabbros of the usual basic type do appear, and to and beyond Aiden Lair and eastward at Hewitt pond, garnetiferous gneissoid rocks, clearly derived from sheared anorthosites, constitute the ridges. At No. 123, just north of an abrupt eastward bend in the road, are typical "augen" gneisses derived from the labradorite rocks, and with large nucleal labradorite "eyes" or "augen," left in lenticular shape.

In the southwestern part of the town, near No. 115, black hornblendic rocks are again met which are presumably derived from gabbro. Along the eastern border, at No. 116b, and to the north the float, even that of a small size, in the valleys is all of Series III, so that the hills to the north, which were not easily reached within my limited time, are doubtless of this series and a westerly extension of the same rocks visited in Schroon, just north of Bailey pond. They connect the latter with the Hewitt pond exposures mentioned above.

Series IV was not met, and it is not likely that it was ever present, unless in the Hudson valley, of which I see no evidence.

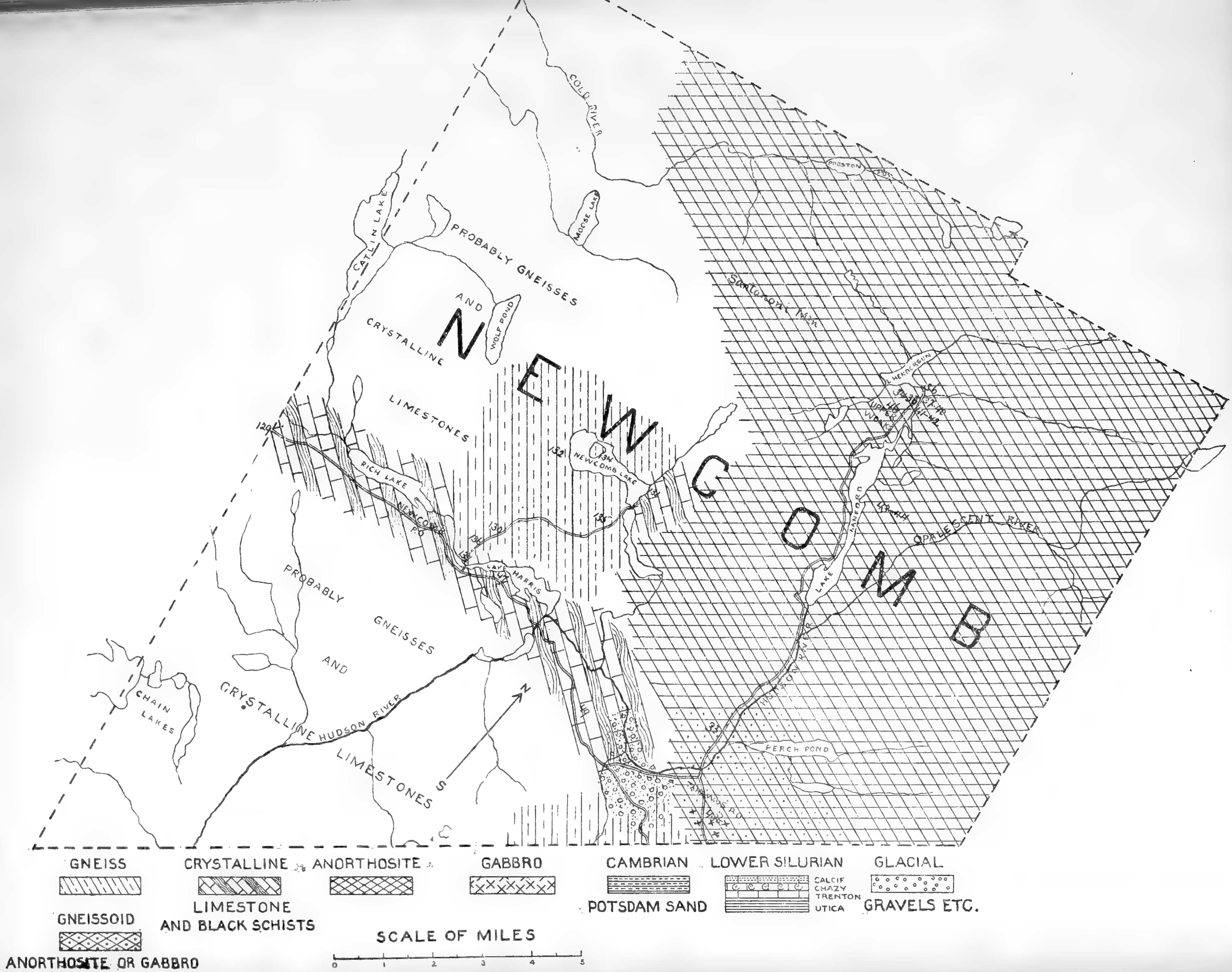
Series V. No trap dikes were met.

Series VI. Glacial gravels are not infrequent and boulders of the massive anorthosites and gabbros from the peaks in Newcomb are very common along the highways. They furnish very fresh and accessible illustrations of the general character of these rocks. The large area that is covered by sand and gravel along the north border, where the highway crosses from Minerva to Newcomb, begins in Minerva, but is most extensively developed in Newcomb. Much sand and gravel also occurs north and south of Minerva post office, but in the portions of the town that were studied, it must be admitted that the glacial deposits furnish much less of interest than in the towns farther south.

Mines. The one little iron-ore prospect referred to under Series I and II, was the only one I met. The quality of the ore precludes its working. Professor Smock mentions a vein northwest of Olmsteadville that was opened by the Burden Iron Co., in 1881, but that is only of small size (Bulletin 7, New York State Museum, p. 36). The only other mineral of importance is garnet, but the present developments for it lie mostly just outside of the town, in Warren county. The one prospect that I saw was high up on the precipitous cliff in the southwestern corner. Although I noted the small dump in the talus while passing at a distance, I did not learn what it was until after I had returned to Minerva. No doubt the region is favorable for the mineral, and some deposits may yet be opened up but, as stated, present developments are in Warren county. The following brief accounts are all that have yet been published about them. F. C. Hooper, "Garnet as an Abrasive," *School of Mines Quarterly*, January, 1895. D. Van Ingen, "New York at the World's Columbian Exposition," p. 341. Further study of them will be of economic importance as well as of scientific interest in illustrating one of the minor results of the general metamorphism. The limestones have certainly been important contributors of their substance toward the formation of the mineral.

Newcomb.

Topography. Newcomb is a very large and sparsely inhabited township that lies along the western border of the county. In its northeastern corner it contains the headwaters of the Hudson in lake Henderson and lake Sanford, and in lake Colden from which flows the Opalescent river. Several high peaks are in this section, for the summit of Mount McIntyre, at 5,112 feet, is just across the line in North Elba, and its southerly ridges at 4,855 feet and less, stretch well into Newcomb. Santanoni, reported at 4,644 feet, lies some miles westward and is an impressive peak because comparatively isolated. Coming south along the eastern border, the valley of the south branch of the Opalescent river is a fairly open one, and is succeeded by the North River mountains, a ridge 3,814 feet at its summit. Minor spurs are characteristic of the southeastern portion, with one good sized lake called Perch pond. Along the southern line the elevations are moderate, but the



GEOLOGIC MAP OF NEWCOMB TOWNSHIP.

country is very wild and but slightly opened up. The Hudson passes out on the southwest, receiving an important tributary from the Chain lakes. The western border has the same character of moderate elevations and exhibits the topography more typical of Hamilton county in which the high peaks disappear except as an occasional one breaks the general stretch of moderate elevations. Mount Goodnow, Mount Baldwin, Catlin mountain and Moose mountain, are the chief eminences. Catlin lake, a rather large body of water, is right on the line. This lake and its tributaries drain south into the Hudson, but on the northwest and north, the Cold river, rising in Preston ponds, flows westward into the outlet of Long lake and ultimately into the Raquette river and the St. Lawrence. The northerly town line passes along the south slopes of Mount Seward, and of Wallface mountain, crosses the Indian pass, which is one of the finest gorges in the mountains, and runs over Mount McIntyre to the northeastern corner. The central part of the town is a comparatively open valley with lakes Andrew, Newcomb, Rich and Harris and across a divide of moderate elevation, lake Sanford, all of which together cover a good part of its area. The change in topography is largely due to the presence of crystalline limestones which have furnished an easy mark for erosion. The highway to Long lake passes along the shores of lake Harris and Rich lake, and in this portion is the village of Newcomb and the only settled part of the township, except as regards summer visitors.

Geology. Field work in this town is still very incomplete. I have crossed the northeast corner at lake Colden, have visited the iron prospects around lakes Henderson and Sanford, and the outcrops along the Hudson from lake Sanford to Newcomb. I have gone from Newcomb post office to lake Newcomb and coasted around it, and have made another trip to the west boundary of the town on the Long lake road, and again along the highways to Minerva and to North Hudson, but the northwestern and the southwestern portion I have not explored, as they were not accessible in the time at command. Specimens of anorthosite have been received from the hills around the Preston ponds, through the kindness of Mr. Charles A. Macy, 2nd.

Series I and II. It is not feasible with present knowledge to attempt to differentiate these two, if, indeed, it ever will be. The crystalline limestones are widespread and have beyond question been a prominent factor in bringing about the lake basins in the central part of the town and in determining the river courses. After crossing the Minerva line the outcrops are buried in gravel until one passes the next cross-roads. At No. 49 is an outcrop of white crystalline graphitic limestone that was quarried forty or more years ago for the furnaces upon lake Sanford. On the road to Newcomb the same rock again appears at several points and furnishes a fine bluff on the south shore of lake Harris near No. 47.* Black hornblendic gneiss forms a hillock at No. 47, while just across the bridge leading to lake Newcomb is a green, rather massive gneiss, which under the microscope exhibits orthoclase, or at least untwinned feldspar, some plagioclase, quartz and hornblende. The same rock is met on the road to Mr. Pruyn's camp, in some of the borrow pits, and has been noted elsewhere in the county. Crystalline limestone and its characteristic associated black schistose and quartzose gneisses are met as far west as the town line. On the road to Newcomb lake, gneisses generally dark and hornblendic are seen, but on the shores of the lake at No. 131, just north of Mr. Pruyn's camp, white limestone again appears, with graphite, brown tourmaline and blue apatite all in small and poorly developed crystals. This ledge was also a source of stock for the early furnace near lake Sanford. At Watch Rock, at No. 132, on the southwest side of the lake, is a quartzose gneiss, and again at No. 134, called Flat Rock point, there is a dark graphitic gneiss, which is doubtless a metamorphosed sediment.

It will be a matter of great interest to determine the geology of the northwestern portion of the town, because it seems probable from the character of the country, as seen from afar, that the anorthosites and gabbros end with Santanoni and that this region of lakes and moderate hills will prove to be gneisses and limestones. The anorthosites are of course well known far to the southwest and may form isolated knobs in the region between Newcomb and the line of the Adirondack and St. Lawrence railroad, and they are present around the Preston ponds, but the country, so far as scattered observations indicate, is mostly gneisses and limestones. Much the same is likely to prove true of the southwestern corner of the town.

Series III. The anorthosites and gabbros practically make up the eastern third of the township. On the highway from North Hudson, gabbro is met at No. 49b, just east of Tahawus. On the road from Tahawus (often called the Lower Works) to the old Adirondack village (the Upper Works, or "Deserted Village") strongly gneissoid rocks first appear, but near lake Sanford's southern end they yield to well-developed anorthosites which form the hills on each side. At the prospects on the great Sanford vein, at Nos. 43 and 44, the wall-rock is a massive aggregate of labradorite, and little else, and from the ledges in the river and hillsides, near the present club-house, the

* This is the locality of the fine tourmalines first brought to notice by Professor Beecher and described by Mr. F. L. Nason in Bulletin New York State Museum, Vol. I., No. 4.

typical coarse, massive, bluish black anorthosite is to be had in endless amount. It is a beautiful rock and could not fail to impress any geologist as a most attractive object of study. The dark color of the fresh rock becomes a pale blue or grey on exposure. Its water-worn pebbles display at times the characteristic play of colors, and suggested the name Opalescent for the creek or small river that drains lake Colden. These rocks extend in typical development to the northeast, and are found in all the peaks around lake Colden. They form the walls of Indian pass and are present around the Preston ponds, but how far they extend to the west I can not state from personal observation.

Lakes Sanford and Henderson are classic ground in connection with the early metallurgy of iron in this country, and as the result of Professor E. Emmons' Report on the Geology of the Fourth District, in 1841, the knowledge of the enormous deposits was spread abroad and no doubt in part through the influence of this report the historic old furnace was constructed. More extended mention of it is made later on, but the purely scientific question of the relations of the ores to the wall-rock may be here discussed. The question is a quite different one from that of the ordinary lenticular deposits of magnetite, parallel to the laminations of gneisses. The ores are titaniferous in varying amounts up to a maximum of nineteen per cent. The walls are a perfectly massive plutonic rock, consisting of little else than labradorite. At the mill-dam opening, where the wall-rocks are the best exposed of any, and on each side of twelve to fifteen feet of pure ore, they are of exactly this type and are perfectly unmetamorphosed. In the river bed near the iron dam or ledge of ore that makes a little reef, and at the mouth of Calamity brook, the ore is mixed through the rock in clots of all sizes, from that of a nut, upward. In the ore itself are found large plagioclase crystals of dark green color because so charged with dusty augites as to be opaque, even in thin section, and around the edge of each feldspar and separating it from contact with the ore is a rim of brown hornblende and biotite, up to an eighth of an inch (three millimeters) thick. These plagioclase crystals are almost as large as a man's hand as a maximum, but they are usually one or two square inches in area. They are not strained, so far as my observation goes, and they show the twinning striae sometimes even to the unaided eye. The best place to study them is at the Sanford bed in the prospect opened up on the hillside about a mile from the lake, approximately at No. 44. There seems no escape from considering these ores as of true igneous origin, separated from a cooling and crystallizing magma, and concentrated by those magmatic changes, regarding which we are accumulating many observations, but of whose causes we yet know little. This same view has been advanced in my previous reports for the smaller ores in gabbros and, as all familiar with the literature know, it is the explanation advanced in later years for the parallel occurrences of titaniferous ores in Scandinavia. It merely assumes an abnormal richness in favored localities of one of the normal but subordinate minerals of these rocks. Details of the size, composition and location of the ore-bodies are given in a subsequent paragraph.

Series IV. There are no Palaeozoic sediments in the township.

Series V. No diabase or other dikes have been met, but there is little doubt that such exist.

Series VI. There is a great deal of drift and gravel south of Tahawus post office, and from there to and beyond Newcomb post office. The borrow pits of the fine highway from Newcomb to Mr. Pruyn's camp on Newcomb lake, give excellent sections and exhibit large boulders often mingled with the finer gravels. The boulders are all of anorthosites or related rocks that have been brought down in great quantity from the mountains on the north, and that supply the most convenient means of studying their varieties.

Iron Mines. The only iron mines of the town are those around lakes Sanford and Henderson, which were opened about 1840. Rumors of the existence of the ore reached the settlements some five years or more earlier, so that an expedition was organized in 1836 and another in 1837, that went in to lake Henderson and brought back reports about the district.* The Natural History Survey of New York was organized at about this time and in the next few years the annual reports of Professor Ebenezer Emmons, who had charge of the work in this part of the State, make extended mention of the ores. Professor Emmons was profoundly impressed with their abundance and extent and regarded them as among the most important resources of the state. In his final report† he gives a fairly complete description and urges their development. Soon after this a small blast furnace was erected, of five tons daily capacity, and some years later a larger one of twelve to fifteen tons, together with puddling furnaces and the necessary machinery for making bar iron.‡ The latter stack is still standing and the accompanying illustration is from a photograph taken by the writer in September, 1894. Mr. Rossi gives

* W. C. Redfield, Some Account of Two Visits to the Mountains of Essex County, N. Y., 1836-1837. American Journal of Science, i. XXXIII., 301.

† Report on the Second District, p. 244, 1842.

‡ See A. J. Rossi—Titaniferous Ores in the Blast-Furnace; Transactions American Institute of Mining Engineers, XXI., pp 832, 1893. Especially p. 835.

PLATE XI

VIEW OF THE BLAST FURNACE AT THE "UPPER WORKS" ON LAKE SANFORD. THIS FURNACE WAS BUILT ABOUT 1852; ITS LINES ARE GIVEN BY A. J. ROSS (TRANS. AMER. INST. MIN. ENG. XXI, PAGE 837). PHOTOGRAPHED BY J. F. KEMP, 1894.

SEE PAGE 608.

the working drawings of the furnace in his paper just cited. The furnace went out of blast about 1859, and the enterprise stopped after having been in operation fifteen or eighteen years, during which the manufactured iron made its labored exit to the markets by means of teams to Crown Point, some fifty miles distant. The expense of haulage proved too serious. The early promoters of the enterprise have found enduring memorials in the local geographic names, Henderson, Colden, McIntyre, etc. Emmons seems not to have known that the ores were titaniferous, nor so far as can be learned were the later operators, at least for some years, aware of this fact. In view of the great prejudice against titaniferous ores to-day this seems remarkable, because, so far as we know, these comparatively primitive furnace men found no difficulty in smelting the ores. The question of their peculiar properties and behavior in the furnace has been taken up in extensive experiments in the last two or three years by Mr. A. J. Rossi* with very encouraging results. With multi-basic slags and high percentages of TiO_2 in them—say twenty to thirty-five—no trouble was met in a low small stack from their reputed infusible properties. The question is an interesting and important one, and it is much to be hoped that it may be solved in the large way and that these great reserves of titaniferous ore may be made available.

The ore-bodies at present exposed are in the situations shown by the accompanying map. The map has been traced in outline from one that was made for the iron company about 1850 and that was engraved and printed. One of the few copies known to be extant was kindly loaned to me by Mr. James MacNaughton for this purpose. In transcribing, some topographic shading has been omitted, and one or two additional names, signs for mines, etc., have been introduced. With one or two corrections, the map is practically the same as that made and printed by Professor Emmons in his early report. The map of 1850, from which the present one here introduced was traced, is smaller than Emmons's original. The long side of the latter is approximately twenty-one inches, while the long side of the former is fourteen inches. The present map is nine inches on this same line.

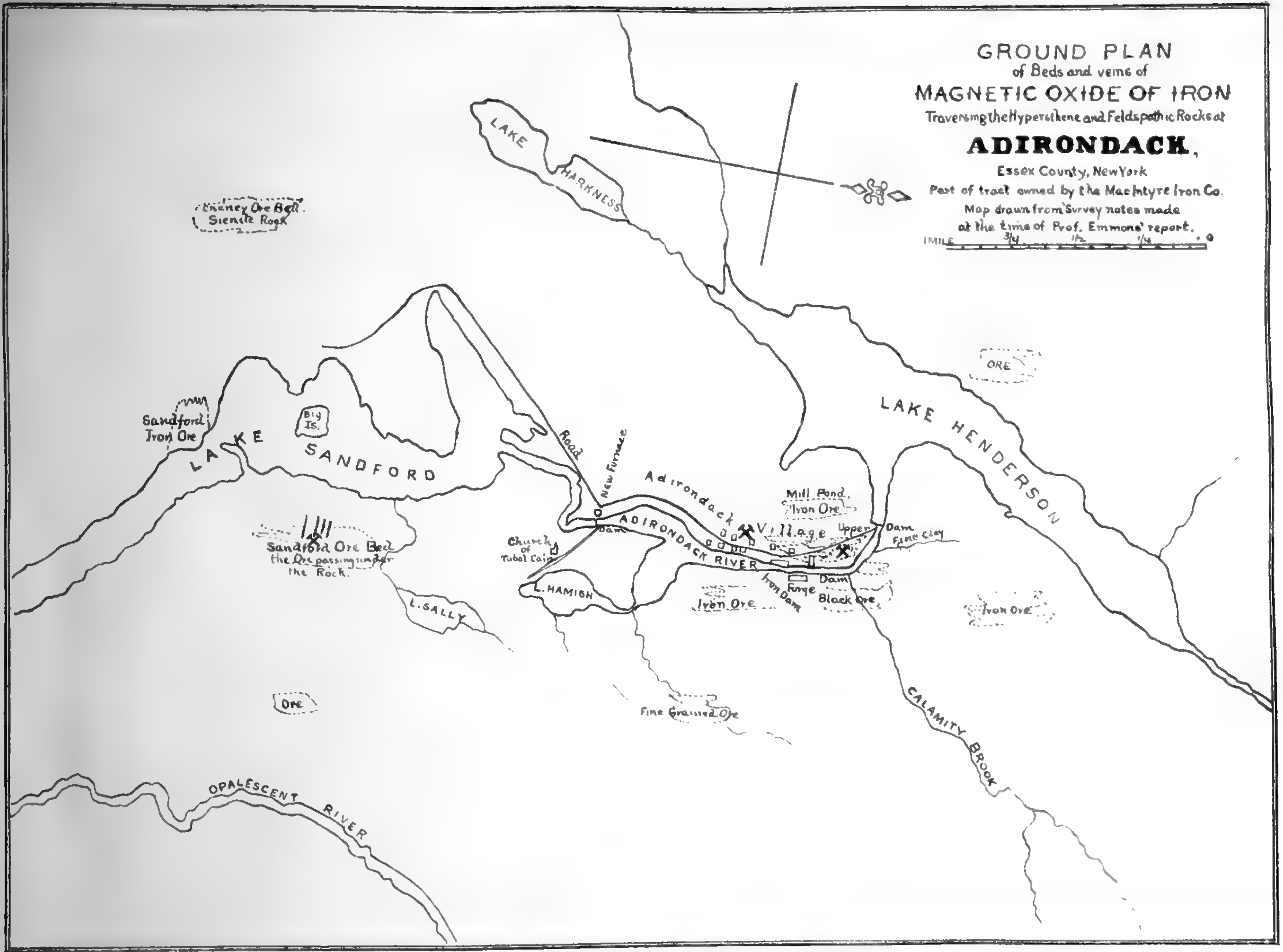
An old opening is northwest of lake Henderson, but I have not seen it. A short distance below the Upper Dam, at the outlet of lake Henderson, is the Millpond opening, on a mass twelve to fifteen feet wide, striking nearly north and south and dipping about 75° E. Its location is shown approximately by the crossed hammers. This was one of the chief sources of ore for the early furnace, so that a pit now remains about twenty-five feet or more

* A. J. Rossi, *Op. cit.;* also, The Smelting of Titaniferous Ores; "The Iron Age," Feb. 6 and 20, 1896.

on the strike and of depth not visible, as it is full of water. The wall rock is massive dark anorthosite, practically pure labradorite A line of strong attraction runs north and south along the east side of the Adirondack river. There is a little show of ore where it crosses Calamity brook, but the amount visible is not great. I was informed by Mr. Buttles, who was in charge of the club house, that it had been opened at the north, where the word *iron-ore* appears on the map. The "Iron Dam," so widely known in connection with the region, crosses the river just above the present club house, and shows as a black strip, striking approximately N. 25° E. The ore is more or less mixed with anorthosite and appears to be an integral part of the rock. In the rear of the ice houses that stand to the west and a short distance back of the club house, there are openings on another body of ore which is revealed in a small excavation. A breast several feet across is exposed. The strike is somewhat indefinite, but the ore bears westerly into the hill.

This entire belt of ore along the river may perhaps be considered as a single one of many individual masses. The ore afforded was called "Black Ore," and the name is still perpetuated on the map given above. Professor Emmons regarded the belt as essentially a single one with many individual masses separated by intervening walls of rock. He also states that "hypersthene, labradorite and small masses of serpentine" were the only foreign admixtures. It is of mineralogic interest that he cites one or two inclusions of pyrites, the size of a butternut, for sulphides are very rare in titaniferous ores. Professor Emmons gives the extreme width of the belt as over 700 feet, and its length as 3,168 feet. Its general character of large masses in the midst of wall rock which is also massive, lends itself to an interpretation of igneous origin with greater readiness than to any other. Great quantities of ore were obtained from the float for the early furnace.

Ore from the Millpond opening was largely used by Mr. Rossi in his experimental run, and several analyses have been published by him to which are added two that I have received directly from him. The analyses show that the percentage in titanic acid is quite variable, ranging in round numbers from ten to twenty. The percentages in iron hold at very good values, and the phosphorus and sulphur are extremely low. The alumina and silica are in small amount in the first two and suggest the presence of labradorite, but the high alumina of the third is difficult to explain on any other supposition than that some form of spinel is in the ore. Titaniferous ores high in alumina have been met in Westport township, and the same inference is still more strongly suggested by them.


GROUND PLAN
of Beds and veins of
MAGNETIC OXIDE OF IRON
Traversing the Hypersthene and Feldspathic Rocks at
ADIRONDACK,
Essex County, New York
Part of tract owned by the MacIntyre Iron Co.
Map drawn from Survey notes made
at the time of Prof. Emmons' report.
1 MILE 3/4 1/2 1/4 0
LAKE HARKNESS
Cheney Ore Bed
Sienite Rock
ORE
LAKE HENDERSON
Sandford Iron Ore
Big Is.
LAKE SANDFORD
Road
New Furnace
Adirondack Village
Mill Pond
Iron Ore
Upper Dam
Fine Clay
ADIRONDACK RIVER
Dam
Church of Tubal Cain
Sandford Ore Bed
the Ore passing under the Rock.
L. HAMISH
L. SALLY
Iron Dam
Forge
Dam
Black Ore
Iron Ore
Iron Ore
Ore
Fine Grained Ore
CALAMITY BROOK
OPALESCENT RIVER

	HABERSHAW.	ROSSI.	ROSSI.	ROSSI.	LEDOUX.
SiO_2	1.09	3.67	1.53		0.91
TiO_2	10.73	13.38	19.74	20.24	20.49
Al_2O_3	0.44	1.50	3.50		
CaO	tr.	little	little		
MgO	tr.	0.50	1.60		
Mn_3O_4	0.13				
Fe_3O_4	87.20	82.37	73.62		
P	none	0.017	0.037		
S	none	0.068	0.08		
Fe	63.45	59.56	53.62	55.62	54.80

After engaging a guide and a boat, I rowed down the river and coasted the east shore of lake Sanford to a point somewhat east or south of east from Big island. We then walked about three-fourths of a mile up hill to the east, to an opening on the Sanford ore-bed, very near the location of the crossed hammers on the map. Considerable ore had been blasted and taken away a short time before. The location was about 300 feet above the lake. A breast about thirty feet wide by fifteen feet high was exposed with no wall rock appearing. It apparently trended northeast, as I followed float ore with no outcrops for a hundred yards. All the loose surface rock met was anorthosite. The ore both in the lump and in the breast contains occasional crystals of green plagioclase, in instances three or four inches in diameter. They show the characteristic situations, but are so thickly charged with minute green augites that a millimeter from the edge, as shown by thin section, they are practically opaque. Each is surrounded by a reaction rim, two to three millimeters wide, of biotite and brown hornblende, so that in no case does the feldspar actually touch the ore. They are extremely curious and interesting phenomena. Undoubtedly the feldspars are original crystallizations from the igneous magma precisely like the ore itself, and becoming involved in it, these rims of minerals of intermediate composition were produced by the reaction of the two on each other. Some samples of ore have given curiously high percentages of alumina, and, as earlier remarked, these included feldspars are in part responsible for it.

The open cut gives no indication of the actual size of the ore-body except so far as the failure to reach the walls implies that it is large. A line of attraction has been traced down to the lake, however, across it and on the other side where the name Sanford appears again. A second line of attraction has also been noted crossing the lake further south.

In Professor Emmons's day, four sections were uncovered on the east side of the lake, across this vein by trenching. The longest were 564 feet and 610 feet respectively, and they exposed ore with occasional streaks of rock for the entire distance. These trenches have long since become filled in, but there is no doubt that the supply of ore is enormous. By the heavy lines running into the Sanford ore-bed I have endeavored to locate these trenches as accurately as possible from the descriptions of Professor Emmons. Were mining again begun, the Sanford ore would naturally be the one first attacked and the indications are favorable to many years of open cut work above the level of the lake.

The composition of the ore is shown by the following analyses of which the first four are given by Mr. Rossi in the *Iron Age*, February 6, 1896 :

	Habershaw.	Ricketts & Banks.	Ledoux & Co.	Rossi.	Miss White.	Concentrates. C. F. Chandler.	Tailings. C. F. Chandler.
SiO_2	0.87	2.46	1.39	1.34	1.39		
TiO_2	10.91	20.03	19.52	18.70	14.52	4.0	47.50
Al_2O_3 . . .	0.53	3.50	4.00		5.81		
CaO							
MgO							
Mn_3O_4 . . .							
Fe_3O_4 . . .	87.60	70.73	70.80	71.03			
P	none		0.022				
S	none		0.028				
Fe	62.65	51.22	51.30	51.44	56.60	62.66	36.86

Experimental attempts to concentrate the ore with magnetic machines were made some years ago in the hope that the richly titaniferous portions could be separated from the non-titaniferous, on the assumption that the latter variety was more highly magnetic than the former. All such experiments are of course based on the supposition that titaniferous ores are mechanical mixtures of normal magnetite with ilmenite, but there is little reason to doubt that where the percentage of TiO_2 is considerable, say ten and above, the mixture is either so intimate as not to be economically broken up, or else it is actually a chemical combination in the nature of ilmenite or some related mineral. Mere magnetism does not preclude titanium, for O. A. Derby has found in Brazil, natural lode-stone with twenty per cent. TiO_2.

Indications of ore have been met across the divide to the east of the Sanford ore-bed and in the watershed of the Opalescent river. I have not visited the locality, as but little work has been expended on it and none in fact since the early operations.

About a mile west of lake Sanford is the Cheney ore-bed that presents some differences both in composition and in wall rock from others. Professor Emmons, on Plate III of his report, calls the wall rock "sienitic," but it really is a gneissoid variety of gabbro, having a laminated structure visibly developed, while the minerals are those of the familiar gabbros of the region. Dark silicates are much more abundant than in the anorthosites that form the walls of the other veins. I did not personally visit the Cheney exposure, but specimens of the ore and wall rock were obtained by Mr. James MacNaughton and kindly furnished to me. I understand that forty or fifty feet of ore are exposed without showing the walls. The following analyses illustrate the composition. They were published by Mr. Rossi in the *Iron Age*, February 6, 1896.

	WILBUR. (RICH ORE.)	ROSSI. (POOR ORE.)
SiO_2		9.79
TiO_2	8.25	15.77
Al_2O_3		7.12
CaO		8.89
MgO		3.00
Mn_3O_4		
Fe_3O_4	86.53	55.64
P	0.39	
S	0.74	1.00
Fe	62.15	40.33

The ore runs higher in phosphorus and sulphur than any of the others yet analyzed. Mr. Rossi has also noted in his experiments, indications of the presence of vanadium, which has been recognized both in Scandinavia and in New Jersey as one of the characteristic ingredients of titaniferous ores. The high alumina in the second analysis, much above any aluminous silicate that might be present, is worthy of note, and the same is true of the lime. Some at least of the magnesia is combined with iron oxide and silica to yield hypersthene; some perhaps with lime and alumina for augite. Some of the lime may be united with silica and titanic oxide to give titanite and some with alumina and silica to form labradorite; but in whatever way the combinations are worked out, there remains an excess of alumina and lime, so that the probability of spinel being present is heightened.

Professor Emmons mentions other ore-bodies whose presence was demonstrated in his time, viz., a vein of "fine-grained" ore about eighty rods east of the works. It would be on the map at or near the southern prolongation of the "Black Ore" belt, but as he states (page 254) that it was 150 feet across and 5,742 feet long, it must be distinct from this vein as mapped. He also cites much float-ore along East river (now called Calamity brook). Since his time float-ore has also been located to the northwest toward the Preston ponds. The magnetic surveys of Mr. Sebenius have indicated strong attraction under the lake and on its shores south of the Sanford belt, and still additional localities of attraction have been met near the Lower Works (now called Tahawus post office) in the gneissoid rocks of that section. In fact, the more one collates the accumulated data, the more one shares in Professor Emmons's impression of the large amount of ore that is present.

For the ore-bodies in the massive anorthosites, the only conception that fits their mineralogic character and geologic associations is that they are great bodies of titaniferous iron oxides, segregated from a vast plutonic magma, through whose crystallized substance they are now distributed in broad and somewhat roughly outlined belts. All gradations can be found from pure metallic oxides to pure masses of labradorite.

As regards their future development, if brought about, it will be by means of an extension of the Adirondack railroad up the valley of the Hudson, along the route that can be easily traced on the maps of Minerva and Newcomb. The grades are gentle and the engineering difficulties are slight.

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

SECTIONS AND THICKNESS OF THE LOWER SILURIAN FORMATIONS ON WEST CANADA CREEK AND IN THE MOHAWK VALLEY.

COMMUNICATED BY

CHARLES S. PROSSER AND EDGAR R. CUMINGS.

James Hall, *State Geologist*.

Sir:—The accompanying paper gives a detailed account of the rock sections at various localities in the West Canada creek and Mohawk river valleys. The results obtained serve to show that the Calciferous sandrock and Utica slate have a much greater thickness than that noted in previous descriptions of these formations.

Respectfully yours,

CHARLES. S. PROSSER,
EDGAR R. CUMINGS.

Union College, Schenectady, N. Y.

PLATE I

WEST

D^4

EAST

VIEW OF THE "NARROWS," FROM LOWER END, WITH SHERMAN FALL IN THE DISTANCE. THE ZONE D^4, OF WHITE, WELL SHOWN ON THE WEST BANK.

Sections and Thickness of the Lower Silurian Formations on West Canada Creek and in the Mohawk Valley.

By Charles S. Prosser and Edgar R. Cumings.

Introduction.

A recent paper describing the geology of the vicinity of Trenton Falls contains this statement: "The writer was unable to find a detailed tabulation of the stratigraphy or local geological boundaries of the type section [of the Trenton formation]." *

In that paper its author has given a detailed account of the stratigraphy and faunas of the various zones along the gorge of West Canada creek, at Trenton Falls, based upon extensive collections of fossils from the entire length of the gorge; these were carefully identified and assigned to the various zones into which he divided the section. In a recent examination of the gorge, made by the writers, some differences in the stratigraphic details were noted, and in order that the description of this interesting formation at its typical locality may be as accurate as possible, it is considered advisable to publish the following section and, in addition, to give some account of the formations in the vicinity of Newport on West Canada creek, which were also described by Mr. White.

* The Faunas of the Upper Ordovician strata at Trenton Falls, Oneida County, New York; by Theodore G. White. Transactions New York Academy of Sciences, Vol. XV, April, 1896, p. 71.

TRENTON FALLS.

The rock section begins near the southern end of the path on the western side of the gorge and extends to the top of Prospect quarry, a distance of about two miles. The path may be followed for a short distance below the hotel stairs; but the lowest rocks, stratigraphically, are exposed in the Narrows above this point. At the water level below the hotel stairs, is the base of Mr. White's section D of station No. 130, which also extended from this locality up the gorge to the Prospect quarries. Section C, No. 130, on the eastern side of the gorge below Section D, was studied by Mr. White, but apparently no considerable thickness of lower rocks was found.

Section of Trenton Falls Gorge.*

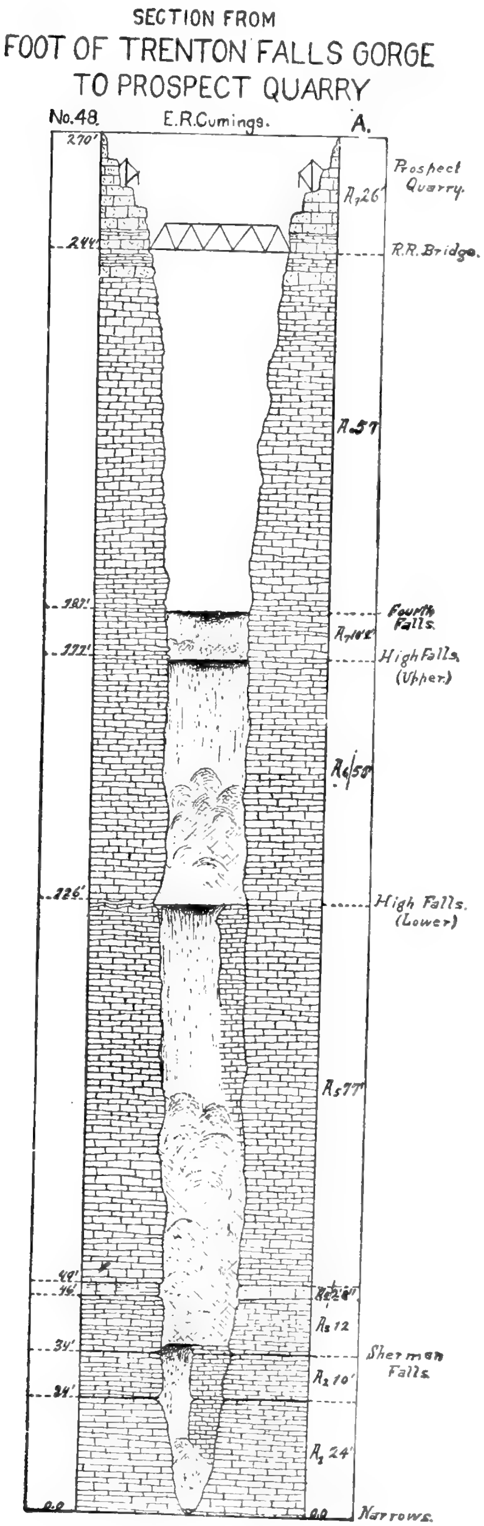
*A*¹. The lowest rocks exposed along the path on the western side of the gorge, are twenty-four feet thick at the Narrows, and on account of the heavy dip down stream, show only the upper eleven feet at the southern end of the path. The upper part is composed of thin layers, three to five inches thick, which form a somewhat clearly defined band two and one-half feet thick. This is Nos. 3 and 2 of White's section. Below this band are similar limestones with shaly fossiliferous partings. In the Narrows, the lowest layers are compact bluish grey, thin-bedded limestones, interstratified with coarser-grained layers containing numerous well-preserved specimens of *Monticulipora (Prasopora) lycoperdon.* The more compact layers are unfossiliferous. In the Narrows are shown Nos. 3, 2 and 1 of White, and apparently about thirteen feet of lower rocks. Feet 24 = 24

1. *Monticulipora (Prasopora) lycoperdon,* (Say). (aa)†
2. *Orthis (Dalmanella) testudinaria,* Dal. (r)
3. *Plectambonites sericea,* (Sowb.), Hall and Clarke. (r)
4. *Ceraurus pleurexanthemus,* Green. (r)
5. Crinoid segments.

*A*². Heavy bed of compact, regular, thin-bedded, very dark blue limestone, from eight to ten feet thick, which separates into layers from three to ten inches in thickness, divided by shaly partings. This heavy bed is prominently shown along both sides of the gorge from the southern end of the path on the western side, to the upper part of Sherman fall. At the end of the path, where the rods are placed, the base of this bed is about eleven Feet 10 = 34

* Station No. 48, Section A. Union College Survey.

† The relative abundance of the species is indicated in the following manner: a = abundant; aa = very abundant; c = common; r = rare; rr = very rare, when but one or two specimens have been found.


SECTION FROM
FOOT OF TRENTON FALLS GORGE
TO PROSPECT QUARRY
No.48.
E.R.Cumings.
A.
Prospect Quarry.
R.R. Bridge.
Fourth Falls.
High Falls. (Upper)
High Falls. (Lower)
Sherman Falls.
Narrows.

feet above the creek level. A little above, is the foot of the hotel stairs on the heavy bed two and one-half feet above its base. Opposite the hotel stairs, this bed is not as sharply shown as in the gorge above, on account of the presence of soil and debris, but it has a thickness of at least eight feet. Rather more than half way from the hotel stairs to Sherman fall, the gorge becomes very narrow and may appropriately be called the Narrows. This part of the glen is well shown in Darton's picture of the "Lower Gorge at Trenton Falls."* At the Narrows the dip is 3° S., but it is variable in this part of the glen. At this point the base of A^2 is twenty-four feet above the creek level, giving the greatest thickness of the lower rocks found in this part of the gorge. This heavy stratum is readily followed along the side of the gorge from the hotel stairs to the Narrows, and may be traced by the eye along the eastern bank nearly all of the distance to the place where it forms the conspicuous bed in the upper part of Sherman fall. Its base is the second noticeable line below the top of the eastern part of Sherman fall. This bed was also traced along the western bank from the Narrows to Sherman fall, where it meets the same bed of the eastern side in the mural front of the fall. At the Narrows and in the cliff opposite Sherman fall it has a thickness of ten feet. This zone is No. 4 of Mr. White's section, which he described as it occurs at the hotel stairs, but he failed to trace it up the gorge to Sherman fall. White's No. 7, described as "the broad seam seen in Sherman fall," is the same as his No. 4; and Nos. 5 and 6, given as between Nos. 4 and 7, belong below No. 4.

A^3. From the top of the heavy bed to the base of the dark blue massive stratum above Sherman fall. The rocks consist of thin layers of limestone with shaly partings and are well shown in the cliff along the path opposite the top of Sherman fall. In the upper part, corresponding to D^{10} of White, are abundant fossils, as may be seen from the list below. Feet 12 = 46

1. *Monticulipora (Prasopora) lycoperdon* (Say). (r)
2. *Diplograptus amplexicaulis*, Hall. (r)
3. *Trematis terminalis* (Emmons), Hall. (r)
4. *Rafinesquina alternata* (Con.), H. and C. (r)
5. *Strophomena* cf. *Scofieldi*, Winch. and Schuch.† (r)
6. *Orthis (Platystrophia) biforata* (Schl.), Bill. (r)
7. *Orthis (Dalmanella) testudinaria*, Dal. (c)
8. *Plectambonites sericea* (Sowb.), H. and C. (aa)

* Thirteenth Annual Report of the State Geologist [New York], 1894, p. 11. See also Plates I and II of the present paper.
† Kindly determined by Professor J. M. Clarke.

PLATE II

D^{11}

D^{4}

NEARER VIEW OF WEST BANK AT THE "NARROWS," SHOWING ZONES D^{4} AND D^{11}, OF WHITE.

9. *Zygospira recurvirostra*, Hall. (c)
10. *Bellerophon bilobatus* (Sowerby). (r)
11. *Asaphus platycephalus*, Stokes. (c)
12. *Calymene callicephala*, Green. = *C. senaria*, Con. (c)
13. *Ceraurus pleurexanthemus*, Green (?). (r)

This zone includes Nos. 8, 9 and 10, of White, the combined thickness of which is twelve feet, the same as that in the present section. (Plate III.)

A[4]. A stratum of massive dark blue limestone conspicuous in the side of the gorge along the path above Sherman fall, varying in thickness from two feet, seven inches, to two feet, ten inches, called for convenience in the general section, three feet. On weathering, the stratum splits into thin irregular layers similar to those immediately above and below. This prominent stratum is a convenient stratigraphic mark for this part of the section and is clearly shown in Figure A Plate IV, of White's article, where it is described as D^{11} of his section. Feet 3 = 49

A[5]. The heavy blue stratum may be readily followed to the foot of the lower fall of High fall, and A^5 includes the rocks from the top of this layer to the base of a conspicuously contorted stratum opposite the top of the lower fall of High fall. The rocks are thin and shaly in the upper part with thicker layers in the lower part. Feet 77 = 126

A[6]. From the base of the contorted stratum to the crest of the upper part of High fall. The folded stratum is well shown in Figure A, Plate III, of Mr. White's article. The rocks are thin-bedded. Both the lower and upper portions of High fall, or zones A^5 and A^6 of this section, are shown in the accompanying plate (IV). The following species were collected in A^6: Feet 51 = 177

1. *Monticulipora (Prasopora) lycoperdon* (Say). (c)
2. *Stictopora*, sp.
3. *Rafinesquina deltoidea* (Con.), H. and C. (aa)
4. *Orthis (Platystrophia) biforata* (Schl.), Bill. (r)
5. *Orthis (Dalmanella) testudinaria*, Dal. (aa)
6. *Plectambonites sericea* (Sowb.), H. and C. (aa)
7. *Tellinomya dubia*, Hall. (r)
8. *Endoceras proteiforme*, Hall. (c)
9. *Cyrtoceras*, sp. (r)
10. *Asaphus platycephalus*, Stokes. (aa)
11. Crinoid segments.

*A*⁷. From the crest of the upper part of High fall to a stratum at the top of the small fall below the Adirondack railroad bridge the rocks have a thickness of ten feet and two inches. A somewhat conspicuous stratum, near the crest of the upper part of High fall, may be followed along the bank as far as the bottom of the small fall below the railroad bridge. The rocks are thin-bedded, rather coarse-grained and fossiliferous. Zones A^5, A^6 and A^7 of the present paper, with a total thickness of 138 feet, are approximately equivalent to zones D^{12}, D^{13}, D^{14}, D^{15} and D^{16}, of White, with a total thickness of 166 feet. The greater part of this difference is in the thickness of the rocks forming the lower part of High fall, which measure by the Locke level seventy-seven feet, while they were estimated as 107 feet in thickness by Mr. White. Feet 10 = 187

1. *Orthis (Platystrophia) biforata* (Schl.), Bill. (a)
2. *Orthis (Dalmanella) testudinaria*, Dal. (c)
3. *Rafinesquina alternata* (Con.), H. and C. (r)
4. Crinoid segments.

*A*⁸. This zone extends from the stratum noted at the top of the falls, just below the Adirondack railroad bridge, to the base of the massive crystalline limestone which forms the upper part of the cliffs above the railroad bridge. At this bridge is an excellent locality for measuring its thickness, the base being marked by the rather heavy stratum which may be traced from the top of the small fall below the railroad bridge to the vicinity of the railroad pier; and its top by the base of the massive limestone outcropping near the top of the cliff under the railroad bridge. This zone, capped by the massive limestone, forms the sides of the gorge from below the railroad bridge to Prospect village. It corresponds with zones D^{18}, D^{19}, D^{20}, D^{21} and D^{22}, of White, which were given as approximately eighty-seven feet in thickness. They are thin-bedded, compact limestones, part of the strata somewhat crystalline, separated by shaly layers. This zone contains numerous fossils, some layers having large numbers of *Orthis (Dalmanella) testudinaria*. At Prospect, along the sides of the creek from a little distance below the falls to the highway bridge, is a good place for collecting. The surfaces of some of the highly inclined layers, by the side of the creek just above the highway bridge, show a large number of fragments of *Asaphus platycephalus*. At the upper end of the gorge the rocks are very much tilted, exhibiting the greatest amount of folding seen in any part of the gorge. The cliff on the eastern side of West Canada creek above the Adirondack railroad bridge is well shown in Plate V. The massive crystalline Feet 57 = 244

PLATE III

WEST

D⁴

EAST

Sherman fall, from above the "Narrows." Zone $D^4 = D^7$, of White, shown on the east side on the bare ledge and zone D^{11} on the west side just above the water.

limestone of A^9 forms the upper part of the cliff, while the thinner limestones of A^8 form the middle and lower part of the cliff. The following species were collected in A^8.

1.	*Monticulipora* (*Prasopora*) *lycoperdon* (Say).	(c)
2.	*Escharopora recta*, Hall.	(r)
3.	*Trematis terminalis* (Emmons), Hall.	(r)
4.	*Rafinesquina alternata* (Con.), H. and C.	(c)
5.	*Rafinesquina alternata* var. *nasuta*, Con.	(r)
6.	*Rafinesquina deltoidea* (Con.), H. and C.	(r)
7.	*Strophomena* cf. *Scofieldi*, Winch. and Schuch.	(r)
8.	*Orthis* (*Platystrophia*) *biforata* (Schl.), Bill.	(c)
9.	*Orthis* (*Dalmanella*) *testudinaria*, Dal.	(aa)
10.	*Plectambonites sericea* (Sowb.), Hall.	(a)
11	*Zygospira recurvirostra*, Hall.	(r)
12.	*Asaphus platycephalus*, Stokes.	(c)
13.	*Calymene callicephala*, Green.	(c)
14.	*Ceraurus pleurexanthemus*, Green.	(r)
15.	*Leperditia fabulites*, Con.	(r)
16.	*Endoceras proteiforme*, Hall.	(r)
17.	*Orthoceras*, sp.	(r)
18.	*Bellerophon bilobatus* (Sowerby).	(r)
19.	*Dendrocrinus gracilis* (Hall).	(aa)
20.	Crinoid segments.	

A[9]. Massive grey Trenton limestone of the Prospect quarries, twenty-six feet thick in quarry on north side of creek near Prospect, burned for quicklime and also used as a construction stone. It forms the top of the steep cliffs along the upper gorge from the Adirondack railroad bridge to a point above the highway bridge at Prospect. This massive crystalline limestone in moderately thick layers, contains numerous fragments of fossils, though the number of perfect specimens is small; while in the thin, black, shaly layers fossils are common. This zone corresponds to D^{23}, of White, which is given as twenty feet thick. Conrad, in 1837, stated: "North of Trenton Falls there is a capping of grey crinoidal limestone,"* and he undoubtedly referred to this division of the Trenton limestone. Feet 26 = 270

1.	*Monticulipora* (*Prasopora*) *lycoperdon* (Say).	(a)
2.	*Stictopora* cf. *acuta*, Hall.	(r)
3.	*Dendrocrinus gracilis* (Hall).	(c)

* First Annual Report Geological Survey, Third District, New York (Assembly Document No. 161), p. 164.

4. *Rafinesquina alternata* (Con.), H. and C. (c)
5. *Rafinesquina deltoidea* (Con.), H. and C. (c)
6. *Orthis* (*Platystrophia*) *biforata* (Schl.), Bill. (a)
7. *Orthis* (*Dalmanella*) *testudinaria*, Dal. (a)
8. *Plectambonites sericea* (Sowerby), H. and C. (c)
9. *Zygospira recurvirostra*, Hall. (r)
10. *Asaphus platycephalus*, Stokes. (c)
11. *Calymene callicephala*, Green. (c)
12. *Ceraurus pleurexanthemus*, Green. (r)
13. *Murchisonia gracilis*, Hall. (r)
14. *Orthoceras*.

The total thickness of this section from the lowest exposures in the Narrows to the top of the Prospect quarries, as determined by the authors with tape and Locke level measurement of the various parts, is 270 feet.* This amount, however, does not give the thickness of the formation, since neither its top nor bottom is shown at Trenton Falls. The thickness of the same section, as given by Mr. White, is 325 feet,† while Mr. Darton stated: "The greatest development of the Trenton which I have observed is at Trenton Falls, where there appears to be a thickness of 120 feet."‡ In 1838, Vanuxem said "at Trenton Falls, the thickness is upwards of one hundred feet,"§ though in his final report he simply states that the sides of the gorge are

* Recently the writer partly remeasured the section using an Abney's level and obtained the same result, 187 feet, for the thickness of the rocks from the creek level in the Narrows to the top of Mill Dam fall. The thickness of the rocks from the foot of High fall to the top of its lower part, is sixty-seven and one-half feet; to the contorted layer, eleven and one-half feet more; from the base of the upper part of High fall to its crest, forty-eight feet; and from that stratum to the top of Mill Dam fall, twenty-two feet. From the foot of the railroad pier, which rests on the top layer of Mill Dam fall, to the base of the massive crystalline limestone, I obtained sixty-two feet, making the total thickness of the section 275 feet. C. S. P.

† Transactions New York Academy of Science Vol. XV, pp. 79 and 80. On page 89 the total thickness of the upper and middle Trenton limestone at Trenton Falls is given at 336 feet; while on page 81 it is stated that the total thickness of the typical Trenton Falls section is 318 feet 10 inches. However, in this latter place, if the sixteen feet in the zones repeated in the lower part of the section be omitted, it will leave ten feet six inches instead of "twenty-six feet six inches below D^7" as stated by Mr. White. In his later paper on "The Original Trenton rocks" (American Journal of Science, Fourth Series, Vol. I, December, 1896, page 430) Mr. White gives 325 feet for the Trenton Falls section. Since the above was written I have received a letter from Mr. White, in which he states that his section was thirty feet too thick, because he mistook "a blurred 6" in his note book for a 9. He further said that the following corrections should be made on pp. 78 and 79 of his article:

	Total thickness. Feet.
"$D^{12.13}$,	106
D^{14},	108¼
D^{15} should read extending to the top of upper portion of High fall,	168
D^{16}, after third fall insert (Mill Dam fall),	182
D^{17} (layer on which pier of R. R. bridge rests),	185
D^{18},	188
D^{19},	191
D^{20},	193
D^{21}, for Mill Dam read Alhambra,	199
D^{22},	269
D^{23},	284

After making the above corrections it will be found that the rocks from the base of High fall to the top of Mill Dam fall have nearly the same thickness in both sections, 138 feet in White's, and 138 feet in that of Prosser and Cumings C. S. P.

‡ Thirteenth Annual Report State Geologist [New York], 1895, p. 425.

§ Second Annual Report Third District (Assembly Document, 1838, No. 200), p. 275.

PLATE IV

HIGH FALL, SHOWING BOTH THE LOWER AND UPPER PARTS. ZONES A^5 AND A^6 OF THE SECTION ARE SHOWN

vertical "with an average height of over one hundred feet,"* and does not give the thickness of the section. An earlier and quite accurate estimate was made by James Renwick, who briefly described the geology in a paper read in November, 1824, saying: "The river has worn itself a passage through the rock for the distance of nearly two miles, forming a series of water-falls, and has thus laid open to view the strata to a depth of probably 300 feet."†

THE NEWPORT SECTIONS.

In Newport township, some eight miles southeast of Trenton Falls, are interesting exposures of the Calciferous sandstone, Birdseye and Black river limestones. One of these is along the western bank of West Canada creek and the cut of the Adirondack railroad, two miles above Newport village, and one and one-half miles below Poland. At this locality the railroad is near the bank of the creek and the cut is about 150 yards north of the fifteenth mile-post. This section was described by Mr. White under the title of the "Poland lime kiln section, No. 130 A."‡

Section of the Newport Railroad Cut.

Along the bank of the creek and at the southern end of the railroad cut is the following section:

XLIX B[1]. Nearly opposite the fifteenth railroad mile-post, in the bed of the creek and exposed about one foot above the level of the water, is a heavy stratum of calcareous sandstone. The lithologic character of this rock is like the Calciferous sandrock, to which formation it is referred. An analysis of a specimen, from this stratum, by Mr. Edward P. McKeefe, of Union College, gave the following result: Feet 1 = 1

SiO_2	74.37	per cent.
Fe_2O_3	7.49	"
$CaCO_3$	15.75	"
$MgCO_3$	2.28	"
	99.89	per cent.

B[2]. Transitional layers from the Calciferous sandrock to the Birdseye limestone. Thickness not accurately determined on account of the high water. The upper six feet of this zone are composed of two layers of impure limestone which are conspicuous in the lower half of the bank Feet 11 + = 12

* Geology of New York, Part III, 1842, p 52.
† Annals Lyceum Natural History, New York, Vol. I, Part I, 1824, p. 185.
‡ Transactions New York Academy of Sciences, Vol. XV, April, 1896, pp. 82–84.

below the railroad opposite the southern end of the cut. At high water the base of this part is only about one foot above water level. Below are thinner layers, shown a little farther down the creek, which are at least five feet thick. Some of the layers in this zone are heavy and strongly arenaceous, while others composed of a compact, dove-colored limestone, very similar to the Birdseye, are quite conspicuous in the lower part. In some of the layers are small *Phytopsis*-like tubes similar to the small ones in the Birdseye filled with calcite. In one of the limestone layers near the bottom of this zone are specimens of *Leperditia* which may be compared with the ostracoid described by Professor Hall as *Cytherina* sp. from the Birdseye limestone of Watertown, N. Y.* A sample from one of the limestone layers near the bottom of this zone was analyzed by Mr. McKeefe with the following result:

SiO_2	17.87	per cent.
Fe_2O_3	1.99	"
$CaCO_3$	79.72	"
$MgCO_3$	1.22	"
	100.80	per cent.

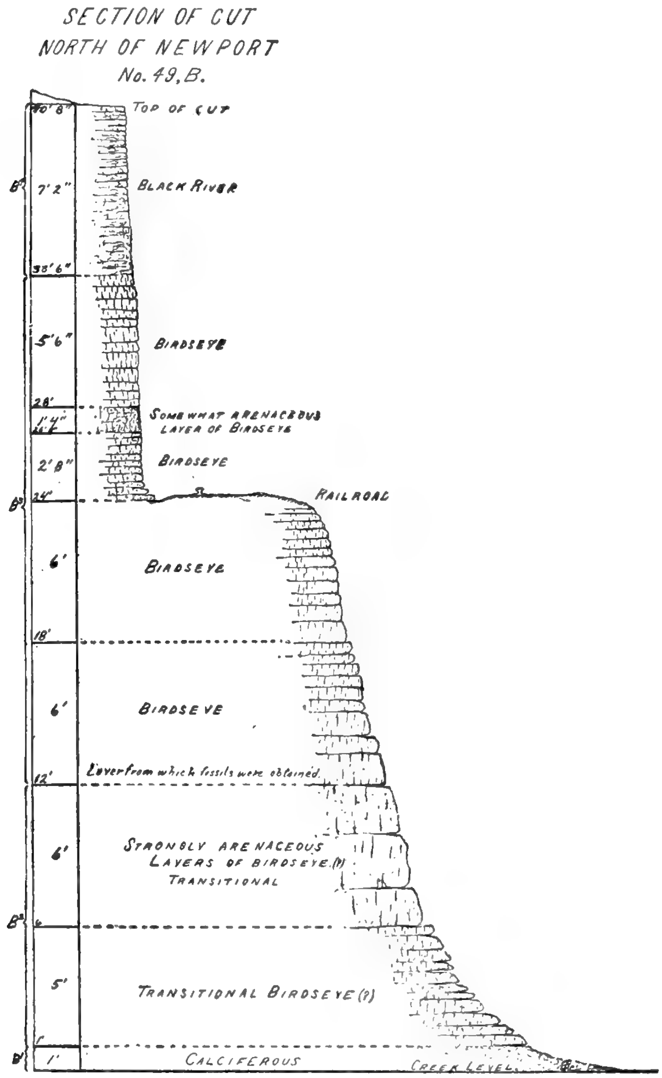
One of the arenaceous layers from the lower half of this zone gave the following result:

SiO_2	52.96	per cent.
Fe_2O_3	11.82	"
$CaCO_3$	32.74	"
$MgCO_3$	2.32	"
	99.84	per cent.

*B*³. Birdseye limestone. For the most part somewhat thin layers of drab, very compact limestone with occasional quite massive layers. In this rock are numerous specimens of what are considered small examples of *Phytopsis tubulosa*, Hall, similar to those figured on Plate 8 (Figure 1c), Pal. N. Y., Volume I. This limestone is well exposed in the railroad cut and the creek bank below the southern end of the cut. Below the railroad track at this place there is, at the bottom of the Birdseye, a vertical ledge six feet thick of drab, typical Birdseye limestone. Near the base of this layer the following fossils were found: *Rafinesquina alternata* (Con.), H. and C.; *Stictopora* sp.; *Leperditia* sp.; and a gastropod. Next there are six feet, one foot of which, perhaps, is covered; and in the railroad cut, nine feet and six inches of typical Birdseye. Feet 21½=33½

* Palaeontology of New York, Vol. I, p. 44, Plate X. Figure 12.

B^4. The upper part of the railroad cut is composed of a dark, Feet 7½ = 41
irregular limestone, consisting of two prominent layers which, on weathering, tend to separate into irregular layers and these in turn to break into lumpy masses. The rock weathers to a grey color and in the railroad cut seven feet and two inches are shown; = Black river limestone.



B^5. Covered between the top of the railroad cut and the Feet 25 = 66
highway.

B^6. In the bank above the highway, near the old lime-kiln, is dark blue, thin-bedded, fossiliferous limestone, with shaly partings, containing abundant Trenton fossils = Trenton limestone.

At the northern end of the railroad cut west of the track is the following section:

No. 1. Mixed drab Birdseye limestone and slate-colored, impure limestone. A little farther down the track all this zone will be found to have changed to the typical Birdseye limestone. This shows the variation in the lithologic character of the Birdseye when followed only a short distance. Feet. 4 = 4

No. 2. Massive layer of somewhat impure Birdseye limestone from one foot to one foot and four inches thick. Vertical tubes similar to those in the more typical Birdseye. This layer forms the top of the Birdseye in Mr. White's section. Ft. in. 1 4 = Ft. in. 5 4

No. 3. Clear, bluish-drab, typical Birdseye limestone in two layers. Ft. in. 5 6 = Ft. in. 10 10.

No. 4. Black river limestone. Dark, bluish-black, fine grained and lumpy, weathering to a grey mottled with blackish spots. Very distinct line between the base of the Black river limestone and the Birdseye. Ft. 5 = Ft. in. 15 10

It will be noticed that the above sections do not agree closely with that described by Mr. White. The greater part, if not all, of the eight feet referred by White* to the Calciferous formation is in the zone which has been called, in this paper, transitional from the Calciferous to the Birdseye. Apparently, the ledge of Birdseye limestone below the railroad was not noticed by White, for it is stated that the ten feet between the top of the so-called Calciferous and the base of the Birdseye on the west of the railroad cut is covered by debris. In the railroad cut Mr. White drew the line of division between the Birdseye and Black river limestones through the Birdseye limestone at the top of No. 2 of our section, at the northern end of the cut. White described this stratum, which may be traced for the entire length of the cut, as "a bed one foot thick, somewhat crushed on the surface, which weathers yellow." However, there are five feet of typical Birdseye above this layer which White referred to the Black river limestone as No. 6 of his section and described as "two heavy barren beds of dark colored, compact limestone, five feet" in thickness. When these beds are referred to the Birdseye limestone its thickness is ten feet and ten inches at the northern end of the cut, and nine feet and six inches at the southern end instead of five and one-half feet, as stated in his section. Nos. 7 and 8 of White's section belong in the Black river limestone, for which he gave a thickness of six feet and nine inches.

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* *Op. cit.*, p. 82.

Section of the Moshier Quarry.

About one-half mile north of Newport is an extensive quarry known as the Moshier, in which both the Birdseye and Black river limestones are quarried.

XLIX A[1]. The Calciferous sandrock is shown in a railroad cut near the Newport station and it may also be seen at various places in the field between the cut and the quarry. Only the upper part of the formation is shown, however, and its thickness was not determined.

A[2]. Compact, drab limestone in the lower part of the Moshier quarry, at its northern end and near the railroad level. The rock is similar to the typical Birdseye limestone to which it is referred. The contact between the Calciferous sandrock and the Birdseye limestone not shown. Feet 3 = 3

A[3]. An arenaceous stratum from ten inches to one foot thick, which splits into layers from two to three inches in thickness. Somewhat like the Fucoidal subformation of the Calciferous. Feet 1 = 4

A[4]. Typical drab-colored Birdseye limestone extending to the top of the lower quarry. Feet 8¾ = 12¾

A[5]. Partly covered Birdseye between the lower and upper quarries. Feet 5 = 17¾

A[6]. Massive Birdseye limestone forming the lower half of the western wall of the upper quarry. It is a drab, compact rock that weathers to a light grey and splits into layers that are thinner than those in the Mohawk valley. This is the top of the Birdseye and the line of division between it and the Black river limestone is beautifully shown in the eastern and southern parts of the quarry. Feet 5 = 22¾

A[7]. The Black river limestone, bluish-grey, breaking into lumpy blocks, is composed of two massive layers in the Moshier quarry, the lower two feet and six inches and the upper three feet thick. The following fossils were collected: Feet 5½ = 28¼

1. *Monticulipora (Prasopora) lycoperdon* (Say). (c)
2. *Columnaria alveolata*, Goldf. (c)
3. *Rafinesquina alternata* (Con.), Hall and Clarke. (c)
4. *Cypricardites* cf. *obtusus*, Hall. (r)
5. (?) *Nucula levata*, Hall. (r)
6. *Raphistoma* cf. *americana*, Bill. (r)
7. *Leperditia fabulites*, Con. (r)
8. *Asaphus platycephalus*, Stokes. (r)
9. *Streptelasma* cf. *profunda*, Hall. (r)

In a ledge a short distance southeast of the Moshier quarry is an exposure of ten and one half feet of Birdseye limestone. From this ledge and the upper part of the Moshier quarry the following species were collected:

1. *Phytopsis tubulosa*, Hall. (c)
   Small specimens similar to figures 1, 1c, Pl. 8, Pal. N. Y., Vol. I.
2. *Murchisonia* cf. *varicosa*, Hall. (r)
3. *Orthoceras multicameratum*, Con. (c)
4. *Modiolopsis* sp. (r)
5. *Rafinesquina alternata* (Con.), Hall and Clarke. (c)
6. *Leperditia* sp.

A specimen from the upper part of the Birdseye limestone at this locality was analyzed by Mr. McKeefe, with the following result:

SiO_2	4.50 per cent.
Fe_2O_3	2.04 "
$CaCO_3$	92.76 "
$MgCO_3$	1.65 "
	100.95 per cent.

All of the limestone shown in the lower part of the Moshier quarry is considered as belonging in the Birdseye, which gives the subformation at this locality a thickness of at least twenty-two and three-quarters feet. Emmons stated that the thickness of the Birdseye to the northwest in Jefferson county, was "not far from thirty feet."*

LITTLE FALLS.

Thirteen miles southeast of Newport in the Mohawk valley, is Little Falls, a locality famous alike for its natural scenery and geologic structure. The section is introduced here in order to give the thickness of the Calciferous sandrock and to show the decrease in thickness of the Trenton limestone as compared with that at Trenton Falls, only twenty-two miles to the northwest. At this place is the upper gorge of the Mohawk river, where the falls and the lower part of the cliffs are composed principally of gneiss, which has generally been referred to the Laurentian system of the Archaean. The gneiss is excellently exposed in the cliffs on the northern side of the river along the tracks of the New York Central railroad, in the eastern part of the city, as may be seen in Plate VI. Above the gneiss are steep walls of Calciferous sandrock which are especially conspicuous on the southern side of the river opposite the railway stations.

* Geology of New York, Part II, 1842, p. 385.

PLATE V

West Shore railroad cut at Little Falls, through Laurentian gneiss; cliff of Calciferous sandstone above the street, looking east.

Section Northeast of Little Falls.

The following section begins at the river level below the falls in the eastern part of Little Falls and continues northerly for about two miles, nearly to the summit of the general elevation for that region.

XLVII B[1]. The Laurentian rocks composed principally of gneiss have a thickness of 203 feet as determined by tape and Locke level measurements. The barometric readings gave 200 feet of the gneiss and this part of the section may be divided as follows: From the river to the New York Central railroad, forty feet of garnetiferous gneiss, the base of which is well exposed along the river; vertical cliff of thirty-three feet of similar gneiss, weathering to a reddish-brown, to level of Little Falls and Dolgeville railroad; gneiss forming cliff above Little Falls and Dolgeville railroad, including the conspicuous layers above the cut, sixty feet; gneiss in the cedar grove where the joint openings are conspicuous, then mostly covered, but exposed near the top just below Loomis street, seventy feet. All the gneiss except the seventy feet of the upper part is well shown in Plate VII, which is a near view, looking westward, of the gneiss along the New York Central railroad in the eastern part of Little Falls. Feet 203=203

B[2]. In the base of the Hiram Boyer quarry on Loomis street, just above the gneiss, is a very coarse-grained, quartzitic sandstone containing quite large quartz pebbles. At present the contact of this sandstone and the gneiss is hardly shown, though Mr. Boyer states that in the deeper part of the quarry, former excavations showed it very distinctly. In general, the gneiss apparently dips heavily to the northeast, while in the quarry the sandstone has a dip of from one to one and one-half degrees to the northwest. Professors Shaler and H. S. Williams studied this exposure some years ago and, it is believed, determined that the sandstone rests unconformably upon the gneiss.* Mr. Walcott stated that this sandstone "has been referred to the Potsdam,"† though he apparently did not accept this correlation, for he said: "it is doubtful if we can claim the presence of the Potsdam at any point in the Mohawk Valley." Feet 3¼–206¼

B[3]. Bluish-black, finely arenaceous shale, nine inches thick, weathering to irregular pieces. It contains fairly well preserved specimens of *Lingulepis acuminata*, Con., which were first discovered by Professors Shaler and H. S. Williams, and reported by the latter at the Washington meeting of the Geological Society of America, in 1890.‡ Feet ¾–207

* See Walcott: Correlation Papers–Cambrian. Bulletin United States Geological Survey, No. 81, pp. 207 347.

† *Ibid.*, p. 347.

‡ *Ibid.*, pp. 207, 347. The paper has never been published, but its title occurs on p 634, Vol. 2, Bulletin Geological Society of America

SECTION FROM
N.Y.C.&H.R.R.R. CUT TO
TOP OF HILL
NORTHEAST OF LITTLE FALLS
No. 47, B,
E.R.Cumings.

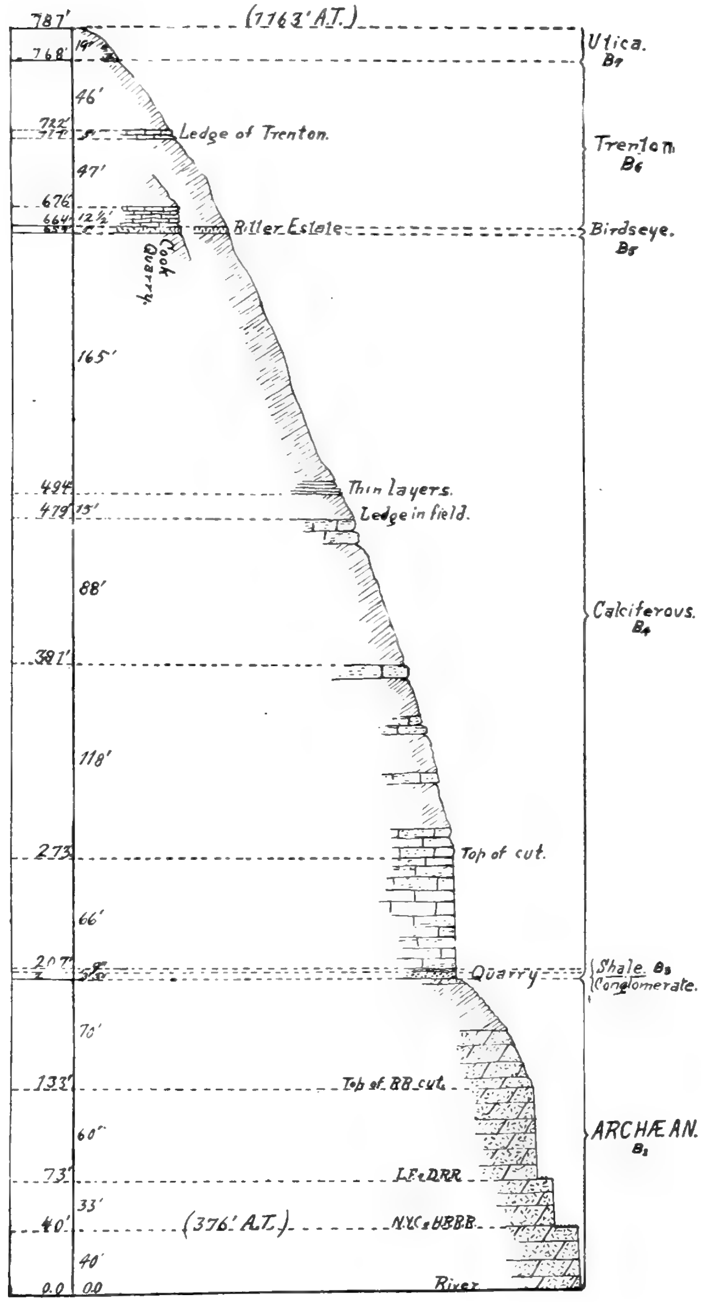
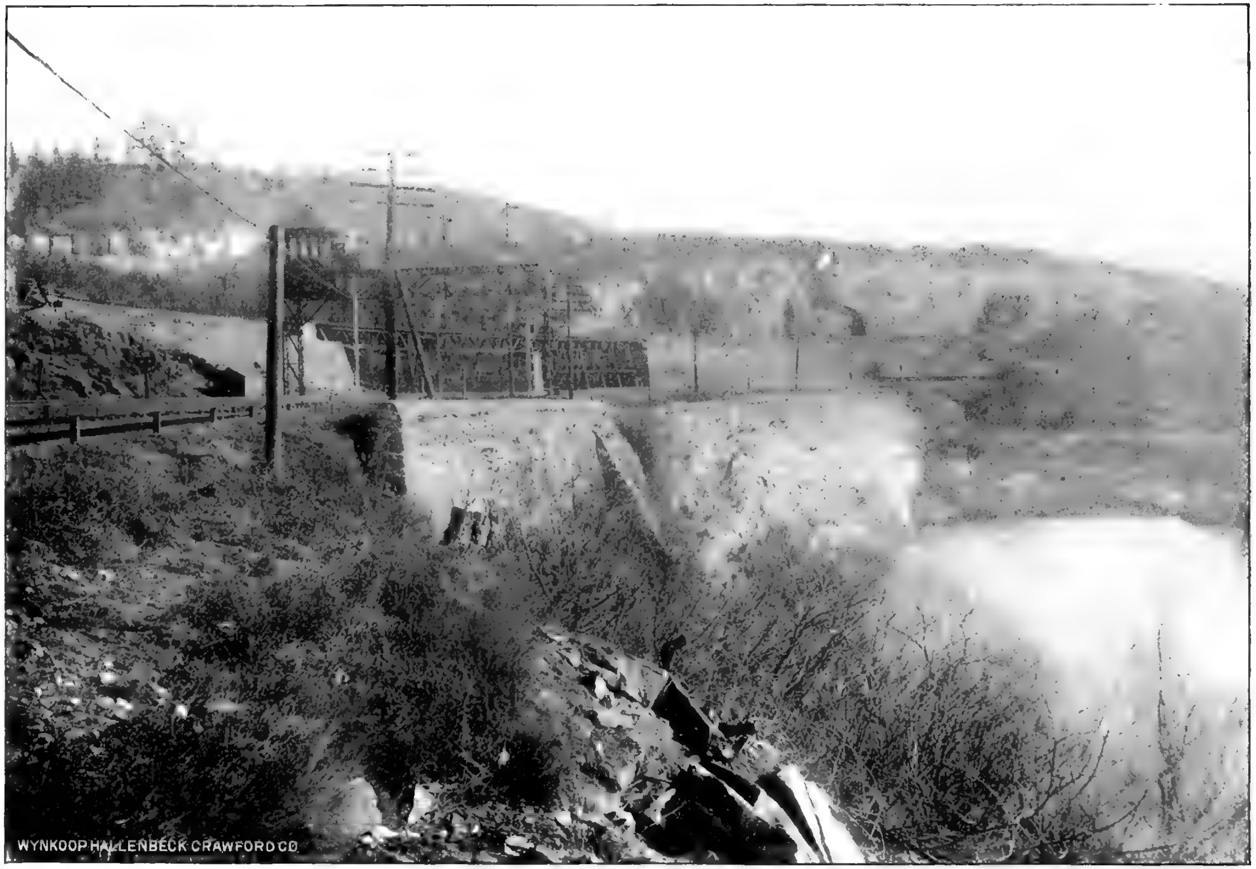


PLATE VI



General eastward view of Laurentian gneiss along the New York Central railroad, in the eastern part of Little Falls. Base of Calciferous sandstone back of upper row of houses.

B^4. Above the shale is the massive Calciferous sandrock, seventy-four feet of which is exposed in the wall of the quarry. This part of the formation is composed principally of compact, thick-bedded, greyish calcareous sandstone that has been quarried. In the lower part are occasional shaly partings, similar to B^3, but no fossils were found in them. This quarry is shown in Plate VIII, where Mr. Birch stands on what is said to be the top of the gneiss, the two heavy layers at the base of the cliff being the sandstone of B^3; the stratum of fossiliferous shale is marked by the hammer, while above is the massive Calciferous sandstone. Feet 452–659

In the fields above the Boyer quarry the rocks are partly covered, yet there are sufficient exposures to make possible the determination of the top of the Calciferous. In the upper part it is thinner bedded than in the lower. No fossils were found.

B^5. On the Ritter farm, near the house, is a ledge composed of thin layers of compact, fine-grained, dove-colored limestone, containing vertical tubules filled with calcite similar to the small ones found near Newport and referred to *Phytopsis*. The thickness is approximately five feet and it is referred to the Birdseye limestone. Feet 5 = 664

B^6. For fifty-three feet above the Birdseye the rocks are covered, when a ledge of Trenton limestone, five feet thick, appears. The rock is a crystalline greyish limestone and contains an abundance of Trenton brachiopods. Above this ledge forty-six feet are covered before the base of the black shale is reached; but it is probable that nearly if not all of this 104 feet belongs in the Trenton. The following species were obtained from the five-foot stratum: Feet 104 = 768

1. *Rafinesquina alternata* (Con.), Hall and Clarke. (aa)
2. *Plectambonites sericea* (Sowb.), H. and C. (a)
3. *Orthis* (*Dalmanella*) *testudinaria*, Dal. (c)
4. *Monticulipora* (*Prasopora*) *lycoperdon* (Say). (a)
5. *Calymene callicephala*, Green. (r)
6. *Asaphus platycephalus*, Stokes. (r)
7. *Orthis* (*Dinorthis*) *pectinella* (Emm.), Hall. (r)
8. *Orthoceras* sp.
9. *Zygospira recurvirostra*, Hall. (r)
10. *Trinucleus concentricus* (Eaton), Hall.
11. *Escharopora recta*, Hall. (r)
12. Crinoid segments.

B[7]. Black carbonaceous shale at the base of the Utica formation; nineteen feet exposed on the hill near the Eysaman house.* Feet 19 = 787

Vanuxem, in describing the rocks about Little Falls, states that "the gneiss rises at the east end to the height of a hundred feet," while the Calciferous is given as having "a thickness of over 200 feet."† In each case it will be noticed that the thickness is more than twice as much as Vanuxem's estimate. Darton gave the thickness of the Calciferous as from "200 to 250 feet on the Mohawk,"‡ while the Birdseye is mentioned as having a thickness of "four feet about Little Falls."§ On the south side of the east and west road west of the Eysaman house is an old quarry and lime-kiln, known as the Cook quarry, in which the contact of the Birdseye and the Trenton limestones is clearly shown.

Section of the Cook Quarry.

XLVII C[1]. Fine-grained, dove-colored Birdseye limestone. In the lower part of the quarry are exposed four and one-half feet, composed of the three following layers in ascending order: two feet and three inches, one foot and five inches, and nine inches. The vertical, small *Phytopsis* markings were present, but no other fossils. Feet 4½=4½

C[2]. Thin, irregular layers of dark-colored Trenton limestone somewhat crystalline and highly fossiliferous; twelve and one-half feet are exposed in the quarry wall. Feet 12½ = 17

1. *Orthis (Dalmanella) testudinaria*, Dal. (aa)
2. *Orthis (Dinorthis) pectinella* (Emm.), Hall and Clarke. (c)
3. *Rafinesquina alternata* (Con.), H. and C. (r)
4. *Plectambonites sericea* (Sowb.), H. and C. (c)
5. *Asaphus platycephalus*, Stokes. (r)
6. *Stictopora* cf. *acuta*, Hall. (r)
7. *Monticulipora (Prasopora) lycoperdon*, (Say). (r)
8. Crinoid segments.

On the south side of the river opposite the central part of the city is a nearly perpendicular cliff of massive Calciferous sandrock, 300 feet in height. About 170 feet above the base is a four-foot stratum containing specimens apparently of *Cryptozöon proliferum*, Hall. Below the Calciferous sandrock is the gneiss which is excellently shown in the West Shore railroad cut east

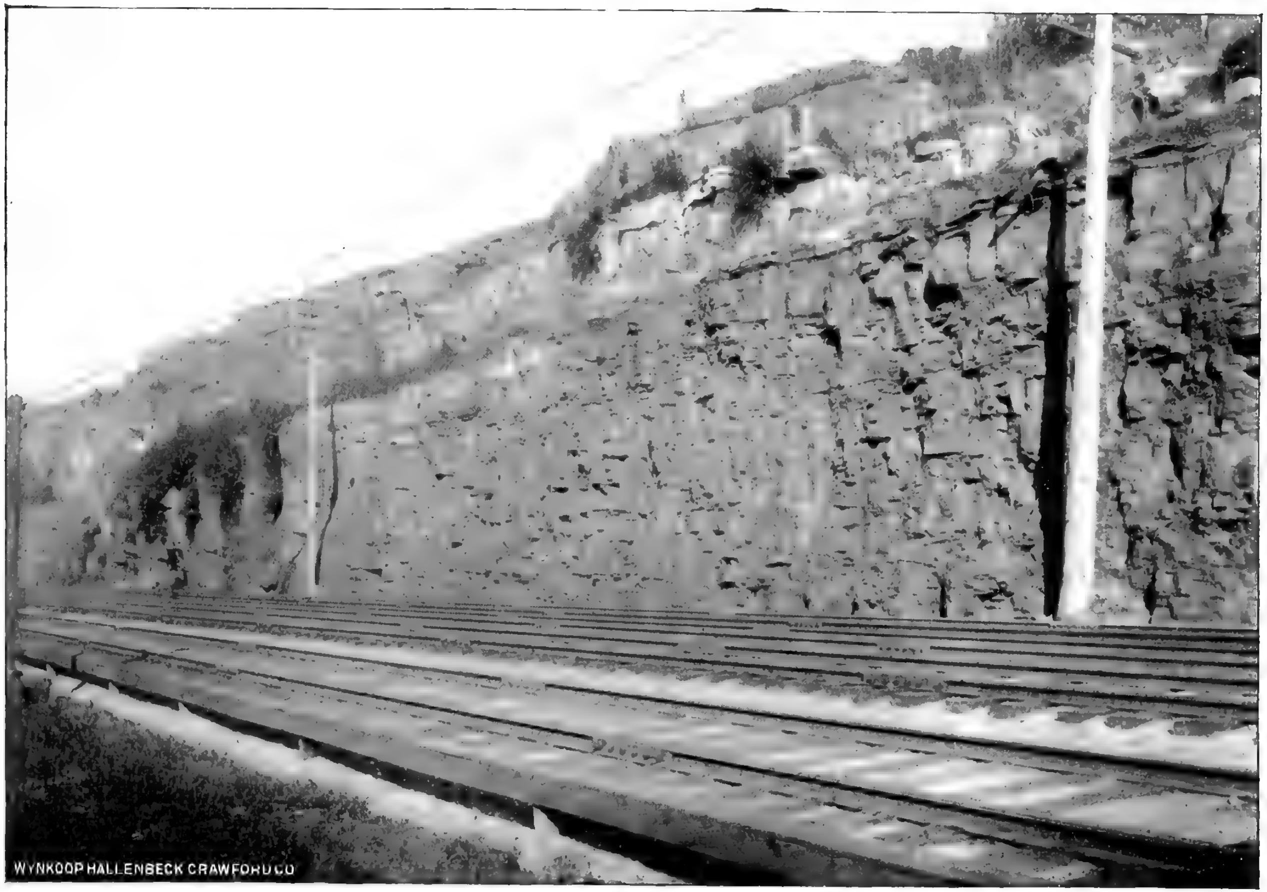
* Recently Mr. M. L. Haviland and other students of Union College, measured the section north of Little Falls. They obtained a thickness of 217 feet for the Laurentian gneiss; 446 feet for the Calciferous; 81 for the Trenton, and 27 feet of Utica slate to the top of the hill. C. S P.

† Geology of New York, Part III, 1842, p. 209. For the thickness of the Calciferous, see also p. 32.

‡ Thirteenth Annual Report State Geologist [New York], 1894, p. 418.

§ *Ibid.*, p. 422.

PLATE VII



NEARER VIEW OF THE CLIFF OF LAURENTIAN GNEISS AT LITTLE FALLS. LOOKING WEST.

of the station. Plate IX gives a view of this locality, looking eastward, the cut being through the gneiss, and the cliff above the street being composed of the lower part of the Calciferous sandrock.

CANAJOHARIE AND PALATINE BRIDGE.

Along the Mohawk river on both the north and south sides, in the vicinity of Canajoharie, are numerous outcrops of the Calciferous sandrock. The exposures are in the upper part of the formation and belong in the substage which was named the *Fucoidal layers* by Vanuxem,* who stated that the best exposition of these layers "was at Canajoharie."†

Shaper Quarry.

In the western part of Canajoharie village is the Shaper quarry, which is extensively worked, exposing some forty-four feet of the Fucoidal layers. The following section from the level of the West Shore railroad to the top of the quarry gives the thickness of the different layers as exposed in this quarry :

No. 15.	Soil on top of quarry.					
14.	3 feet, 9 inches.					
13.	2	"				
12.	2	"				
11.	2	"	2	"		
10.	2	"	7	"		
9.	1	"	4	"		
8.	1	"			(Not fucoidal.)
7.	4	"	4	"	(Not fucoidal.)
6.	2	"	4	"	(Fucoidal markings very conspicuous.)
5.	7	"			
4.	4	"	7	"	(The top of this layer forms the floor of the middle part of the quarry and is its main ledge.)
3.	4	"			
2.	3	"	3	"	(Lowest layer in the quarry.)
1.	20	"			(From the bottom of the quarry to the level of the West Shore railroad.)

The above section gives a thickness of forty feet and four inches of Calciferous sandrock in the quarry, or a total of sixty feet and four inches

* Fourth Annual Report Geological Survey of the Third District [New York] (Assembly Document No. 50, 1840), p. 369.
† Geology of New York, Part III, 1842, p. 37.

for the section from the level of the West Shore railroad below the quarry to its top. The dip is about sixty degrees west of south and the amount varies from four to eight degrees in the different portions. This quarry was described some ten years ago by Professor Smock.*

Canajoharie Creek Section.

The Canajoharie creek flows through the central part of the village, and exposures of the Calciferous sandrock begin along its sides opposite Arkell & Smith's paper bag factory. Along this part of the creek the banks are not steep, but about one-half mile farther up the stream they become steep and in places there are vertical rock cliffs, seventy-five feet or more in height. Near the lower end of this gorge the Calciferous passes beneath the bed of the creek and is succeeded by seventeen feet of thin bedded Trenton limestone, above which is the Utica slate forming the cliffs of the greater part of the glen. In describing this region Mr. Darton stated that in descending the Mohawk river the thickness of the Trenton limestone gradually decreases until at Canajoharie "the amount is only six feet," and further says, "the formation is well exposed on the creek behind Canajoharie."† In the upper part of the gorge the older rocks are covered by a deposit of boulder clay, which in places has a thickness of some seventy-five feet.

LII B[1]. Fucoidal substage of the Calciferous sandrock from the base of the Trenton to the level of the West Shore railroad. The lowest exposures noted are on the bank of the creek opposite the Arkell & Smith factory above the West Shore railroad bridge, and about on a level with the track. Feet 53 = 53

B[2]. Thin-bedded dark blue, very fossiliferous Trenton limestone, separated by shaly partings, with a total thickness varying from sixteen to seventeen feet, as measured on the vertical banks of the creek. The line of division between the Trenton and Calciferous formations in this section is clearly shown, for the upper part of the Calciferous is slightly flexed and upon it the regular layers of the Trenton rest. This shows a slight folding of the Calciferous previous to the deposition of the Trenton and indicates between them a time break of considerable duration which, in northeastern New York, is filled by the Chazy limestone. Darton gave a picture of the creek bank, showing the contact of the Calciferous and Trenton.‡ Feet 17 = 70

* Bulletin New York State Museum, No. 3, 1888, pp. 109–110. See *ibid.*, Vol. 2, No. 10, 1890, p. 245.
† Thirteenth Annual Report State Geologist [New York], 1894, p. 425.
‡ *Ibid.*, pl. 5.

PLATE VIII

Boyer quarry in Calciferous sandstone. Lingula shale indicated by hammer.

*B*³. Very black, bituminous Utica slate forming the greater part Feet 300 = 370 of the walls of the glen. It is quite calcareous and more fossiliferous than that in the exposures farther down the Mohawk valley, and the exposure of fully 300 feet in the gorge belongs in the lower part of the Utica formation. In the lower part of the gorge is a fall over Utica slate, the top of which is about forty-five feet above the base of the slate. This locality was cited by Mr. Darton as "one of the finest exposures [of Utica slate] in the Mohawk valley," and a picture of the falls was given in his report.*

The thin layers of Trenton limestone in the Canajoharie gorge are abundantly fossiliferous and the following species were collected:

1. *Rafinesquina alternata* (Con.), Hall and Clarke.	(c)
2. *Calymene callicephala*, Green (?).	(r)
3. *Orthis* (*Dalmanella*) *testudinaria*, Dal.	(a)
4. *Asaphus platycephalus*, Stokes.	(c)
5. *Monticulipora* (*Prasopora*) *lycoperdon*, Say.	(r)
6. *Modiolopsis mytiloides*, Hall (?).	(rr)
7. *Tellinomya levata*, Hall.	(rr)
8. *Zygospira recurvirostra* (Hall), Winch. and Schuch.	(rr)
9. *Plectambonites sericea* (Sowb.), H. and C.	(c)
10. *Trinucleus concentricus*, Eaton.	(r)
11. *Atrypa* (*Protozyga*) *exigua*, Hall.	(rr)
12. *Ceraurus pleurexanthemus*, Green (?).	(rr)
13. *Murchisonia bellicincta*, Hall.	(rr)
14. *Murchisonia gracilis*, Hall (?).	(rr)
15. *Camarella* cf. *Volborthi*, Bill.	(rr)
16. *Stictopora* sp.	(r)

As already stated, the Utica slate contains a larger number of fossils than has been found in the more eastern exposures. The list is as follows, and it undoubtedly might be materially increased by further search.

1. *Lingula quadrata* (Eich.), Hall (?).	(c)
2. *Plectambonites sericea* (Sowb.), H. and C.	(a)
3. *Orthis* (*Dalmanella*) *testudinaria*, Dal.	(c)
4. *Triarthrus Becki*, Green.	(c)
5. *Graptolites*.	(a)
6. *Asaphus platycephalus*, Stokes.	(r)
7. *Tellinomya nuculiformis*, Hall.	(r)

* *Ibid.*, p. 429, pl. 7.

8. *Pterinea Trentonensis* (Conrad). (rr)
9. (?) *Edmondia subtruncata* (Hall). (rr)
10. *Endoceras proteiforme*, Hall. (c)
11. *Raphistoma lenticulare* (Emmons). (r)
12. *Trocholites ammonius*, Conrad. (r)
13. *Rafinesquina alternata* (Con.), H. and C. (r)
14. *Orthis (Dinorthis) pectinella*, Emm., var. *semiovalis*, Hall. (rr)
15. Crinoid segment. (rr)
16. *Leptobolus insignis*, Hall. (r)
17. *Lingula curta*, Con. (a)
18. *Monticulipora (Prasopora) lycoperdon*, Say. (rr)
19. *Bellerophon* sp. (rr)

The Mohawk Valley Stone Company's Quarry.

On the northern side of the Mohawk river to the west of Palatine Bridge is the extensive quarry of the Mohawk Valley Stone Company, formerly called the Frey. This quarry is in the Fucoidal substage of the Calciferous and in recent years a large amount of stone has been shipped from it. At present it is, probably, the most largely worked quarry in the Mohawk valley. On the upper surface of the rock, near its eastern end, are glacial striae.

LII C[1]. Covered from the level of the New York Central railroad track to the base of the quarry. Feet 29 = 29

C[2]. The lower half of the quarry, consisting of fucoidal Calciferous sandrock which splits into three prominent layers that become thinner on the weathered surface and thus do not extend for any considerable distance. Feet 12 = 41

C[3]. Nine feet and four inches of fucoidal Calciferous sandrock, in fairly thick layers, forming the upper part of the quarry. Feet 9 = 50

In the field to the northeast of the quarry a ledge of Calciferous rock was noticed, but no other formation was seen below the highway. Mr. Darton stated that the Fucoidal beds in the vicinity of Canajoharie, "have a thickness of about ten feet and lie about six feet below the top of the formation."* It is perfectly evident after an examination of the quarries on either side of the Mohawk river at Canajoharie, that the thickness of the Fucoidal substage is much greater than ten feet.

* Thirteenth Annual Report of the State Geologist [New York], p. 421.

PLATE IX

Cliff on the east side of West Canada creek above the Adirondack railroad bridge. The massive crystalline limestone is shown in the upper part of the cliff. Zones A^8 and A^9 of the section

SPRAKERS.

Twenty miles southeast of Little Falls and three miles below Canajoharie is the small village of Sprakers,* at the upper end of the lower gorge of the Mohawk river. About a mile below the railroad stations the valley is very narrow and is bounded on each side by nearly perpendicular walls, in places 350 feet in height, composed largely of Calciferous sandrock. About two miles below the New York Central railroad station, on the northern side of the river, is a conspicuous point known as the Great Nose, where the Laurentian gneiss is exposed, above which the massive Calciferous sandstone is clearly shown. On the southern side of the river opposite this point and farther down the river in the valley and in the West Shore railroad cuts at the foot of Little Nose, the gneiss is also shown. The scenery in this gorge is very picturesque and the locality is one of the most charming in the beautiful Mohawk valley.

Flat Creek Section.

At Sprakers, Flat creek enters the Mohawk river from the south, the banks along its lower course being steep and rocky. From the village to a point a short distance above the falls, the rocks along the creek belong to the Calciferous sandrock, while the bank above shows about seventeen feet of Trenton limestone, capped by Utica slate. A quarter of a mile farther up the creek the second gorge begins, the steep sides of which are composed entirely of Utica slate. At least 230 feet of the slate are shown in the bank of the creek. There is a fall formed by some of the harder layers of the slate, while pillars of erosion and several very pretty amphitheaters occur.

VII A[1]. Covered slope from the river level to the lowest rocks exposed in Flat creek. Feet 23 = 23

A[2]. Light grey, massive, calcareous sandstone exposed in the creek bed and along its steep banks. Calciferous sandrock. Feet 95 = 118

A[3]. In the upper part of the Calciferous, a portion of the layers is thinner and contains great numbers of fucoidal markings. There is no sharp line of division, but these fucoidal layers begin to be conspicuous some ninety-five feet below the top of the Calciferous. In the upper part of the fall, about one mile south of Sprakers, are thick strata similar to those quarried at various localities in the Mohawk valley termed the "Fucoidal layers," Feet 95 = 213

*On most of the maps this village is called Sprakers Basin, but *Sprakers* is the name of the post office and of the railroad stations.

by Vanuxem. The statement that these massive fucoidal layers are from ten to fifteen feet in thickness and confined to the upper twenty-five feet of the formation is misleading, for layers of similar structure and appearance occur along the Mohawk valley at least 130 feet below the top of the formation. In a quarry on the east side of the creek, near the top of the bank, are layers of the massive fucoidal limestone containing specimens of *Ophileta complanata*, Van.

A[4]. Thin layers of dark blue, fossiliferous limestone, well exposed in the steep bank above the fall and highway bridge, from sixteen and one half to seventeen feet in thickness. Trenton limestone. Feet 17 = 230

A[5]. Very black, argillaceous shale which forms the steep banks of the creek in the second gorge. Utica slate. The 230 feet do not represent the thickness of the formation in this region, but should be considered to refer simply to its lower part which is admirably exposed in this gorge. Feet 230 = 460

The above section is important from the fact that it shows the thinning of the Trenton formation from an approximate thickness of 109 feet at Little Falls, twenty miles northwest, to about seventeen feet in Flat creek. Furthermore both the Birdseye and Black river limestones are wanting. The dip varies from 5° to 7°, N. 84° W. along the lower gorge.

Some ten years ago, a diagrammatic section of this creek was published, which represented the Calciferous, Chazy, Trenton and Utica formations.* The thickness of the Trenton limestone is given as "from ten to fifteen feet,"† which is the only measurement recorded, and the Chazy limestone appears not to be present.

West Shore Railroad Cut Section.

About one and one-fourth miles below Sprakers is the West Shore railroad cut, with a nearly perpendicular southern wall of Calciferous sandrock which reaches a height of 350 feet.

VII B[1]. Top of the Laurentian gneiss, exposed at the eastern end of the cut.

B[2]. Basal part of Calciferous sandrock extending from the top of the gneiss, 1,500 feet along the side of the railroad to the point where the nearly vertical cliff of Calciferous was measured. The thickness is estimated from the dip which is about 1°, N. 85° W. Feet 25 = 25

B[3]. From the railroad level to the brow of the cliff forming the nearly perpendicular wall of the railroad cut. The cliff is composed entirely Feet 360 = 385

* Fifth Annual Report of the State Geologist [New York], 1886, p. 9.
† *Ibid.*, p. 8.

PLATE X

FALLS IN FLAT CREEK, SPRAKERS, OVER THE CALCIFEROUS SANDSTONE.

of the massive, light grey Calciferous sandrock and is one of the best outcrops of the formation to be found in the Mohawk valley. A specimen of *Cryptozoön proliferum*, Hall, was found near the middle of the cliff.

B[4]. In the field south of the cliff, mostly covered, showing only occasional outcrops of the Calciferous sandrock with a conspicuous stratum at the top of the first terrace south of the cliff. Feet 65 = 450

B[5]. Partly covered, still showing plenty of outcrops of an arenaceous, compact, greyish rock with irregular fucoidal markings. Several specimens of *Ophileta complanata*, Van., and also the form named *O. levata* by Vanuxem*, have been found in the somewhat shaly layers of this division. The Calciferous sandrock caps the highest land about one mile southwest of the railroad cliff, although it is undoubtedly near the summit of the formation. Feet 40 = 490

The above section shows that the Calciferous formation has a thickness of 500 feet in the region of Sprakers and the lower gorge of the Mohawk river. This decided increase over the supposed thickness will be appreciated when it is stated that Vanuxem gave it as "upwards of 200 feet thick at the Noses and Little Falls."† Darton states that "the formation has a thickness of 200 to 250 feet on the Mohawk, and the amount appears to be constant over a wide area."‡ The thickness of the Calciferous sandrock along the Mohawk valley is thus shown to be 500 feet which is some 250 to 300 feet greater than has generally been given.

Section at Yosts.

On the northern side of the Mohawk river at Yosts, three miles below Sprakers and five miles above Fonda, is a high and steep cliff composed of the Calciferous sandrock. This locality is at the eastern end of the lower gorge of the Mohawk river and the massive, nearly horizontal layers of the Calciferous formation are conspicuously visible from the trains of the New York Central railroad. (See Plate I.)

VI C[1]. Covered from the railroad track to the base of the cliff. The greater part if not all of this covered division belongs in the Calciferous. Feet 112 = 112

C[2]. Massive layers of Calciferous sandrock, forming the nearly perpendicular cliff. From the base of the Calciferous ledges to the brow of the cliff. Feet 293 — 405

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* This species is referred to *O. complanata* by Whitfield. See Bulletin American Museum of Natural History, Vol. II; p. 49

† Geology of New York, Part III, p. 32. On p. 205 Vanuxem stated that the Calciferous cliff at the Noses "rises vertically to two hundred and more feet."

‡ Thirteenth Annual Report of the State Geologist [New York], p. 418.

C[3]. From the brow of the cliff to the top of the hill. Partly covered but showing ledges of Calciferous sandrock to the top of the hill. Feet 160 = 565

The Calciferous sandrock forms the top of this hill and no indication of the Trenton was found. The Fonda sheet of the United States topographic map shows that the difference in altitude between the New York Central railroad and the top of this hill is between 560 and 580 feet. This section shows at least 450 feet of Calciferous sandrock to which, probably, the greater part if not all of the covered 112 feet at the base of the section should be added, which would indicate a thickness of more than 500 feet of Calciferous.

TRIBES HILL AND FORT HUNTER.

North Side of the Mohawk.

Tribes Hill is a small village about half way between Fonda and Amsterdam, and opposite the mouth of the Schoharie creek, which enters the Mohawk river from the south. The Trenton limestone is exposed on both sides of the Mohawk at this locality, the most extensive outcrop being in the quarry below the railroad and the cut above it just west of the Tribes Hill station. The section of this quarry and railroad cut is as follows:

XLIV A[1]. Compact, dove-colored limestone, with smooth fracture, weathering to an ash-grey color. The basal layer in the eastern part of the quarry; its contact with the underlying rock not shown. Birdseye limestone.

A[2]. One or two layers of very lumpy, fine-grained blackish limestone with small, sparkling crystals of calcite. Very few fossils; now and then a specimen of *Rafinesquina alternata* (Con.), H. and C., and *Streptelasma* sp. This zone is doubtfully referred to the Black river limestone. Feet 3 = 3

A[3]. Massive, dark blue limestone, mostly fine-grained but with crystalline layers which usually contain some fossils, *Streptelasma* being the most abundant. In the eastern end of the quarry the limestone has almost the appearance of a single layer, though it divides along several indistinct bedding planes. Trenton limestone. Feet 12 = 15

A[4]. Varies from thin, very unevenly bedded greyish, crystalline to dark-colored, highly fossiliferous limestone. Lower part appears as a thick layer when freshly opened. Feet 11 = 26

A[5]. Thin-bedded, uneven, dark-blue limestone in the railroad cut above the quarry. Trenton. Feet 17 = 43

The dip varies in different parts of this exposure as, for example, in one part of the quarry it is 5½°, S. 45° W., and in the railroad cut 4°, S. 50° W.

PLATE XI

Base of Calciferous sandstone in West Shore railroad cut, west of Downing.

On the river bank a little west of the quarry and apparently forming the bottom of the river is the top of the Calciferous sandrock.

From the thin-bedded Trenton limestone of A^4 the following species were collected:

1.	*Plectambonites sericea* (Sowb.), H. and C.	(aa)
2.	*Orthis (Dalmanella) testudinaria*, Dal.	(aa)
3.	*Orthis (Dinorthis) pectinella*, Emm.	(c)
4.	*Escharapora recta*, Hall (?).	(r)
5.	*Stictopora acuta*, Hall (?).	(rr)
6.	*Stictopora elegantula*, Hall.	(rr)
7.	*Asaphus platycephalus*, Stokes.	(c)
8.	*Ceraurus pleurexanthemus*, Green.	(r)
9.	*Rafinesquina alternata* (Con.), H. and C.	(a)
10.	*Leperditia fabulites*, Con.	(c)
11.	*Rhynchotrema capax* (Con.), H. and C.	(c)
12.	*Murchisonia gracilis*, Hall.	(c)
13.	*Murchisonia bellicincta*, Hall.	(c)
14.	*Raphistoma lenticulare*, Emm.	(c)
15.	*Endoceras proteiforme*, Hall.	(r)
16.	*Schizocrinus nodosus*, Hall.	(c)
17.	*Modiolopsis mytiloides*, Hall (?).	(rr)

On the upper side of the railroad, a short distance east of the Tribes Hill station, is a large quarry in the upper part of the Calciferous formation. The section from the base to the top is as follows:

XLIV B^1. Compact, blue, somewhat "fucoidal" limestone. Feet 2½ = 2½

B^2. Dark grey, non-fucoidal limestone in one to three layers, showing yellow streaks on weathered surface. Feet 3 = 5½

B^3. Massive drab to light grey limestone in one or two heavy layers. Weathered surface finely mottled by horizontal streaks. Fucoidal limestone. Feet 5½ = 11

B^4. Strongly fucoidal massive beds of bluish-grey color, capped by a dark blue thin layer containing *Ophileta complanata*, Van. Feet 13 = 24

B^5. Medium thick beds of arenaceous limestone which weathers to a buff. Feet 28 = 52

B^6. Two layers of Calciferous immediately back of the crest of the quarry. Feet 3 = 55

The entire quarry is composed of Calciferous sandrock, though there is a four-inch layer of Birdseye limestone just above it and apparently in place.

The dip is 6°, S. 50° W. Mr. Darton, in giving a description of the various layers shown in this quarry assigned to them a total thickness of only thirty-four and one half feet which is clearly an underestimate.* The greater part of the wall of the quarry is perpendicular so that there is no difficulty in measuring it accurately.

South Side of the Mohawk.

On the southern side of the Mohawk river, about two miles east of Fort Hunter, are clear exposures of the fucoidal beds of the Calciferous, along the West Shore railroad and in the side of the hill south of the highway. Quarries in this division of the Calciferous are at present worked by the Wemple Brothers. A section in the western part of the quarry is as follows:

XLIV C[1]. Fine-grained, non-fucoidal layer. . . . . Feet 2 = 2

C[2]. Fine grained, dark drab, non-fucoidal layer. Main quarry bed. Feet 2 = 4

C[3]. Layer merging into the one above, but with tendency to divide into thin layers. Ft. in. 1 3 = Ft. in. 5 3

C[4]. Mainly in one thick, compact layer, the upper part quarried, still greater tendency to split along the middle. Steel-grey color weathering to a mottled light grey and buff. Ft. in. 4 8 = Feet. 10

C[5]. Three dark grey layers, eight, nine and ten inches below the top. Ft. in. 2 3 = Ft. in. 12 3

C[6]. Layer not so fucoidal as those above. . . . . Ft. in. 1 2 = Ft. in. 13 5

C[7]. Buff weathered layers with pitted surface; the fucoidal material conspicuous and in horizontal layers. Ft. in. 4 7 = Feet. 18

About 700 feet east of the quarries, Utica slate is exposed in the bed of a small brook to the railroad level; and about 100 feet east of the quarries the shale may be seen in the hillside not far above the railroad, the layers being highly inclined to the east. In the railroad cut not far west of this point, the fucoidal rock is shown and a section is as follows:

XLIV D[1]. Heavy bed with disseminated fucoidal material separated from layer above by a band of very fucoidal character. Feet 3½ = 3½

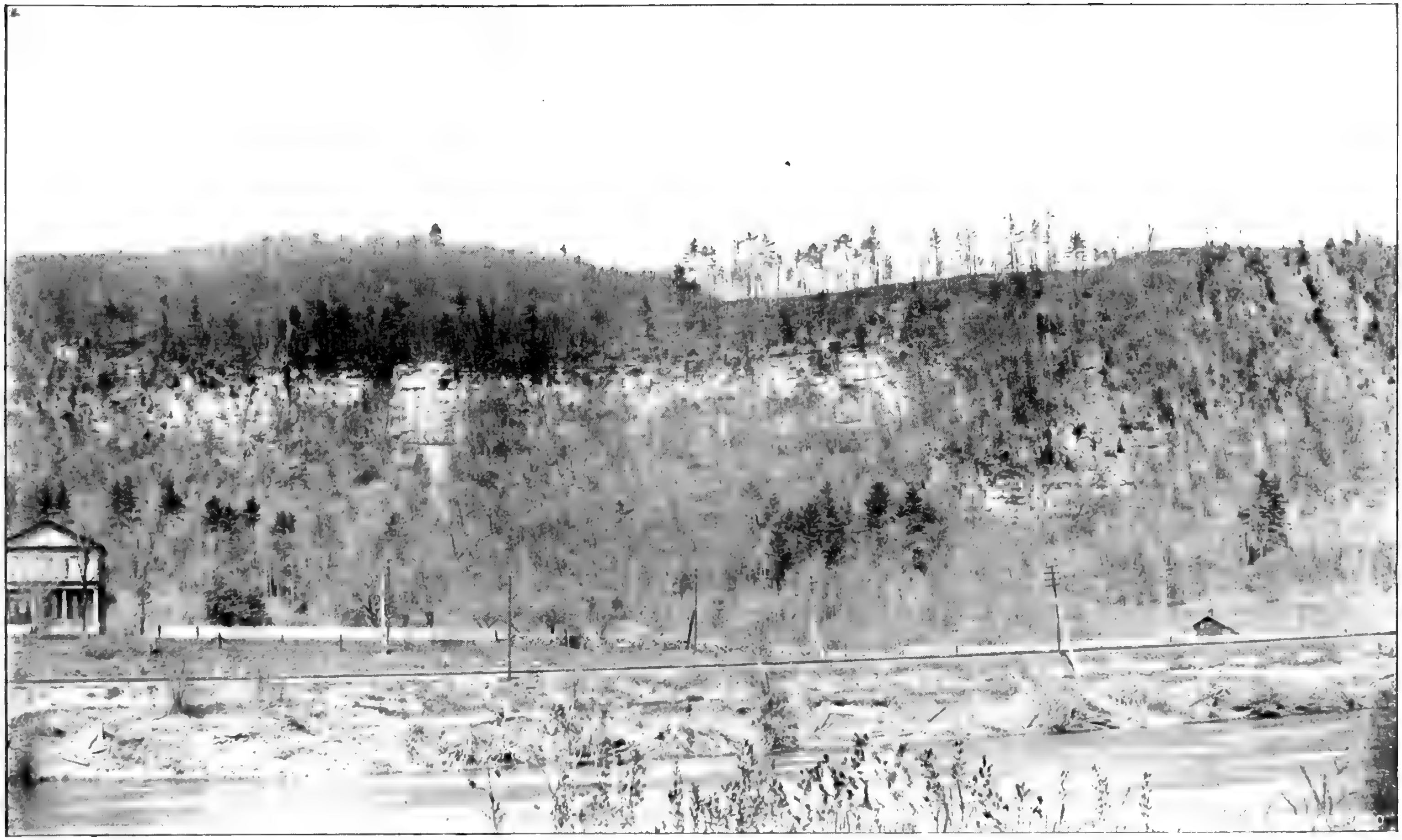
D[2]. Layer with several prominent buff bands; one very conspicuous about four inches wide. Feet 2 = 5½

D[3]. Similar to the following (D[4]) but with greater number of streaks. Feet 5½ = 11

D[4]. Massive bed of even weathering limestone with some obscure yellowish streaks when weathered. Feet 6½ = 17½

* Thirteenth Annual Report of the State Geologist [New York], p. 421.

PLATE XII



Cliffs of Calciferous sandstone on the north bank of the Mohawk, at Yost's.

The Calciferous sandrock outcrops frequently along the railroad between the cut and Fort Hunter. On the side of the hill not far west of the Wemple quarries, the Trenton crops out and was extensively quarried when the Erie canal was built."* The opening is an extensive one, the wall eight or nine feet high, but it has not been worked in a long time and is not a favorable place for collecting.

THE AMSTERDAM–HOFFMAN REGION.

The following sections on the north and south sides of the Mohawk river, between Amsterdam and Hoffman, will give a clear idea of the lithologic characters and thickness of the Calciferous, Trenton and Utica formations in the eastern part of Montgomery county. The section on the southern side of the river, to the south of Amsterdam, is especially important in giving the great thickness of the Utica slate in this part of the Mohawk valley.

Section along Morphy Creek to the Top of Adebahr Hill.

On the south side of the Mohawk, half way between Crane's Village and Amsterdam (Port Jackson), on the estate of Mr. Benjamin Morphy, is an old quarry in the bed of a creek, which empties into the canal, and which may be called Morphy creek. One and three-tenths miles south of this quarry, a north and south line through the latter point passes near the next creek east of Morphy creek at some distance above its mouth. This line also passes through Adebahr hill. A section was measured beginning at the canal level below the Morphy quarry and extending nearly due south to the top of Adebahr hill. (Section XLVI F.)

*F*¹. Canal level. Thick bedded layers of steel-grey, arenaceous limestone with thinner, mottled layers near the top which contain *Ophileta* in abundance. Feet 34 = 34

*F*². Medium dark, dove colored, very compact, fine-grained limestone, with conchoidal fracture, containing occasional examples of *Phytopsis tubulosa*; weathers light bluish grey. Birdseye limestone. Feet 4 = 38

*F*³. Dark blue, fine grained limestone, somewhat lumpy, weathering to an ash-grey. Contains corals. Base of Black river limestone. Inches 5

*F*⁴. Dark blue, fine grained limestone with occasional crystals of calcite; contains corals and *Rafinesquina alternata* (Con.), H. and C. Inches 8

* This quarry is that mentioned by Vanuxem as the Sage and Reed quarry, opposite Tribes Hill (Geology of New York, Part III, p 37)

F^{5}. Dark blue, fine grained, compact limestone with small sparkling crystals of calcite. Fossiliferous. In. 11 = Ft. 40

F^{6}. Two feet covered, then one foot of dark blue, fine grained limestone with sparkling crystals of calcite. Fossiliferous. Feet 3 = 43

F^{7}. Somewhat crystalline, blue fossiliferous layer. Base of Trenton limestone. Inches 3

F^{8}. Compact, fine grained, bluish-grey layer with glittering surface on fresh fracture. Fairly abundant Trenton fossils. Feet 1 = 44

F^{9}. Bluish-black, fine grained massive layer, weathering bluish-grey with yellowish fucoid-like markings on vertical and horizontal faces. Well preserved specimens of *Rafinesquina alternata* are fairly abundant. Ft. 2 in. 6 = Ft. 47

F^{10}. Uneven, dark, compact, fossiliferous layer with crystalline lenticles; the fossils mostly in the lenticles. Feet 1 = 48

F^{11}. Dark blue, fine grained layer with crystalline fossiliferous lenticles which, by weathering darker and yellowish, give a mottled appearance to the surface. Ft. 1 in. 2 = Ft. 49

F^{12}. Greyish-blue, crystalline, fossiliferous layer . . . . Inches 4

F^{13}. Dark blue, fine grained, with crystalline lenticles, and weathering similar to No. 11. Fossiliferous. Ft. 1 in. 4 = Ft. 50

F^{14}. Medium light colored, weathering with yellowish streaks as in No. 11. Abounds in Trenton fossils. Feet 2 = 53

F^{15}. Thin, irregular, dark blue, fine grained layers with intercalated black, carbonaceous shale. Contains great numbers of fossils, especially *Monticulipora* (*Prasopora*) *lycoperdon* (Say), and *Trinucleus concentricus* (Eaton), Hall. Feet 27 = 80

F^{16}. Utica slate exposed in creek bed and in contact with the Trenton below. Thin, even layers of black, carbonaceous, calcareous shale; above this, covered to first creek east of Morphy creek. Difference in altitude between these two points, 270 feet. Utica slate. Feet 270 = 350

F^{17}. In the first creek east of Morphy creek, at a point one and four-tenths miles almost due south of the Morphy quarry, are exposed even layers of very black, strongly calcareous, slaty shale containing seams filled with calcite. These thin layers are occasionally interrupted by thicker, compact, very fine-grained layers with conchoidal fracture. The latter resemble the hard, fine-grained layers of the upper Trenton in No. 15. The dip is uniformly southerly. Feet 50 = 400

F^{18}. Covered . . . . Feet 40 = 440

F^{19}. Black, carbonaceous, slabby, calcareous shale, exposed in the creek bed and to the first branch of the creek, not far below the highway north of Adebahr hill. Feet 60 = 500

F^{20}. No rock is exposed in place, but plenty of fragments of calcareous shale occur in the soil of the hillside, becoming especially abundant in a small knoll on the northeastern declivity. Feet 180 = 680

F^{21}. Top of Adebahr hill. Black, crumbling, calcareous shale with thicker coherent layers exposed in the open pasture on the southern brow of the hill. Below this point covered. The top of Adebahr hill is barometrically 820 feet above the base of the section. The New York Triangulation bench mark, seen on its northern crest, is 1,062 feet A. T. The difference between this and the altitude of the canal at the base of the section is 800 feet. Feet 140 = 820

The members of the Trenton and Calciferous formations of this section were measured by Mr. Darton in the summer of 1892, and described in 1894.* In his section the Birdseye is given as above the Black river. There does seem to be a peculiar blending of the lithologic characters of the massive member of the Trenton and the Black river in Nos. 8 and 9 of the present section, so that there is not a sharp line between the two subformations. The Birdseye is well defined, however, in its proper stratigraphic position, being sharply separated from the underlying Calciferous, and less sharply, though distinctly, from the overlying Black river. It contains no, or at least very few, fossils. The upper, thin-bedded member of the Trenton is excellently shown and seems to pass gradually into the Utica slate above, although the line between the two is fairly distinct if drawn where the Trenton fossils cease. The Utica slate is exposed at intervals from Morphy's to the top of Adebahr hill, a vertical distance of 740 feet, with quite constant characters, especially the persistence of slabby, calcareous layers. The distance between Morphy's quarry and the bench mark on Adebahr hill is just three miles, hence if the south dip be 140 feet per mile, the actual thickness of Utica in this section is 1,160 feet.

Minaville Section.

In the slope of the hill, southwest of Minaville, and at a point about one and four-tenths miles south by southwest of the centre of the village, the Utica slate is exposed in several small glens. A section was measured beginning at the level of Chuctenunda creek and extending to the top of the hill.

*Thirteenth Annual Report of the State Geologist [New York], pp. 426, 427.

XLV K[1]. Mostly covered, but showing brownish weathering, slabby shale in the west bank of Chuctenunda creek, just above Minaville. Utica slate. Feet 165 = 165

K[2]. Top consisting of slaty layers, containing graptolites in abundance. Below this point the black calcareous shales are exposed to within 165 feet of creek level. Feet 90 = 255

K[3]. Black shales, becoming olive to blackish at top. These shales show a transition from the black, calcareous, slabby shale of the Utica to the arenaceous, thin, crumbling, olive shale of the Hudson river formation. Transitional shales. Feet 165 = 420

K[4]. Mostly thin sandstones and arenaceous shales, with a massive two-foot layer at the base in the south branch of the deep glen. This portion of the section comprises the cap of the hill and is mostly covered. Hudson river formation. Feet 120 = 540

The above section is the only one noticed in this region, which gives the passage from the Utica to the Hudson river formation, and is of especial interest on that account. Within the limits of a continuous exposure of 255 feet of shales, there is exhibited a complete transition from the typical lithologic characters of the Utica to those of the Hudson river. The Utica, at the lower part of this exposure, is black with brownish streak, and weathers brown with a greenish tint. It is strongly calcareous and disposed in even, well defined layers, which usually split into laminae, having smooth flat surfaces. These, in turn, crumble to square-edged fragments. In some cases, however, coherent layers occur from an inch to four or five inches in thickness, which are quite hard and break with a conchoidal fracture. These are the well-known slabby layers of the Utica formation. The shale shown in the upper part of this exposure is blackish to dark olive or grey, very friable, and weathers to a dirty brown. It is not sufficiently calcareous to effervesce with cold acid, and is disposed in layers which break up into irregular laminae with uneven rounded surfaces which, in turn, weather to small, thin, sharp-edged, usually quadrilateral scales that readily pass into soil. The Graptolite bed is of especial interest and no other fossils were found in it. The shales at this point exhibit a combination of the characters of the Utica and Hudson river formations, and the layers split into laminae with irregular surfaces. The difference in altitude between the first exposure of sandstone in this section and the level of the Mohawk at its nearest point, is 740 feet, and the distance is nearly five miles. This indicates a thickness of approximately 1,440 feet, if the dip be 140 feet per mile, as is shown to be the case later in this paper, at Crane's Village and Hoffman. As the thickness of the Utica obtained in this section is much greater than any previous estimate, it is interesting to review the former statements in regard to its thickness.

Emmons stated that the Utica slate "in the gorges of Lorrain and Rodman is about seventy-five feet thick; it is, at least, less than one hundred feet;"[1] a statement which was repeated four years later in the Agriculture of New York.[2] Vanuxem estimated that the maximum thickness of this formation "is about 250 feet,"[3] while Dana gave the thickness of the Utica formation as 250 feet in Montgomery county.[4] More recent estimates are those of Messrs. C. D. Walcott and C. S. Prosser, derived mainly from well records. Walcott gave the thickness of Utica slate passed through in the Campbell well near Utica, as 710 feet;[5] and in a diagram[6] indicates that the formation thickens eastward. In the section described by Mr. Walcott along the south branch of Sandy creek in Jefferson county, he gave 180 feet of Utica slate with 100 feet of transitional beds above, composed of "alternating banks of shale and grey, fine grained, calcareous sandstone; the shales predominating."[7] Prosser gave the thickness of the Utica slate in the Chittenango well, thirty-two miles west of Utica, as 233 feet, below which are sixty feet of transitional shale and limestone to the massive Trenton limestone. In this well 640 feet of blue argillaceous shale and bluish-grey arenaceous shale and sandstone are referred to the Hudson river.[8] In the Rochester well the thickness of Hudson river and Utica taken together, is given as 598 feet.[9] In the Altamont well, about seventeen miles west of Albany, the drill started 595 feet below the base of the Helderberg limestone, which caps the Hudson river formation in that vicinity, and passed through 2,880 feet of sandstone and shales before reaching the Trenton limestone.[10] The thickness of Utica slate was not ascertained in this boring, but a thickness of 3,475 feet of both formations indicates a considerable thickness of Utica. Mr. Henry M. Ami says: "By some of the early writers it [Utica formation] was spoken of as consisting of shaly strata whose total thickness *exceeded 900 feet*, whilst by others the very humble, yet perhaps truer estimate was given of about

[1] Geology of New York, Part II, 1842, p. 118.
[2] *Loc. cit.*, p. 124
[3] Geology of New York, Part III, 1842, p. 56.
[4] Manual of Geology, Fourth Edition, p. 494.
[5] Proceedings American Association Advancement of Science, Vol. XXXVI, p. 212. Also, Bulletin Geological Society of America, Vol. I, 1890, p 347.
[6] *Ibid.*, p. 350 (diagram).
[7] *Ibid.*, p. 348, and see diagram on p. 350.
[8] *Ibid.*, Vol. IV, p. 99.
[9] Proceedings of Rochester Academy of Science, Vol. II, p. 92.
[10] Ashburner, Transactions American Institute of Mining Engineers, Vol. XVI, pp 951, 952.

seventy-five feet in thickness."* The highest estimate for Montgomery county is that of Vanuxem, also taken by Dana, of 250 feet. Mr. Walcott's diagram, already alluded to, would indicate a thickness of 800 or more feet in this region, but is not a formal estimate. Two hundred and fifty feet is the generally received estimate of the thickness of the Utica slate in Montgomery county.

The Eva's Kill Section.

Along the Eva's kill, which empties into the Mohawk river, just west of the Crane's Village station, are numerous exposures of Calciferous sandrock, and about one and one-half miles back of Crane's Village is a small isolated hill just west of the highway, capped by the lower members of the Trenton formation. The section beginning at the level of the Mohawk and extending to the top of the hill is as follows:

XLV A[1]. Mostly covered. Top consists of massive, thick-bedded, grey, calcareous sandstone exposed in the bed of the Eva's kill. Ninety feet from river level to base of exposure. Feet 90 = 90

A[2]. Partly covered. Heavy bedded, compact, calcareous sandstone. Feet 60 = 150

A[3]. Medium to thin bedded arenaceous limestone with fucoidal markings, especially near the top where the color is dark blue and the weathering very light ash-grey. Contains iron pyrites. From level of Eva's kill to the Manny corners highway, 130 feet. Feet 130 = 280

A[4]. Mostly covered. Calcareous sandrock exposed at the base in the road above the Eva's kill and at the top in the side of Quarry hill, where it is thin bedded and mottled, and weathers with rough, jagged surface. Top of Calciferous sandrock. Feet 120 = 400

A[5]. Dove-colored, with flat conchoidal fracture; disposed in thin layers, weathering more unevenly than usual for this limestone. Birdseye. Feet 2½ = 402½

A[6]. Dark blue-black, fine grained, lumpy, heavy bedded limestone, containing *Columnaria alveolata*. This fossil ranges through eight and one-half feet of compact limestone and marks an horizon which varies in thickness from seven to nine feet within the limits of the quarry. Feet 9 = 411½

A[7]. Greyish-blue, semi-crystalline limestone, weathering dark grey, containing several small specimens of *Columnaria* and abundant crinoid segments. In places the rock is filled with pebbles of sandrock, which are similar to the Calciferous. Feet 1½ = 413

* Reprint from Canadian Record of Science, October, 1892, p 3.

A[8]. Thin bedded, dark blue limestone; abounding in fossils, including *Rafinesquina alternata* (Con.), Hall and Clarke. Feet 5 = 418

This section presents several interesting features. The upper part of No. 3, representing the Fucoidal member of the Calciferous formation, is of unusually dark color and weathers almost as light as the Birdseye. The surfaces of the layers are often covered with the markings which have suggested the name by which this rock is known. In the side of Quarry hill, the Calciferous sandrock seems to present a somewhat transitional character, becoming less and less arenaceous toward the top. Capping these layers in the eastern brow of the hill are the two and one-half feet of Birdseye mentioned in the section; but just over the brow of the hill in the northeastern part of the quarry the fossiliferous Black river beds are seen to rest directly on grey, arenaceous rock. Apparently the Birdseye has totally disappeared within a distance of two rods. In the western part of the quarry there is again a dove-colored, fine grained limestone below the *Columnaria* horizon. In the central part of the quarry the *Columnaria* ranges through from seven to nine feet of very compact limestone. In this part of the quarry also occur the pebbles of Calciferous (?) imbedded in a layer which caps the massive Black river bed. This layer also contains several small specimens of *Columnaria*, but the latter may have been derived in the same manner as the pebbles, from fragments of lower strata. In the south side of the quarry the layers corresponding in position to the Black river contain an abundance of iron pyrites and pockets lined with crystals of white calcite. At this point the upper surface of the rock is striated, the striae running N. 85° W. The dip is in general about 2½°, S. 20° W. Vanuxem has noted the presence of pebbles about Amsterdam similar to those mentioned above. Speaking of the base of the Trenton, he says: "One of the lower layers at Putnam's quarry [Tribes Hill] shows some scattered irregular pebbles, forming masses or concretions having the same character in all respects as the yellow-colored Calciferous sandrock, and accurately resembling those observed in a quarry at Shelpintown [Rockton]; the largest of them are fully four inches in diameter and of greater length."*

Section opposite Crane's Village on the south side of the Mohawk River.

Opposite Crane's Village† station, the cut on the West Shore railroad has exposed the Calciferous sandrock, and a section, beginning at this point, is as follows:

* Geology of New York, Part III, 1842, p 44.

† This place is given as Cranesville on the Amsterdam sheet of the United States Geological Survey; but is known locally as Crane's Village and is so given on the timetables of the New York Central and Hudson River railroad

XLVI C[1]. Medium to thin bedded calcareous sandstone. Layers irregular. To canal level. Calciferous sandrock. Feet 52 = 52

C[2]. Heavy bedded, massive arenaceous limestone. . . . . . Feet 23 = 75

C[3]. Mostly covered. Steel grey arenaceous limestone, containing flint and calcite. Feet 80 = 155

C[4]. Dove-colored, very compact, even bedded limestone with flat conchoidal fracture, and weathering ash white. This rock contains abundant examples of *Phytopsis tubulosa* and rests upon buff arenaceous limestone. Birdseye limestone. Ft. 2–4 = Ft. 159

C[5]. In the large quarry, just east of the small creek that empties into the canal, a few rods east of the cut, is exposed dark bluish-black, massive, fine grained limestone, which weathers light and contains Black river corals. Black river limestone. Feet 6 = 165

C[6]. About 200 yards east of the creek is a large quarry in which the basal layers are thick, even bedded and somewhat crystalline, and weather light bluish-grey. They contain *Rafinesquina alternata* and other Trenton fossils. Base of Trenton. Feet 9 = 174

C[7]. Above the heavy layers of C[6] are thin, irregular, dark blue layers abounding in fossils. Feet 12 = 186

C[8]. Base of Utica. In the bed of the creek, near the highway, black, even bedded, calcareous shale. The difference in altitude between this point and the top of the hill, just to the south, is 148 feet. Utica slate. Feet 148 = 334

At the railroad cut, where Nos. 1 and 2 of the above section are exposed, the rocks of No. 1 exhibit a rather abrupt bending of the layers. Near the eastern end of the cut is a nearly vertical line, east of which the dip is ten degrees east, and west of which the dip is one degree west, or nearly normal. This section furnishes the best outcrop of the Birdseye limestone to be found anywhere in this region. At this place the Birdseye presents the characters so typical of it along the northern branches of the Mohawk river to the northwest. It is dove-colored, impalpably fine grained, with flat conchoidal fracture, smooth vertical joint faces; and weathers ash white with a delicate bluish tint. The peculiar plant-like reticulations of *Phytopsis tubulosa* are very conspicuous in the rock at this locality, since they weather buff, whereas the rock matrix weathers nearly white. The vertical columns, the extremities of which give the "birdseye" appearance to the surfaces of the layers, are larger than in the rock of this subformation near Newport and Little Falls, where they are quite small and composed of calcite, while in the Birdseye of the lower Mohawk they are composed of argillaceous material. Within the limits of the exposure—a small quarry—this limestone varies from two to four feet in thickness, both delimiting terranes being in place. The upper surface of the subjacent Calciferous sandrock is irregular, and the line of contact between it and the overlying Birdseye very sharply defined. Above, the Birdseye seems to pass into the superjacent Black river limestone without any sharp line of demarkation.

The base of the Trenton formation in this section is approximately 380 feet A. T., while in the exposure west of the Eva's kill, one and one-half miles north, the base of this formation is 600 feet A. T. This gives a south dip of 147 feet per mile.

Hoffman and Van Epps Hill Section.

Just west of the railroad station, at Hoffman, Schenectady county, is a conspicuous cut on the New York Central railroad, in which the Calciferous sandrock is well exposed. The base of the cut is about twenty feet above the Mohawk river. A section, beginning at river level and extending to the top of Van Epps hill, is as follows:

*H A*¹. Massive, thick-bedded, steel grey, arenaceous, buff- Feet 290 290
weathering limestone or calcareous sandstone; the lower twenty feet covered beneath the railroad, and forty-eight feet immediately succeeding, exposed in the cut. Above the cut, partly covered. The joints and seams of this rock are often filled with calcite, and some chert occurs.

*A*². Top covered for the most part; base consisting of dark blue, Feet 60 = 350
moderately fine-grained, arenaceous limestone, with weathered surface marked by plant-like reticulations which weather yellowish, exposed in the roadside at an elevation of 350 feet above river level. Fucoidal division of the Calciferous.

*A*³. West of the Schenectady-Montgomery county-line road, at Feet 5 = 355
an altitude of 350 feet above river level, is a five-foot bed of compact limestone, containing a large specimen of *Columnaria alveolata* near the base. Black river limestone.

*A*⁴. In the fault escarpment, a short distance to the northeast of Feet 30 385
the exposure of No. 3, is another of about twenty-five feet of thin, hard, dark-colored layers, containing Trenton fossils including *Trinucleus concentricus*. These layers rest directly upon thick layers of Calciferous sandrock, and from this fact and their strong dip, it is probable that they were displaced from their normal stratigraphic position in the faulting. In the open field east of the highway, opposite the exposure of Black river, and at an altitude of about 350 to 355 feet, is a small exposure consisting, at the top, of three

feet and eleven inches of grey crystalline limestone (Trenton). underlaid by two and one-half inches of limestone weathering ash white (Black river?), then seven inches of crystalline rock (Trenton), and finally, at the base, three and one-half feet of compact light-weathering limestone. In the field on the west side of the road and opposite a farm house, a short distance beyond the exposures of No. 3, are exposed at the top eight inches, in two thin layers, of rather coarse grained, semi-crystalline limestone, containing fragments of brachiopods, trilobites and crinoids. Below this is one foot, in thin layers, of fine grained, drab-grey limestone, weathering ash white and apparently barren of fossils. The basal layer is bluish-drab to grey, coarser grained, and has a thickness of four inches. Five feet above the top of this exposure, and a short distance east of it are five feet of crystalline highly fossiliferous limestone. These five feet of rock should be added to the twenty-five feet seen in the fault line, as it is a representative of layers not shown in the latter place. Trenton, with possibly Black river at base.

A[5]. Black, calcareous shale seen mainly as small brown-weathered fragments in the side of Van Epps hill; in only a few places is evidence of stratification preserved. Utica slate. Feet 230 = 615

This section has been carefully studied by field parties from Union College, and the measurements above given have been compared with those obtained on several such excursions, so that they may be considered to possess a fair degree of accuracy. This section, it will be noticed, gives 350 feet of Calciferous sandrock measured in an almost vertical ascent. As the gneiss is not brought up here, the total thickness of Calciferous is not shown; but enough is shown to indicate that in this eastern region the Calciferous sandrock is a thick formation though, perhaps, not attaining as great a thickness as at Sprakers and Little Falls.

The Pattersonville Section.

About one mile west of the Pattersonville station, on the West Shore railroad, is a long cut made partly by the excavation for the canal and partly by the West Shore railroad. A section was measured at this locality beginning at the bottom of the canal.

II B[1]. Bottom of canal. Compact thick bedded, steel-grey, arenaceous limestone weathering yellowish and containing abundance of flint and calcite. The dip at the western end of the railroad cut is about 4°, N. 55° W., and at the eastern end 4° in the opposite direction. Calciferous sandrock, thirty feet in the canal cut and eighteen feet in the railroad cut. Feet 48 = 48

B^2. Above the cut and through the fields to an old quarry, are numerous exposures of massive arenaceous limestone having, especially in the lower layers, fucoidal markings. Fucoidal member of the Calciferous. Feet 135 = 183

B^3. About one-half mile southwest of Pattersonville, and at the head of a small run, is a small quarry to the south of an old limekiln. The Calciferous is exposed in thin layers at the bottom of the quarry in the run, and resting upon it is a layer about a foot in thickness, of bluish-drab fine grained limestone which weathers ash grey. The outlines of several fossils are shown on the surface of this layer, and notably that of the cephalic shield of a large trilobite (*Asaphus platycephalus?*). Above this are exposed about five feet of thin, bluish-black, fine grained, irregular, lumpy layers, weathering light ash-grey and abounding in fine specimens of *Columnaria alveolata*, Goldfuss. In the east side of the quarry the rock is exposed in thicker layers, the lower containing *Columnaria*. Just over the fence to the east is a larger quarry in which the upper layers of the former quarry are exposed and contain large masses of *Columnaria alveolata* in the same stratigraphic position. In this quarry the light-weathering layers are capped by dark-weathering, crystalline layers. Black river limestone. Feet 7 = 190

B^4. A short distance south of the exposures of No. 3 is an extensive quarry, the western end of which is known as the Walker quarry, and the eastern end as the Moore quarry.* The lowest rock exposed in these quarries is dark, bluish-grey, crystalline limestone, massive and weathers bluish-grey. Highly fossiliferous. Heavy bedded member of the Trenton. Feet 8 = 198

B^5. Resting on the massive layers are thin, irregular dark blue layers of fine-grained limestone with intercalated black carbonaceous shale. Highly fossiliferous; especially rich in brachiopoda.

B^6. Covered from top of limestone in the quarry to lowest exposure of shale in an open drain south of the quarry. Feet 50 = 248

B^7. Black, argillaceous shale to the top of the hill. Utica slate. Feet 327 = 575

The above section is of interest on account of the excellent exposure of the fossiliferous Trenton and Black river limestones, and from the fact that it affords an opportunity for determining the south dip by comparison with the exposures across the river exactly one mile to the north. The base of the Trenton limestone on the north side of the river is approximately 590 feet A. T., and on the south side 450 feet, giving a southerly dip of 140 feet per mile.

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* Bulletin New York State Museum, No. 3, 1888, p. 105.

The thin-bedded limestones of B[5] are very fossiliferous, this quarry being one of the best localities for the collecting of Trenton fossils in the lower Mohawk valley. From A[4] and A[5] the following species were collected:

1. *Monticulipora (Prasopora) lycoperdon*, (Say). (a)
2. *Stictopora elegantula*, Hall. (c)
3. *Rafinesquina alternata* (Con.), Hall and Clarke. (aa)
4. *Plectambonites sericea* (Sowb.), H. and C. (c)
5. *Orthis (Dalmanella) testudinaria*, Dal. (c)
6. *Orthis (Dinorthis) pectinella* (Emm.), Hall. (r)
7. *Rhynchotrema capax* (Con.), Hall. (r)
8. *Raphistoma lenticulare*, Emm. (?) (r)
9. *Murchisonia bellicincta*, Hall. (r)
10. *Murchisonia gracilis*, Hall. (r)
11. *Asaphus platycephalus*, Stokes. (c)
12. *Trinucleus concentricus*, Eaton. (r)
13. *Dalmanites callicephalus* (Hall). (r)
14. *Leperditia fabulites* (Con.). (c)
15. *Schizocrinus nodosus*, Hall. (a)
    Segments of stems.

To the southeast of Pattersonville, and west of Rotterdam, is the high and steep hill named Waterstreet on the Amsterdam topographic sheet of the United States Geological Survey. The top of the northern end of the hill is given as 1,385 feet A. T., and the rocks from near the level of the Mohawk river to the top of the hill consist of alternating layers of shales and sandstones which belong in the Hudson river formation and give a thickness of some 1,125 feet. This, of course forms only a part of the thickness of the Hudson river formation, since it was shown by Ashburner that at Altamont, some ten miles to the south, the thickness of the Hudson river and Utica formations taken together is 3,475 feet.*

Nine-tenths of a mile west of the Schenectady pump station, on the West Shore railroad, are a deep glen and a long cut. The section of the glen and cut is as follows:

I C^1. Covered from level of Mohawk river to Erie canal. . . . . Feet 25 = 25

C^2. Fine shale which at the base of the glen does not weather readily to soil. Graptolites are fairly abundant. Feet 110 = 135

C^3. Very fragile shale exposed in the railroad cut. . . . . . . Feet 12 = 147

C^4. Thin sandstone layer. . . . . Feet $\frac{2}{12}$ =

* Transactions American Institute of Mining Engineers, Vol. XVI, pp. 951, 952.

C^5. Shale. . . . . Feet $1\frac{5}{12} = 148\frac{7}{12}$

C^6. Thin layer of sandstone. . . . .

C^7. Crumbling arenaceous shale. . . . . Feet $3\frac{5}{12}$ 152

C^8. Heavy layer of sandstone by the highway which runs under Feet $2 = 154$ the railroad track east of the cut. Dip, 3°, S. 50° W.

From a very thin layer of loose grained, arenaceous shale exposed near the base of the railroad cut on both sides of the track and largely composed of the comminuted fragments of fossils, the following species were collected:

1. *Triarthrus Becki*, Green. (c)

    Numerous small fragments of the pleurae and a few complete specimens of the glabella.

2. *Trinucleus concentricus*, Eaton. (c)

    Mostly fragments of the spines and cheeks.

3 *Plectambonites sericea* (Sowb.), H. and C. (?) (c)

    All the specimens are very small and rather coarsely striated.

4. *Orthis (Dalmanella) testudinaria*, Dal. (?) (r)
5. *Orbiculoidea* sp.
6. *Monticulipora (Prasopora) lycoperdon*, Say (?). (r)
7. Crinoid segments. (r)
8. *Graptolites*.

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

(GEOLOGICAL MAP.)

REPORT
ON THE TALC INDUSTRY OF ST. LAWRENCE COUNTY.

JAMES HALL,
State Geologist.

C. H. SMYTH, Jr.,
Assistant.

1895.

JAMES HALL, *State Geologist*,

SIR:—The accompanying report on the talc industry of St. Lawrence county embraces certain results of my investigations in this region which it has seemed well to bring together in a special chapter.

Respectfully yours,

C. H. SMYTH, JR.

HAMILTON COLLEGE, CLINTON, N. Y., *February 27, 1896.*

Report on the Talc Industry of St. Lawrence County.

By C. H. Smyth, Jr.

In a former report,* an account was given of the southwestern portion of the talc deposits, which extend from the central part of the township of Fowler, nearly across Edwards. The examination then made was incidental to a reconnaissance of a portion of St. Lawrence county not including the town of Edwards in which the talc has its greatest development. On this account, the description of the deposits was very incomplete, and the conclusions drawn as to their origin were limited to such portions as were actually studied. The explanation of the deposits suggested was, however, of such a nature that it was difficult to see how it could apply to a part of them and not to the whole; and this general application was withheld simply because the descriptions of the talc in Edwards, which had been published at that time, were so at variance with the facts observed in Fowler. In the latter town, as stated in the report referred to, the talc gives every indication of being a bedded deposit, constituting a portion of the crystalline limestone formation so important in this region.

Published accounts of the talc in Edwards, however, stated that it formed a clearly-defined vein, with granite or gneiss walls.† As it hardly seemed possible that the talc should exhibit such different relations at points on a continuous belt and separated by only a few miles, it was thought advisable to examine the entire series of deposits, their economic importance being sufficient to warrant a determination of their geologic character.

Such an examination, made during the past summer, served to remove the seeming contradictions which formerly existed. The deposits in Edwards were found to agree in every important particular with those of Fowler, and all the facts observed are in harmony with the explanation given for the latter. The deposits only remotely resemble veins, while the walls of granite and gneiss have no existence.

The chief mines form a group in and near Talcville, and here the talc is well shown. It occurs in two or more horizons only a few feet apart, forming

* Report of the New York State Geologist for the year 1893, pp. 493–515.

† A. Sahlin; The Talc Industry of the Gouverneur District, St. Lawrence county, N. Y.; Transactions American Institute of Mining Engineers, Vol. XXI, p. 583.

Talc; The Mineral Industry, Vol. I, p. 435.

beds from ten to above twenty feet thick, averaging about sixteen feet. The beds dip to the north and strike northeast, conforming in both respects with the crystalline limestone in which they lie. The walls of the talc consist of a tremolite or enstatite schist which passes over gradually into the limestone.

While, in mining, the talc is easily separated from its walls, every possible gradation exists between the two rocks, and it is evident that they are different phases of one rock body. The schist probably has resulted from the metamorphism of a siliceous and magnesian portion of the limestone, being a product of the general metamorphism of the region. Subsequently, parts of the metamorphic silicates have been altered into talc by addition of water and loss of lime. This alteration, while most pronounced along certain horizons in the schist, is more or less irregular, causing variations in the thickness and precise location of the talc beds, which are further increased by mechanical disturbances.

Most of the Edwards talc shows the fibrous structure of the original minerals and, in fact, as at the Fowler localities, contains a greater or less amount of residual tremolite or enstatite. This is shown by tests of the hardness of different parts of specimens, or, still better, by a microscopic examination.

The formation of the talc by the process suggested (and discussed more at length in the previous report) would not be a merely superficial phenomenon, like weathering, but would be the work of solutions which might extend to great depths, and there seems to be no reason for fearing that the deposits may be shallow and quickly exhausted. As a matter of fact the weathered material at, and near the surface, is very poor, good talc appearing only at some depth where it has been protected from the attack of superficial agents.

As it comes from the mines, the talc is white with a more or less intense tinge of green. Its lustre is silky or pearly, and its structure decidedly fibrous. Mingled, however, with the fibrous talc there is often some that is scaly or wax-like. The latter variety is nearly always developed upon the surfaces of the rather abundant slickensides.

At the present time ten mines are in operation in the talc district, all but one, that of the American Company described in the previous report, being situated at Talcville.

The product of the American Company's mine is ground by steam power in a mill situated only a few rods from the mine, but the other mines send their product over the recently constructed Gouverneur and Oswegatchie railroad, to mills scattered along the Oswegatchie river, which furnishes their motive power.

The process of manufacture is purely mechanical, having for its aim the reduction of the talc to a fine powder of uniform grain and free from grit. On account of its fibrous structure, the talc, when powdered, has a strong tendency to pack into a sort of felt. For this reason it can not be bolted, and special methods of treatment are required.

The process begins with a sorting of the material at the mines, where the hard and darker-colored pieces are thrown out. The good talc, in lumps ranging from a foot or more in diameter down to coarse powder, is then loaded on cars and shipped to the mills. Here it passes through Blake crushers, and then goes to rolls or burr stones and is reduced to grains about the size of a pea.

From the rolls or burr stones, the talc goes either to Griffin mills or direct to the Alsing cylinders. These are drums of half-inch steel, six feet in diameter and ten feet in length. They are supported by trunnions at the ends, and revolve about twenty-five times a minute. The cylinders have a lining of glazed brick, and in each one are placed some three and one-half tons of round flint pebbles, about the size of an egg. A cylinder is charged with an amount of talc equal to one-quarter or one-third the weight of flint pebbles and, after the manhole is closed, is revolved till the talc is reduced to the requisite degree of fineness. This operation usually takes about two hours. When it is completed, the closing plate is removed and a grating substituted, which will retain the pebbles and permit the discharge of the talc. The cylinder is then revolved again till the talc is all removed, ready for packing and shipment.

Several grades of talc are produced, varying in fineness and color. Extreme and uniform fineness and a blue-white color, are the desirable qualities. The fibrous structure is found in all grades and is, doubtless, a most important factor in giving value to the material. The felting of the powder, which gave much trouble in the earlier attempts at manufacture, is the foundation of its most extensive application. Under the microscope, even the finest and most impalpable portions of the powdered talc are seen to consist of ragged, fibrous masses, elongated in the direction of the fibres, and frayed and shredded at the ends. It is evident that the fibrous structure is present on so minute a scale as to extend to the finest particles of the mineral.

This structure alone, however, would not suffice to give to the material its valuable properties; indeed, it is not an inherent property of talc but, instead, is a product of its mode of formation. The value of the talc follows from its complex origin, in virtue of which it combines the fibrous structure resulting from its derivation from the other silicates with its own pliability and softness. The value of either mineral in its typical form would be much less than that of the material which combines some of the properties of both.

Tremolite and enstatite, although fibrous, would, on account of their brittleness, grind to a granular powder with no binding properties; and the same would be true, though perhaps to a less degree, of massive or foliated talc.

In the district under consideration the terms "massive" and "foliated" are often applied to varieties of talc in which the fibrous structure, although present, is so fine as to be inconspicuous, except under the microscope. In such cases, the character of the ground material is the same as of that produced from the coarsely fibrous talc; although sufficient talc that is truly massive or foliated may sometimes be present to render the grinding more difficult and the finished product of less value.

The presence of scales of talc, in many specimens, indicates that it can not be regarded as entirely pseudomorphous, as these scales certainly do not have the form of the original minerals. On the contrary, the form is that of talc itself and must have resulted directly from the independent growth of that mineral. The materials, doubtless, were supplied by the constituents of the schist, but the structure of the latter, physical as well as chemical, has broken down. From this, it seems possible that the fibrous structure of the deposits may be an indication of a lack of completeness in the process of alteration which, if continued to its ultimate end, would convert all of the schist to scaly talc. From what has been said above, it is evident that the possibility of such a complete change of structure has an economic bearing, as it would result in the destruction of the most valuable properties of the talc. From this point of view the question is two-fold, involving the possibility of such a complete change, and the probability of its taking place at moderate depths, so as to put a stop to profitable mining. On neither of these points are there conclusive data at hand but, while it is not impossible that such a complete alteration may have occurred in some portions of the deposits, it would, doubtless, be very irregularly distributed; and as it would be independent of the present topography, would be developed, at such depths as to prevent further working, only by a coincidence. For these reasons, it seems entirely justifiable to neglect this factor in estimating the extent and value of the deposits.

In the case of most mine products, the chemical composition is the most important feature, the aim being to secure the greatest amount possible of one or more constituents of the material mined and in a condition suitable for extraction. With the talc, this is not so; its value is entirely dependent upon its physical properties, and its chemical composition is of importance only as it conditions these. The connection between physical properties and chemical composition is, of course, most intimate, and hence the composition is of importance indirectly. The value of the material does not, however, depend upon the presence of some one element which is to be extracted, but, instead, upon the character resulting from the union of all the elements present.

If any one constituent can be said to have particular value, it is the water. Its importance lies in the probability of its giving the soft and pliable character to the mineral. Of course, it is impossible to say that this is positively the case, but it is a familiar fact that many minerals which contain the elements of water are softer than other minerals having nearly the same composition aside from this constituent. In using the term "water" in this connection it is not meant to imply anything definite as to the condition in which its elements are present; for in most cases, as with the talc itself, this is a disputed point.

The predominant importance of the physical properties of the talc renders simple mechanical tests of more practical value than elaborate chemical analyses in determining its grade. Were the material of sufficient value to demand careful discrimination in dealing with it, microscopic examination of the powder would perhaps afford the most accurate method of grading. By this means the perfection of fibrous structure, together with the relative amounts of talc, tremolite and foreign impurities could be rapidly determined. With existing prices, however, such refinements are unnecessary.

A chemical analysis, of course, shows whether the alteration of the schist into talc is complete and, if made on a sample taken from a fibrous mass, is a thorough test of the value of the material. But a ground sample might afford an excellent analysis, and yet lack entirely the fibrous structure necessary to give it the desired binding properties. In this way, a purely chemical examination might lead to very inaccurate conclusions as to the quality of the material.

The following analyses suffice to indicate the composition of the talc:

	I.	II.	III.	IV.	V.
SiO_2	60.59	59.92	52.42	61.28	62.10
Al_2O_3	0.13	0.50	.....	.....	.....
Fe_2O_3	.....				
FeO	0.21	.....	.....	.....	1.30
MnO	1.16	0.76	.....	.....	2.15
MgO	34.72	31.37	36.24	26.58	32.40
CaO	.....	0.57	.....	.....	.....
Na_2O	.....	0.48	.....	.....	.....
H_2O	3.77	6.25	.....	.....	2.05
Total,	100.58	99.85	88.66	87.86	100.00

All of these are analyses of fibrous talc, except III, which is the foliated variety. I and II are from Dana's System of Mineralogy, page 679; III and IV from "The Mineral Industry," Volume I, page 425; and V is communicated by Mr. A. J. McDonald, Superintendent of the International Pulp Company, to whom the writer is indebted for much information used in the preparation of this report.

The figures shown in I, II and V agree quite well with the theoretical composition of talc, and present some features which seem difficult to reconcile with the hypothesis offered to account for the formation of the deposits, notably the small amount of lime and alumina. But it is probable that these analyses are made on selected samples, and that the average composition of the product of the mines would show more of these impurities. Moreover, the thickness of the deposits makes it possible to mine only the best and most completely altered material, thus tending to keep the average composition fairly close to the theoretical percentages. That there are, however, wide variations, is shown by the incomplete analyses, III and IV, which probably represent the ground product.

During the past year the industry has been in a fairly active state, though not so flourishing as formerly. The output for the year is estimated, by a competent authority, to be about forty thousand tons. The selling price of the finished product ranges from seven to twelve dollars, depending upon the quality.

The great bulk of the product is used as a filler and weighter in the manufacture of the medium grades of paper. Its value here is a result of its fibrous and pliable character, which causes it to be retained in the paper pulp, to which its binding properties give added toughness. Formerly, various clays were used as fillers, but these did not strengthen the paper, and only thirty to forty per cent. of the clay was retained by the pulp, while of the talc, seventy to ninety per cent. is retained.

Smaller quantities of talc are used in the manufacture of cheap grades of soap, in toilet powders, in the adulterations of various substances, and in the manufacture of dynamite.

There seems to be no reason for doubting that the demand for talc will continue, and increase with the revival of business interests in general. As existing plants can largely expand their output at any time, it is not probable that any new properties will be developed in the near future. The many advantages enjoyed by the plants now in operation are sufficient to prevent new competitors from entering the field, unless there be some great increase in the demand for talc. The present conditions are not such as to stimulate search for new deposits, and past efforts in this direction have not been encouraging. The great extent of crystalline limestone in the region makes it probable that other talc deposits exist, but it would be surprising if any which equal in size and quality the deposits now worked, should have remained undiscovered till the present time.

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

PHYSICAL TESTS OF THE DEVONIAN SHALES OF NEW YORK STATE TO DETERMINE THEIR VALUE FOR THE MANUFACTURE OF CLAY PRODUCTS.

JAMES HALL,
State Geologist.

HEINRICH RIES,
Assistant.

Physical Tests of the Devonian Shales of New York State to Determine their Value for the Manufacture of Clay Products.

By Heinrich Ries.

The extensive developments, in recent years, of the manufacture of clay products having an impervious or vitrified body, as well as strength and toughness, has led the manufacturers of these goods to experiment considerably in order to determine what class of clays is best suited for the production of them. The result of these experiments has been the almost universal adoption of shale for this purpose.

The production of a vitrified body depends on the proper amount of fusible impurities in the clay, and that these fluxes shall be of such nature that the clay can be brought to vitrification without danger of its becoming viscous. It is in shales that these qualifications are usually found.

An extensive branch of the clay-working industry depending upon shale for its support, has thus sprung up. The product is principally paving brick and sewer-pipe.

Some idea of the extent to which shale is used may be gained from the following figures of production given in the "Mineral Resources" of the United States Geological Survey, for 1895. The states given are those in which shale is almost exclusively used.

PRODUCTION OF VITRIFIED PAVING BRICKS IN 1895.

STATE.	THOUSANDS.	VALUE.
Alabama,	2,300	$23,500
Illinois,	82,526	643,997
Indiana,	22,313	204,000
Iowa,	31,704	243,928
Missouri,	6,816	54,640
New York,	10,896	121,892
Ohio,	96,555	787,878
Total,	253,110	$2,079,835

These figures, though large; do not include other shale products, such as sewer-pipe, stoneware, terra-cotta, pressed brick, etc., and as will be seen from them, Ohio and Illinois are the largest producers. The works in these two states have been erected on a large scale, and the products find a wide application.

Until recently shale was little used by clay workers in the eastern states, but, having become convinced of its value, they are now taking full advantage of it.

The whole southern half of New York state is underlaid by a formation including among its members many extensive shale deposits. These have been tried with success at several points, and their utilization should expand rapidly in the near future.

General Properties of Shales.

A shale is practically nothing more than a hardened clay, having been formed in the same manner, viz.; as a fine sediment deposited in the quiet portions of lakes or seas, but subsequently hardened by burial under other sediments laid down upon it.

Although shales are apparently very distinct from clay, on account of their rock-like condition, the two materials have practically the same physical and chemical characters, and shale, when ground and mixed with water, possesses the same plasticity as clay.

Shale-like clay may vary considerably, for just as a clay, by an increase of its siliceous contents, may pass into sand, so a shale, by an increase of sand grains in its composition, may grade into a sandstone. This is not at all an uncommon occurrence.

Shales may also exhibit another change, viz.; passing into slate as a result of metamorphism. Such slates, when ground and mixed with water, will never have the same plasticity as shale. They also show a false bedding developed as a result of pressure, while the original layers of sedimentation are almost obliterated, the slate showing no tendency to split parallel to them.

At times shales run so low in impurities that they are adapted for the manufacture of refractory materials. Such shales are restricted almost entirely to the Carboniferous period (in the eastern United States) and are therefore not to be sought in New York state.

It sometimes happens that shales are so charged with bituminous matter, that this impurity has to be taken into consideration in the process of burning, on account of the enormous heat which it is likely to develop.

Most shales contain a large percentage of fusible impurities and it is this which enables them to burn to a hard, dense, tough body so essential to vitrified wares, and especially to paving brick. Their action under heat, however, varies with their physical and chemical properties, which may be briefly stated.

Chemical Properties of Shales.

Pure clay is fusible only at extremely high temperatures, but the presence of a slight amount of impurities may lower its melting point considerably. The impurities found in clays and shales are silica, alumina, iron, lime, magnesia, alkalies, water, organic matter, titanic acid, phosphoric acid, sulphur and sometimes manganese. All these impurities may be placed in one of two classes, depending on whether they are active or fluxing impurities, or inert or non-fluxing ones.

Fluxing Impurities.

These, in the order of their effectiveness, are alkalies, lime, magnesia and iron. The manganese, sulphur and phosphorus would come under this head, but are seldom present in sufficient quantities to be worth considering.

Alkalies. The alkalies in clay may be ammonia, potash, soda and lithia. The lithia is extremely rare and need not be considered. The ammonia is frequently present in shales, but as it volatilizes at low temperatures its only effect is to give a slight, characteristic odor to the material when moist.

Soda and potash are powerful fluxes, which are found in nearly all shales. They vary in quantity from a trace up to nine or ten per cent. This variation depends on the quantity of feldspar grains present, for this mineral is the usual source of the alkalies in shales and clays. Aside from the feldspars, mica may also furnish potash. The mica shows itself as small glistening scales scattered through the shale.

The alkalies are sometimes present in soluble form as sulphates, which may cause considerable trouble. In the drying of the clay the water coming to the surface to evaporate will leave these soluble alkaline salts on the surface as a white coating. In salt-glazing sewer-pipe the sodium vapors from the salt thrown into the fire unite with the silica and alumina of the clay, thus forming the glaze. If, now, a coating of these soluble sulphates is present, it prevents this chemical union and formation of the glaze. Furthermore, if the heat is not raised sufficiently to decompose any sulphate salts present, they may form a white coating on the surface of the burned ware. The decomposition of sulphates is also accompanied by the disengagement of sulphuric acid, which, if it escapes with violence, may cause blistering.

Lime is a common detrimental impurity. It is abundant in some members of the New York shales, especially those of the Salina group in central New York. When present to the extent of only two to three per cent. it is practically harmless. The common source of lime in shales is feldspar, which is a double silicate of lime and soda; or calcite, which is carbonate of lime. The latter may be detected by the effervescence produced on the addition of muriatic acid.

Lime in the condition of silicate may serve as a useful flux, if present to the extent of four or five per cent.

Carbonate of lime may render a shale very fusible and materially lower the difference in temperature between the points of incipient fusion and viscosity. Lime also diminishes the shrinkage of a clay in burning; in fact, an excess, say twelve to fifteen per cent., may cause the clay to swell slightly.

An excess of lime over iron will counteract the reddening effect of the latter by the formation of a silicate of lime, iron and alumina.

Seger found that if the lime exceeded the iron in the proportions of three to one, the product is a good buff. He also found that a good brick could, with care, be made from a clay containing twenty to twenty-five per cent. of carbonate of lime, but it is not safe to make a vitrified one from such clay. Sulphate of lime is not uncommon in some New York shales, and its action on heating may be the same as described under sulphates of the alkalies. Some of the marly shales of central New York may be found more suitable for the manufacture of Portland cement than for clay products.

Magnesia is not an abundant element in most shales, although in some of the Salina shales it is common. Magnesia is derived from the same classes of compounds as lime, and, as far as known, exerts the same influence.

Iron. This element acts not only as a flux but also as a powerful coloring agent of clay materials, both in their green and burned conditions. It may exist in clays in a variety of forms, according to the mineral of which it is a component element. These mineral compounds may be silicates, carbonates, oxides or sulphates. In all these combinations it exists in the condition of either a ferrous or ferric salt; but in burning, the former generally become oxidized to the latter, unless the fire is reducing in its action. When pyrite occurs in the shale, it will, if in grains or lumps, produce fused spots in burning. It acts as a strong flux.

Ferrous iron compounds are more fusible than ferric ones, and consequently with reducing fire the clay will fuse at a lower temperature; at the same time, it will not burn to as bright a red. If treated to an oxidizing fire, the presence of ferrous salts need not be considered. Iron salts are affected by varying conditions in burning. If the temperature is raised too rapidly the outer portion of the piece of clay being burned may shrink and become dense before the air has had time to permeate the clay and oxidize the iron in the centre of the body. The centre of a brick or other piece of clay ware may thus be dark and porous while the surface is red and dense. A further result of this will be a differential shrinkage between centre and exterior and possible cracking.

Unburned shales may be yellow, blue, brown, red, gray or green in color, depending generally on the relative amounts of ferrous and ferric salts present. The same variety of shades and colors is produced in burning. Ferrous iron alone may impart a green color to burned clay, and ferric oxide red or, with hard firing, purple. The higher the temperature to which a clay is subjected, the deeper usually is the color produced by the same amount of iron.

Non-Fluxing Impurities.

These include silica, titanium, organic matter and water.

Silica. This may be present either as quartz combined with alumina and water in the form of kaolinite, or combined with other elements, as in feldspar and mica. Silica renders a clay more refractory, lessens its shrinkage in burning and decreases the plasticity. On this account plastic clay or shale is added to very siliceous ones.

Titanium is a seemingly rare element in clays, due to the fact that it is seldom looked for in chemical analysis. It is never present in great quantities, rarely over one per cent., and only exerts a fluxing influence at high temperatures and when six or seven per cent. of it are present.

Organic matter. Very common in black and in some grey shales, and may mask the color which any iron present might produce. It may be present as finely disseminated particles or in the form of stems or other plant remains. Organic matter burns off at a bright red heat. Its chief influence lies in the increased plasticity of a clay or shale, provided an excess of sand is not present.

Water is present in shales in two forms, viz., chemically combined water and mechanically combined water or moisture. The moisture in unweathered shales is generally low, but in mellowed portions of their outcrops it may be twenty or thirty per cent. Air drying expels most of the contained moisture and at the same time a shrinkage of the material takes place. Sandy, coarse grained clays show the least shrinkage, but fine grained ones may sometimes show considerable diminution of volume on air drying. The larger the quantity of water absorbed by a shale in tempering, the more will it shrink in drying. If the clay is fine grained, rapid drying may cause it to split. The last traces of moisture are generally driven off in the kiln during the early stages of burning.

Combined water. This is present in all shales. It usually varies from three to eight or ten per cent. in shales, depending on the amount of clay substance and perhaps other hydrated minerals present. Combined water is driven off at a low red heat, or about 1,200° F., and with the passing off of it there also begins a second shrinkage. While the amount of combined water does not stand in any close relation to the plasticity, nevertheless when once the combined water is driven off, the clay can no longer be rendered plastic.

Physical Properties.

These are considerations of as much importance as the chemical ones, for they exert fully as much influence on the characters of clay or shale. The important physical properties which should always be considered, are fusibility or behavior under heat, plasticity, tensile strength or cohesion and absorption.

Plasticity. This is one of the two important properties which makes clay of such use to man, for it permits of molding it into any desired form, which is retained when the clay is dried. Plasticity, however, is a variable property, some clays possessing it to only a slight degree, others having it highly developed. The former are called "lean," the latter "fat." Very fine and very coarse grained clays are generally lean. An excess of sand also tends to diminish the plasticity, and consequently very siliceous shales, those passing into shaly sandstones, should be avoided, or should not be used unless mixed with more plastic material. Organic matter frequently increases the plasticity of a clay and makes it very fat, unless there is an excess of sand present. If water be gradually added to dry clay and the mass thoroughly kneaded, it will be found that its plasticity increases up to a certain point, but if more water is added it begins to decrease until finally the clay runs like soft mud. The amount of water absorbed by shales or clays depends in general on their plasticity, very "fat" ones requiring the addition of a large quantity of water, and "lean" ones usually needing but little. Of course there are exceptions to this rule.

The production of maximum plasticity has a practical bearing in the tempering of the clay, for if too little water is added, the clay will frequently crack in molding.

Tensile Strength, or Cohesion.

The plasticity of a clay has been found to be due to the interlocking of its particles,* consequently a mass of clay, when air dried, offers a resistance (which may be great) to any force tending to pull it apart. This tensile strength or cohesion stands in close relation to the plasticity, and consequently serves as a measure of it. The tensile strength is expressed in pounds per square inch and is determined by forming the wet clay into briquettes of the same shape and size as those used in testing cement, allowing them to air dry and then pulling them apart in a cement testing machine.

Clays which appear moderately plastic when worked in the hand, will show a tensile strength of 100 to 150 pounds per square inch when air dried. Lean clays may run about fifty pounds per square inch, often lower. Very plastic clays may show 250 to 300 pounds tensile strength per square inch. Very fine and very coarse grained shales or clays show a low strength.

Behavior under Increasing Temperature.

Shrinkage. The amount of shrinkage that clay materials undergo in drying, depends somewhat on the amount of water absorbed or the porosity of the clay. Coarse grained clays may absorb much water and yet shrink very little. Having larger pores, they will also permit the water to escape more rapidly and consequently can be dried quicker, while fine grained ones, owing to the smaller size of their pores, must dry slowly.

The air shrinkage of a clay begins as soon as it is molded and set out in the open air or put in tunnels to dry, and continues until all the moisture is driven off. It may be as low as two per cent. in lean, coarse grained clays, or reach twelve or thirteen per cent. in others. The highly plastic clays do not always shrink the most.

The fire shrinkage begins when the combined water commences to pass off, or at a temperature of about 1,200° F. It may also vary within the same limits as the air shrinkage. It is, however, affected by several factors. It

* Olchewsky. *Töpfer und Ziegler Zeitung*, 1882, No. 29.

often increases with the amount of organic matter or combined water present, and diminishes with the amount of sand which the shale or clay contains. Lime in excess exerts the same influence as sand.

Between the points at which air shrinkage ceases and fire shrinkage begins, the clay shrinks little or not at all, therefore in burning clay wares the heat can be raised rapidly between these two points, but above and below them it should be raised slowly as long as any water is passing off, to prevent cracking.

Fusibility.

No clays, on being subjected to a rising temperature, pass suddenly from a solid to a fluid or viscous condition; on the contrary, they change slowly from the condition of solidity to that of viscosity. This change may occur within a range of 75° F., as in very marly shales, while in others it may require a rise of 400° F. to convert the material from solidity to viscosity.

As the heat is raised to a temperature varying from 1,500 to 2,000° F. in different shales and clays, the particles of the clay soften somewhat, and become tightly stuck together. In fact, the individual grains may no longer remain distinct, and the clay can barely be scratched with a knife. This is the point of *incipient fusion* and, as Wheeler* has suggested, this is a good term to use in defining this stage.

As the temperature is raised from 100° to 200° F. higher (also depending on the clay), the clay becomes completely vitrified; the body resembles one solid mass and is impervious or nearly so. The clay has also acquired its maximum toughness and maximum shrinkage. With an additional varying rise of temperature, viscosity occurs. The point of vitrification is generally midway between incipient fusion and viscosity, and these two latter points may be from 100° to 400° F. apart; the nearer 400° the better. It should not be less than 200°, otherwise there is the danger of loss in burning, for with so little margin between vitrification and viscosity it is hard to run the burning to the former point without passing it and reaching the latter.

Manufacture of Paving Brick.

As the most extensive use of shale is for the manufacture of paving brick, it may not be out of place to describe briefly the methods employed.

Owing to its hard nature, shale generally has to be mined by blasting, although in some cases, as at Galesburg, Ill., a steam-shovel has been found

* Vitrified Paving Brick, Indianapolis, 1895

efficient and economical. The economy of this latter method depends, however, on its being kept at work as steadily as possible, and consequently it is chiefly applicable to larger plants.

Preparation. Before being mixed with water or tempered, the shale is first ground in dry-pans or disintegrators.

Dry-pan. This consists of a circular iron pan with perforated bottom. In the pan are two mullers about twelve inches wide and supported on a horizontal axle. The mullers weigh from 2,000 to 4,000 pounds and revolve by the tangential friction of the pan floor, which is turned by power transmitted from the engine. Scrapers attached to the axle of the mullers keep the material charged, in their path. The shale when ground fine enough falls through the slits in the pan-bottom. These slits are generally one-eighth to three-sixteenths of an inch wide. The capacity of a dry-pan varies with the size of the screen openings and character of the clay, but one hundred tons in ten hours with one-eighth inch screen openings is a fair capacity.

Disintegrators, consisting of concentric wheels bearing cross pieces and revolving in opposite directions, or of an axle bearing steel arms which revolve between a series of parallel steel bars, are often found effective. The pieces of shale are ground not only by being hit by the rapidly moving arms, but also by being thrown against each other.

Screening. The ground shale is generally transported from the dry-pans or disintegrators to the screens by means of bucket elevators or traveling belts. Three general types of screen are used.

1. *Inclined screens*, ten to fourteen feet long, with wire cloth or perforated metal bottom. They are often provided with a tapping device to keep them from becoming clogged. Inclined screens are simple and cheap, but have small capacity.

2. *Rotary screens*, of cylindrical or octagonal form, usually provided with automatic devices, such as brushes to keep them clean.

3. *Shaking screens*, fixed at one end and driven by crank and piston or eccentric. These are cheap and simple in operation.

While all these screens are designed to perform their work automatically, still few of them can be left without attention for any length of time.

The tailings from the screens are returned to the crusher or disintegrator.

Tempering is usually done in wet-pans or pug-mills.

Wet-pans. These resemble dry-pans, but have a solid instead of perforated bottom. The clay is charged in lots of 600 to 1,000 pounds and water added. Wet-pans are very rapid in their action, a charge for brick or sewer pipe being tempered in a few minutes. The charge is generally removed by means of a long-handled shovel pivoted on an upright arm. Wet-pans have a greater capacity and are more efficient than pug-mills, but consume more power.

Pug-mills consist of a horizontal or inclined trough in which there revolves a shaft bearing knives or a worm screw. The material with water is charged at one end and, by means of the screw thread or knife blades, is mixed thoroughly and at the same time passed to the other end of the trough, where it is discharged. To insure thorough tempering, pug-mills should not be less than eight or ten feet long. They are extensively used by paving-brick manufacturers, and so arranged that their contents are discharged directly into the molding machine.

Molding. Paving brick may be manufactured by one of three processes, viz., the stiff-mud, soft-mud or dry-clay process.

Stiff-mud process. This is the most used by paving-brick manufacturers. In this process the clay is discharged from the machine through a rectangular steel die, whose cross-section may be 9x4 or 2x4 inches, depending on whether the brick is to be end-cut or side-cut. As the bar of clay issues from the machine it is received on the cutting table and cut up into bricks, either by a series of parallel wires fastened to a moveable frame, or by means of a revolving wheel, also bearing a series of wires. The capacity of the machine may be materially increased by having a double or triple die, so that more than one bar of clay issues at the same time, but a single die will give an auger machine a capacity of 50,000 brick in ten hours. The clay should be thoroughly pugged before being charged into the machine. Auger machines combine economy and large capacity, and their use has not only become widespread but necessary to enable the manufacturer to compete successfully with his rivals.

Auger machines are adapted to a wide range of clays, except very lean or very plastic ones. The former seldom have enough cohesion to hold together in passing through a die, and the bar of clay cracks and tears. Very plastic clays develop a series of concentric laminations in the brick which are a serious detriment to its strength. The laminations in two bricks made from the same shale may be very differently developed, if molded in machines of different make. Much attention is, therefore, paid to improving the construction of the dies and other portions of the machine as small changes may often cause considerable difference in the structure of the brick.

Stiff-mud brick are frequently repressed, as it is considered to improve the quality of the product and, indeed, this is true within certain limits.

In a series of experiments recently made by Professor E. Orton, Jr., it was found that end-cut bricks were tougher than side-cut ones, and when repressed they were still more so. These experiments are important and interesting and worth mentioning in detail. A number of bricks were made from the same lot of shale, but molded on different machines. They were, however, all burned together in the same kiln. These brick were tested in a rattler and it was found that the loss by abrasion was least in the case of the end-cut repressed brick.

Soft-mud process. This method is sometimes used for shales or clays which can not be molded in stiff-mud machines, and works well. It is being used at one locality in New York state for the manufacture of paving brick. The soft-mud process gives a brick of thoroughly uniform texture, but on account of its limited capacity the cost of production is greater than with stiff-mud machines.

Drying. Paving brick are generally dried by artificial heat. Two general systems of drying may be noticed, viz., floor-dryers and tunnel-dryers. The latter have the most extended application.

Floor-dryers. These may be of brick, heated by flues underneath them, which conduct the heat from the fire-place at one end. Such floors are cheap, but the heat is very unequal at the two ends, and the use of such floors involves considerable labor in handling. Slatted floors, such as those used for drying sewer pipe, may be used, but their cost of installation is great, and the bricks also require much handling.

Tunnel-dryers. The tunnels are made of brick or wood and heated by hot air, steam or flues running under them. The bricks are piled on cars, which are run on tracks into the tunnel. The cars are run in at one end and always taken out at the other. The hot air is introduced at the end where the bricks are taken out.

A recent improvement is the drawing of hot air from the cooling kilns and blowing it through the tunnels. Though still in the experimental stage, this method will no doubt be widely used before long.

Burning. Paving brick are generally burned in down-draft kilns. These are of rectangular or circular shape, the former having a capacity of 160,000 to 200,000 and the latter about 30,000. The rectangular ones are quite generally used now, and it is only in a few districts that the manufacturers cling to the circular ones.

Continuous kilns are used at several localities, and while they work fairly well, still they can hardly be considered to have completely emerged from the experimental stage.

In burning paving brick the temperature is gradually raised to the point of vitrification and the kiln held at this temperature for several days in order to allow the heat to thoroughly penetrate each brick and cause it to get its maximum shrinkage. The kiln is then cooled very slowly to anneal the brick and give a hard, tough product.

The temperature attained in paving-brick kilns varies, but it may be said in general to vary from 1,700° F. to 2,000° F. In experiments made by Professor Orton, Jr., of the Ohio Geological Survey, the temperatures of paving-brick kilns when at their best heat varied from 1,800° F. to 1,920° F. In the New York shales tested it was about 2,100° F.

Requisite Qualities of Paving Brick.

As paving brick are laid in streets, they are subjected to considerable wear and tear, which they should be able to withstand if of good quality. In order to determine by experiment in the laboratory whether a paving brick possesses the requisite characters, certain standard methods of testing have been devised.

Recently the National Brickmakers Association appointed a committee to carefully go over the various methods of brick testing and draw up a set of standard specifications. The tests considered were the rattler, absorption, cross-breaking and crushing test, and the recommendations of the committee were as follows:

Specifications for Abrasion Test.

I. Dimensions of the machine. The standard machine shall be twenty-eight inches in diameter and twenty inches in length, measured inside the rattling chamber. Other machines may be used, varying in diameter between twenty-six and thirty inches, and in length from eighteen to twenty-four inches, but if this is done a record of it must be attached to the official report. Long rattlers may be cut up into sections of suitable length by the insertion of iron diaphragms at proper points.

II. Construction of machine. The barrel shall be supported on trunnions at either end; in no case shall a shaft pass through the rattling chamber. The cross-section of the barrel shall be a regular polygon having fourteen sides. The heads and staves shall be composed of grey cast iron, not chilled or case hardened. There shall be a space of one-fourth of an inch between the staves for the escape of dust and small pieces of waste. Other machines may be used having twelve to sixteen staves, with openings from one-eighth to three-eighths of an inch between the staves; but if this is done, a record of it must be attached to the official report of the test.

III. Composition of the charge. All tests must be made on charges composed of one kind of material at a time. No test shall be considered official where two or more different bricks or materials have been used to compose a charge.

IV. Quantity of the charge. The quantity of the charge shall be estimated by its bulk and not by its weight. The bulk of the standard charge shall be equal to fifteen per cent. of the cubic contents of the rattling chamber, and the number of whole brick whose united volume comes nearest to this amount shall constitute a charge.

V. Revolutions of the charge. The number of revolutions of a standard test shall be 1,800, and the speed of rotation shall be thirty per minute. The belt power shall be sufficient to rotate the rattler at the same speed whether charged or empty. Other speeds of rotation between twenty-four and thirty-six revolutions per minute may be used, but in this case a record of the speed must be attached to the official report.

VI. Condition of the charge. The bricks composing the charge shall be dry and clean, and, as nearly as may be possible, in the condition in which they were drawn from the kiln.

VII. Calculation of the results. The loss shall be calculated in percentage of the weight of the dry brick composing the charge, and no result shall be considered official unless it is the average of two distinct and complete tests, made on separate charges of brick.

Specifications for Absorption Test.

1. The number of bricks for a standard test shall be five.

2. The tests must be conducted on rattled bricks. If none such are available, the whole bricks must be broken into halves before treatment.

3. The bricks should be dried for forty-eight hours at a temperature ranging from 230° to 250° F. before weighing for the initial dry weight.

4. The bricks should be soaked for forty-eight hours, completely immersed in pure water.

5. After soaking and before weighing, the bricks must be wiped dry from surplus water.

6. The difference in weight must be determined on scales sensitive to one gram.

7. The increase in weight due to water absorbed shall be calculated in percentage of the initial dry weight.

Specifications for Cross-Breaking Tests.

1. Support the brick on edge, or as laid in pavement, on hardened steel knife-edges, rounded longitudinally to a radius of twelve inches and transversely to a radius of one-eighth inch, and bolted in position so as to secure a span of six inches.

2. Apply the load to the middle of the top face through a hardened steel knife-edge, straight longitudinally and rounded transversely to a radius of one-sixteenth inch.

3. Apply the load at a uniform rate of increase until fracture ensues.

4. Compute the modulus of rupture by the formula

$$f = \frac{3\ w\ l}{2\ b\ d^2}$$

in which

f = modulus of rupture in pounds per square inch.

w = total breaking load in pounds.

l = length of span in inches = 6.

b = breadth of brick in inches.

d = depth of brick in inches.

5. Samples for test must be free from all visible irregularities of surface or deformities of shape, and their upper and under surfaces must be perfectly parallel.

6. Not fewer than ten bricks shall be broken, and the average of all be taken for a standard test.

Specifications for Crushing Test.

1. The crushing test should be made on half bricks, loaded edgewise, or as they are laid in the street. If the machine used is unable to crush a full half brick, the area may be reduced by chipping off, keeping the form of the piece to be tested as nearly prismatic as possible. A machine of at least 100,000 pounds capacity should be used, and the specimen should not be reduced below four square inches of area in cross-section at right angles to the direction of the load.

2. The upper and lower surfaces should be preferably ground to true and parallel planes. If this is not done they should be bedded in plaster-of-paris while in the testing machine, which should be allowed to harden ten minutes under the weight of the crushing planes only before the load is applied.

3. The load should be applied at a uniform rate of increase to the point of rupture.

4. Not less than an average obtained from five tests on five different bricks shall constitute a standard test.

It was resolved by the commission that "from the experimental work done so far by the commission, or by others so far as is known to us, in the application of the cross-breaking and crushing tests to paving brick, it is not possible to show any close relationship between the qualities necessary for a good paving material and high structural strength as indicated by either of these tests."

Extent of New York Shales, together with Tests of Samples from Type Localities.

The shale bearing formations occurring in New York state, beginning with that geologically oldest, are as follows:

Lower Silurian	Hudson river.
Upper Silurian	Medina. Clinton. Niagara. Salina.
Devonian	Hamilton. Portage. Chemung.

Of these formations only the shales of the Salina, Hamilton, Portage and Chemung are at present being utilized.

Hudson river. This formation is abundantly displayed in the counties of Lewis, Oneida, Montgomery, Schenectady and Columbia. Its tendency is to exhibit siliceous or slaty phases, but in eastern Columbia county it becomes at times argillaceous and at the same time contains considerable iron.

Medina. The Medina formation at times is shale bearing, as along the Genesee river, where it is also marly, but the extent of the shaly layers is unimportant. (Hall, Geology of the Fourth District of New York, p. 38.)

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The *Clinton* group is shale bearing in its lower members in eastern Wayne county. It is a bright green shale and is about thirty feet thick. At Sodus Point the shale is purplish. It occurs at other localities, but is very thin, not more than two to four feet (*Ibid.*, p. 59.) The second green shale of the Clinton group is less brilliant in color and everywhere full of fossils. It is well exposed at Rochester and at Wolcott furnace, in the banks of the creek, where it is over twenty-four feet thick. The shale is probably frequently calcareous.

Niagara. Although a prolific shale formation in New York state, the writer has not seen any exposures of it which were not either very siliceous or calcareous, so that it would probably not work well for the manufacture of clay products. When ground and mixed with water it possesses no plasticity.

According to Professor Hall (Geology of the Fourth District of New York, p. 80), the Niagara shale forms a member of great development in the lower part of the Niagara group. It is a dark bluish shale which, on exposure, forms a bluish grey, marly clay. It is well shown at Lockport, in the sides of the gorge at Rochester, just below the railroad bridge, and at many localities in Wayne and Monroe counties. The lower layers of the shale are less calcareous than the upper ones.

The following is an analysis of this shale, the sample taken from the gorge at Rochester (Sixteenth Annual Report United States Geological Survey, part IV, p. 569).

Silica,	28.35
Alumina,	10.47
Ferric oxide,	1.90
Lime,	21.47
Magnesia,	8.24
Alkalies,	5.73
	76.16

H. T. Vulté, *Analyst.*

The shale is also to be found in many of the ravines and gorges, from Rochester to the Niagara river.

Salina. The shales of this formation are contained in a belt extending from Syracuse westward along the line of the New York Central railroad to

Buffalo. As a rule they are extremely impure and at times even marly. They are soft shales, which weather very easily, and are generally red or green in color and contain the beds of gypsum and salt.

The Salina shales are well exposed at Warners, near Syracuse, where they are utilized for making brick.

Professor Hall says of the Salina or salt group (Geology of the Fourth District of New York, p. 117), that it forms an immense development of shaly marls and limestones, with interbedded deposits of gypsum. The formation extends from Syracuse westward through southern Wayne county, and northern Ontario and Seneca counties, northern Genesee and Erie counties and a small part of the southern portion of Niagara. This group contains important shale beds, although they are unfortunately very calcareous at times and consequently require careful manipulation.

The red shale forming the lower divisions of the group was not observed west of the Genesee river. It appears in eastern Wayne county, as indicated by the deep red color of the soil overlying it. At Lockville the greenish blue marl with bands of red has been quarried from the bed of the canal. West of the Genesee this is the lowest visible mass; the red shale has either thinned out or lost its color, becoming gradually a bluish-green; while otherwise the lithologic character remains the same. On first exposure it is compact and brittle, presenting an earthy fracture, but a few days are sufficient to commence the work of destruction, which goes on till the whole is resolved into a clayey mass.

The green marl of the lower division appears near the canal at Fairport and again at Cartersville. The bed of the stream at Churchville shows the greenish-blue marl.

"The prevailing features of the second division of this group," says Professor Hall, "are a green and ashen marl, with seams of fibrous gypsum and red or transparent selenite. It occurs in the vicinity of Lyons and numerous points farther west."

The third division contains large gypsum beds and is probably not suitable for use.

The Salina shale, as stated above, is worked at Warners, Onondaga county, by the Onondaga Vitrified Brick Company.

The shale as exposed in their bank consists of a green or red, soft, argillaceous shale, of considerable impurity as the following analyses furnished by the company show.

	CALCAREOUS LAYER IN BANK.	RED SHALE.	BLUE SHALE.
Silica, ...	25.40	52.30	57.79
Alumina, ...	9.46	18.85	16.15
Ferric oxide, . . .	2.24	6.55	5.20
Lime, ...	22.81	3.36	2.73
Magnesia, ...	10.39	4.49	4.67
Carbonic acid, . . .	20.96	3.04	3.42
Potash, ...	.95	4.65	4.11
Soda, ...	....	1.35	1.22
Water and organic matter, ...	7.60	5.30	4.50
	99.81	99.89	99.79
Total fluxing impurities, ...	36.39	20.40	17.93

These shales must be quite fusible owing to their high percentage of fluxing impurities.

At the works of the Onondaga Vitrified Brick Company, the shale crops out in considerable thickness near the yard, and is of various shades of red, green and some grey; it disintegrates very rapidly and the whole bank is traversed by numerous cracks so that a small blast brings down a large amount.

The material is mixed with a surface clay in the proportions of one of clay to three of shale; it is ground in a dry-pan, and molded in an auger machine; the green bricks are dried in tunnels and burned in circular kilns; the product is of a light-red color.

Marcellus shale. This formation presents numerous undesirable features, so that its occurrence is of little importance to clay workers. It is generally slaty, gritty, and contains not unfrequently much iron pyrite and bituminous matter. The rock is well exposed in the bed of the river at Le Roy.

As the Hamilton, Portage and Chemung are the most promising and most extensive of the shale formations occurring in this state, a series of physical tests was made on samples from several localities, to determine their characters as related to each other and also as compared with other deposits.

The samples were ground to pass through a thirty-mesh sieve.* The determinations made on these samples were: (1) Amount of water required

* Of most of the shales ground up by disintegrations, about sixty per cent. of any sample will pass through a thirty-mesh sieve, and the balance through a one sixteenth or an one-eighth inch mesh.

to make a workable paste, (2) shrinkage in drying, (3) shrinkage in burning, (4) plasticity, (5) tensile strength of air-dried briquettes, (6) temperature of incipient fusion, (7) vitrification, (8) viscosity.

The localities from which samples that were tested came, are Jamestown, Angola, Hornellsville, Alfred Centre and Cairo.

Hamilton. The Hamilton is one of the great shale bearing formations of New York state. It is also widely distributed, extending from the Hudson river to lake Erie, and at these two points shows wide extremes in its lithologic character. In the east it is a true sandstone, in the west a clay shale. "The valleys of Seneca and Cayuga lakes are both excavated, for more than half their length, in the shales of this group." (Geology of the Fourth District of New York, p. 187.)

The Hamilton shales extend from Port Jervis northeastward along the edge of the Chemung area in a belt about five miles wide, and then swing westward from a point a few miles west of Albany, to Buffalo. In the central part of the state the Hamilton belt is about twenty miles wide, and thins to about twelve miles in the western half. The Finger-lakes are largely bounded on the north by the Hamilton shale area.

Along the banks of Seneca and Cayuga lakes the full section of the Hamilton group may be seen. The lower members are the most northern, and dip to the south under the higher ones. Professor Hall makes the following divisions:

1. Dark, slaty fossiliferous shale, resting on the Marcellus shale.

2. A compact, calcareous blue shale, of little thickness.

3. An olive or blue shale, which in its upper layers is stained by oxide of manganese. This is one of the best adapted for clay products.

4. Ludlowville shales, often sandy in their nature.

5. A limestone.

6. Moscow shales, of greyish blue color, and slightly calcareous in places.

These subdivisions can all be seen along the eastern shore of Cayuga lake from Springport to Ludlowville.

Cairo, Greene county. This is the only locality at which the Hamilton shale is mined. The material which is shipped to the works of the Catskill Shale Paving Brick Company at Catskill, is a reddish gritty clay possessing little plasticity. This material was at first used alone, but found difficult to work on account of its excessive leanness, and consequently is now mixed with fifty per cent. of common red clay also obtained from Cairo. Samples of this mixture were tested with the following results. The moderately plastic paste shrank four per cent. in drying, and nine per cent. in burning. Air dried briquettes had an average tensile strength of ninety-seven pounds per square inch, and a maximum of one hundred pounds per square inch.

Incipient fusion occurred at 1,900° F., vitrification at 2,050° and viscosity at 2,150° F.

The mixture of clay and shale is ground in dry-pans and then passes to the pug mill on the floor above, whence, after tempering, it is discharged to the auger side-cut machine. The bricks are repressed, dried in tunnels, and burned in down-draught kilns. The company has recently erected a large continuous kiln; in this kiln, most of the firing is done in temporary fire-places built in the doorways of the kiln, no grate bars being used; it is claimed that practically no fuel is charged through the small openings in the roof of the kiln.

Portage. (See Geology of the Fourth District of New York, p. 224). Another important shale occurs in this member of the Devonian formation. The group consists of a lower shaly member, the Cashaqua shale, a middle member of shales and sandstones, and an upper one of sandstones.

The Cashaqua shale is exposed along Cashaqua creek where it is a soft green shale that weathers to a tough clay. It also occurs along Seneca lake and at Penn Yan, but east of this becomes very sandy.

Good exposures are seen along Allen's creek and Tonawanda creek, and the branches of Seneca and Cayuga creeks. On lake Erie at Eighteen-mile creek it is thirty-three feet thick, while along the Genesee river it is 150 feet thick.

Concerning the Gardeau shales, Professor Hall states that they are exposed along the Genesee river where the section involves alternating layers of shales and sandstones. Toward the east the sandstones become more prominent, but to the west, the shales increase and predominate so that along lake Erie, "the Cashaqua shale is succeeded by a thick mass of black shale, and this again by alternations of green and black shales" which aggregate several hundred feet in thickness.

Angola, Erie county. The Portage shale is used by J. Lythe & Sons at this locality for the manufacture of sewer pipe, fire-proofing, drain-tile, and terra-cotta. The clay is somewhat less gritty than that at Jamestown. It is a greyish, moderately coarse grained shale and contains scattered streaks of bituminous matter.

When ground to thirty mesh it required 21.4 per cent. of water to make a workable paste, which was moderately plastic. This paste shrunk four per cent. in drying and an additional ten per cent. in burning. The air-dried briquettes had an average tensile strength of ninety-two pounds per square inch, and a maximum of ninety-five pounds per square inch. Incipient fusion occurs at 1,900° F., vitrification at 2,050° F., and viscosity at 2,200° F.

The analysis of the clay is as follows:*

Silica	65.15
Alumina	15.29
Ferric oxide	6.16
Lime	3.50
Magnesia	1.57
Alkalies	5.71
	97.38
Total fluxing impurities	16.94

In general composition it resembles a Carboniferous shale used for paving brick at Kansas City, Mo.† This shows the following analysis:

Silica	64.37
Alumina	19.73
Ferric oxide	9.07
Lime	.82
Magnesia	2.32
Alkalies	3.78
Total impurities	16.97

The principal output of these works is sewer pipe and fire-proofing. On account of its softness the shale is easily mined and transported in cars to the dry-pans, where it is first ground and then tempered in a wet-pan. The tempered material is then conveyed to the upper floors and discharged into the usual form of sewer pipe press. The glazing of the sewer pipe is done by means of salt.

Chemung. The most southern shale formations of New York state are included under this head. As a whole, the group consists of interbedded shales and sandstones, the former prominent towards the west, the latter becoming predominant to the east. The shales vary in color, and are black,

* Bulletin New York State Museum, III, No. 12, p. 228.

† Clay Worker, December, 1893.

olive or green. The shales sometimes pass into shaly sandstones, and these are often highly micaceous. The members of the group recognized by Professor Hall, beginning at the top, are:

6. Sandstone and conglomerate.
5. Old red sandstone.
4. Grey and olive shales and shaly sandstone.
3. Green shale with grey sandstones.
2. Black, slaty shale.
1. Olive, shaly sandstone.

Portage sandstone.

Of these members 2, 3 and 4 are the most important to clay workers, and the beds of shale exposed are often twenty or thirty feet in thickness and free from sandstone.

"On the Genesee river the shale is often in thick beds of a bright green color and scarcely interrupted by sandy layers."

"Westward from the Genesee river there appears to be a constant augmentation in the quantity of the green shale, which is often the predominating rock, though from weathering to an olive color it does not always appear as distinctly."

"In the ravines in Chautauqua county, extending toward lake Erie, the shale still retains its green color."

Jamestown, Chautauqua county. This sample of shale came from the bank of the Jamestown Shale Paving Brick Company.

This was a rather gritty shale, which required 18.5 per cent. of water to make a workable paste; plasticity, lean. The paste shrunk 4.5 per cent. in drying, and an additional 7.5 per cent. in burning, making a total shrinkage of twelve per cent. Air-dried briquettes made of this mud had an average tensile strength of sixteen pounds per square inch, and a maximum of twenty pounds per square inch. This low tensile strength was due to the siliceous character of the shale which, however, permitted rapid drying.

Incipient fusion occurred at 1,950° F., vitrification at 2,050° F., and viscosity at 2,200° F. The clay burns to a deep red and dense body.

Alfred Centre, Alleghany county. Chemung shale is used at this locality for the manufacture of roofing-tile. The shale is somewhat argillaceous, and moderately fine grained.

It requires twenty-two per cent. of water to make a workable paste which is slightly plastic. The shrinkage of this paste in drying is four per cent. and in burning, nine per cent. The tensile strength of air-dried briquettes was, on the average, sixty-one pounds per square inch, with a maximum of sixty-two pounds per square inch.

Incipient fusion occurs at 1,900° F., vitrification at 2,050° F. and viscosity at 2,150° F.

The composition of the shale according to an analysis furnished by the Celadon Terra Cotta Company, of Alfred Centre, is:

Silica,	53.20
Alumina,	23.25
Ferric oxide,	10.90
Lime,	1.01
Magnesia,	.62
Alkalies,	2.69
Sulphuric acid,	.41
Titanic acid,	.91
Water,	6.39
Manganese oxide,	.52
	99.90
Total fluxing impurities,	15.74

This shale corresponds very closely in composition to that used at Kansas city, Mo.,* for the manufacture of paving brick, but there is a considerable difference in the fusibility, the Missouri shale being very fine and consequently more fusible.

When this factory was first started, both terra-cotta and roofing-tile were produced, but now the Celadon Terra-Cotta Company confines itself entirely to the manufacture of vitrified roofing-tile, which is of a superior quality, and bears an excellent and wide-spread reputation. At first a mixture of clay and shale were used, but now the latter material alone is found sufficient; the shale after grinding and careful tempering is molded either by hand or steam-power machines, and then set aside to dry slowly. The tile is no longer burned in saggars as was formerly done, but is placed in pockets in the kiln. The shale burns to a tough, cherry-red body.

Hornellsville, Steuben county. The shale at this locality frequently contains interbedded layers of sandstone, which are separated in mining without much trouble. The shale is rather gritty, and on the addition of twenty per cent. of water gave a lean, workable paste, which shrunk 2.7

* Missouri Geological Survey, XI, p. 565.

per cent. in drying and 5.3 per cent. in burning. The tensile strength of the air-dried mud per square inch was on the average thirty-four pounds, with a maximum of thirty-nine pounds.

Incipient fusion occurs at 1,900° F., vitrification at 2,050° F., viscosity at 2,200° F.

The shale burns to a dark red. It is used in the manufacture of paving brick.

The composition of the clay, from an analysis furnished by the Hornellsville Brick Company, is as follows:

Silica	64.45
Alumina	17.77
Ferric oxide	7.04
Lime	.58
Magnesia	1.85
Potash	2.52
Soda	1.95
	96.16
Fluxes	13.94

The method of manufacture followed at these works consists of the usual dry-pan for grinding the shale and wet-pan for tempering it. The molding is done by stiff-mud, side-cut machine, and the green brick are repressed. The burning is in down-draught kilns.

From the tests cited above it will be seen that the shales used compare very favorably with the requirements of a paving-brick material. Most of them are slightly more siliceous than the average run of paving-brick clays, but this is no serious objection.

The lean character of many can be overcome by the addition of plastic clay, as in the case of the Cairo shale, in which instance the mixture, as already stated, had a tensile strength of one hundred pounds per square inch.

The amount of fluxes present permits of their vitrifying at comparatively low temperatures. But if necessary their refractoriness could be easily increased by the addition of a certain amount of fire-clay.

Most of the shale deposits are easily accessible and located in close proximity to railroads.

THE DISCOVERY OF A SESSILE CONULARIA.

COMMUNICATED FOR THE REPORT OF THE STATE GEOLOGIST

By R. RUEDEMANN.

The Discovery of a Sessile Conularia.*

By R. Ruedemann.

In collecting, in a layer of the lower Utica shale, problematic filiform fossils to which Professor J. M. Clarke had directed the writer's attention, a *Conularia* was found to which are attached several smaller cuneiform fossils by organs which at first sight appear like rings. A thorough search in the locality has furnished four more specimens of *Conularia* which bear such appendages; also a few impressions of shells of *Trochonema* to which were attached, in one case, a single individual of the supposed *Conularia* (Pl. II, fig. 1), and in another case many, but mostly poorly preserved, remains of *Conularia;* also the ever present *Diplograptus foliaceus*, Murch. sp., and the above-mentioned *problematicum*, which will be described later.

That the *Conulariæ*, their cuneiform appendages and the similar larger bodies attached to shells of *Trochonema* belong together, is a supposition for which this note is intended to submit the arguments.

The *Conulariæ* to which the supposed young are attached (Pl. I, fig. 1, in which the interior cast of the shell is partly seen), as well as those found without the young in the same layer, compare best with *Conularia gracilis*, Hall.† This form was described from the shaly upper part of the Trenton limestone near Middleville, N. Y., while the specimens of the writer's collection were found in the lowest Utica shale.

One specimen (Pl. II, fig. 5) has been figured on account of its remarkably well preserved ornamentation and the structure of the angular grooves. It expands more rapidly than the others, the average angle of which is only 12°. A specimen with a length of 14.3 cm. has an angle of 11°. The specimen illustrated rests on one edge. This, however, is not the common mode of compression in this species, for the great majority of specimens apparently show only two angular grooves and one face of the pyramid, because the whole shell has been compressed into the face on which it originally rested. According to Holm ‡ this mode of compression is found with *Conulariæ* of quadratic section, while those of rhombic or rhomboidal

* Two instalments of this paper, with three of the accompanying plates, have already been published in the *American Geologist;* Article I, in Vol. XVII, March 1896, pp. 158–165, and Article II, in Vol. XVIII, August, 1896, pp. 65–71. The observations heretofore unpublished begin with page 711 of the present article, and are illustrated by an additional plate.

† Pal. of New York, Vol I, p. 224, Plate LIX, figure 5, 1847.

‡ Sveriges Kambrisk-Siluriska Hyolithidæ och Conulariidæ; Sveriges Geol. Undersökning, Ser. C, No. 112.

section are compressed in the direction of the obtuse angles. The shell of *C. gracilis* Hall, which I have seen only strongly compressed, therefore probably had equal faces and a quadratic section.

The complete flattening of the specimens without breaking, as well as the common bending of the proximal parts of the shell (Pl. I, fig. 4), are indications of a slight flexibility of the shell. Hall's type also was "slightly bent or arcuate." This remarkable character of *C. gracilis* is causally connected with the extreme thinness of the walls already observed by Hall. As the observation of small wall fragments (Pl. I, fig. 6) and the abundance of smooth casts of *Conulariæ* indicate, the wall was very easily destructible. This may also account for the frequent absence of wall remains in the young *Conulariæ* while the edges are preserved. Plate I, figure 4, and Plate II, figure 5, well illustrate this breaking out or dissolving of the walls between the edges in even larger individuals.

The sculpture consists of "sharp, undulating, transverse striæ and scarcely conspicuous longitudinal ones." (Pl. II, figs. 5 and 6.) The finer longitudinal ribs alone, however, are continuous and the wavy cross-ribs connect with them. Although the latter sometimes unite to form continuous and very prominent cross bands, their whole appearance is such as to suggest that they are wrinkles of shrinkage. The undulating transverse and the finer straight longitudinal ribs are so characteristic a feature that they can safely be used to distinguish this form from *Conularia Trentonensis*, Hall, *C. Hudsoni*, Emmons, and *C. quadrata*, Walcott, which have straight and continuous transverse ribs. The undulating transverse ribs are of special importance in the study of the young *Conulariæ*, as they are easily recognized by their characteristic form whenever the surface film is sufficiently preserved, however delicate it sometimes may be.

The cast of the interior often shows, in different parts of the same specimen, either the filling of the transverse ribs as similar ridges, or pustules (cf. Pl. I, fig. 1) and deep furrows in place of the longitudinal ribs, or only the latter, or in many places the cast is perfectly smooth. The last fact is accounted for by specimens similar to that represented in Plate I, figure 4. This interesting young *Conularia*, which at the distal end shows the straight sulcate edges of a *Conularia*, has in the middle part preserved the wall which consists of two layers—an exterior deep black, apparently carbonaceous one, which shows the characteristic ribs of *C. gracilis*, and a much stronger inner layer which has a more greyish, mineral appearance and is probably richer in calcium phosphate. This second layer in the middle part between the two upper grooves, where it is apparently least crushed, is almost smooth, with only an obscure indication of transverse lines of fracture. On the sides it is broken into transverse ring segments. Although it is thicker than the outer layer, it is more frequently lost, leaving, however, a smooth cast.

The segmental line appears as a shallow groove, scarcely conspicuous in most specimens. It therefore is of no help in identifying the young *Conulariæ*. Of greater importance in this regard is the structure of the grooves at the edges of the pyramid, as this is generally the best preserved part of the fossil. In the specimens, for instance, represented in Plate I, figure 4, and Plate II, figure 5, the side walls of the grooves alone are preserved in the distal part, the connecting wall being either dissolved, as indicated by the smooth surface between the edges in Plate I, figure 4, or broken away as in Plate II, figure 5. The walls of the grooves are much thickened, this strengthening extending also to the adjoining parts of the faces, so that the grooves are lined by two thick ridges. The connection between fragile thin faces and stout edges seems to be found in other species also. *Conularia Linnarssoni*, Holm,* is described as having the grooves stronger than the segmental line and being fragile toward the aperture.

As the original of Plate II, figure 5, shows at the upper groove, and as has been observed in other species, the surface film extended—here with its wavy transverse wrinkles—over the groove, covering and closing it (Pl. II, fig. 2, *a*). Where the outer layer is lost, but the underlying parts are fully preserved, there appears next below a thin smooth layer (*b*) with indications of transverse lines of fracture; this layer in its turn covers a milky white laminated substance (phosphate of lime). The latter (*c*) fills the groove and contrasts strongly with the black shining walls (*d*). Often, however, this substance is lost, leaving the groove empty or giving place to a filling by iron oxides. The side walls of the empty groove show mostly very marked transverse fractures with upturned margins. The groove seen from the inside (Pl. II, Fig. 3) has a roof-like form with strongly slanting sides, which are either smooth or exhibit the same transverse joints as seen from the outside. Sometimes oblique pressure caused these joints to be pushed over each other. Where the top is broken off the white phosphate of lime appears again.

From these observations it may be stated that the edges of the pyramid of *Conularia gracilis*, Hall, formed a kind of supporting framework for the faces; that the grooves, therefore, had strong walls which were continuous

* *Op. cit.*, p. 130, Plate IV, figures 38-40

with the second mineral layer; that the grooves were filled with phosphate of lime and covered by the sculptured outer layer with an underlying thin film similar in appearance to the second layer. The groove, therefore, appears to be altogether an expansion of the second layer of the wall. A diagrammatic section of the groove at the angle of *C. gracilis* is given in Plate II, figure 4.

The reasons which the writer has for regarding the cuneiform appendages of *C. gracilis*, and the bodies attached to *Trochonema*, etc., as remains of young individuals of *C. gracilis* are as follows:

1. Wherever an appendage is preserved completely it shows four divergent grooves, such as would form the edges of a pyramid, with about the same angle as the older shells of *C. gracilis* (Pl. I, figs. 2, 3, Pl. II, fig. 1). Some apparently show only three grooves, but investigation will generally bring out the fact that the fourth is divergent from the plane of the others and hidden in the matrix. Generally, however, the whole fossil appears only as a cuneiform film between two thick edges, which are formed by two coinciding grooves, while the two originally vertical faces have been folded inward between the horizontal ones or partly bulge out from between them (Pl. I, fig. 1, *a*). Some appendages show even but one groove; the proximal parts of the other grooves, however, are also ordinarily traceable into the matrix (Pl. I, fig. 2). It is to be concluded from this that the complete appendages contained grooves which originally did not lie in one plane.

2. The four grooves show exactly the same structure and composition as those of *C. gracilis*, i. e., the V-shaped section, the filling with milk white phosphate of lime, the extension of the carbonaceous sculptured surface film over them, and especially the very characteristic and easily discerned transverse ridges of the side walls of the groove. (Cf. Pl. I, figs. 1, *b*, 2, 5; Pl. II, figs. 1, 7.)

3. The space between the grooves of the appendages is generally perfectly smooth, thus indicating that between them was a connecting wall which is now lost. However, in many places the tender carbonaceous surface film is still preserved. Where this is the case the longitudinal ribs, as well as the characteristic undulating transverse wrinkles, are clearly discernible, as indicated in Plate I, figures 1, 2, and Plate II, figures 1, 7, at *s*.

4. The carbonaceous cup-shaped bases, by which the supposed young *Conulariæ* are attached to the older individuals, are exactly similar to those of some larger fossils which can be safely referred to *C. gracilis*, and especially similar to the basal cups of the two important specimens repro-

duced in Plate I, figure 4, and Plate II, figure 1. The latter, which on account of its general form, the structure of the four grooves and the sculpture of the surface film, must be regarded as identical with, or very closely related to *C. gracilis*, has a beautifully preserved cup of the same size and structure as those attached to the original of Plate II, figure 2.

5. Finally, it may be adduced as an additional argument for the similarity of the observed appendages and the shell of a *Conularia*, that in some of the former (Cf. Pl. I, fig. 1, *e*) a triangular subcarbonaceous plate is preserved which is strongly suggestive of the flattened apertural process of the uppermost face.

It is permissible to meet some of the objections which are easily suggested in comparing the appendages with *Conularia*. There is first the strangely curved form of many of the smaller and medium sized individuals. As already stated, Hall's type, of about two inches in length, is "slightly arcuate." The axes of the older specimens, however, which the writer possesses, as also the axis of the specimen figured in Plate II, figure 5, are always perfectly straight. An examination of the shells of the young *Conularia* establishes the fact that the better they are preserved the straighter they are. (Cf. Pl. I, figs. 1, 2.) Even some of the very smallest *Conulariæ* are straight. This, as well as an examination of such specimens (Pl. I, fig. 4), in which the youngest part only is bent and the older is perfectly straight, leads to the conclusion that the young shells also of *C. gracilis* were straight, but probably more flexible than the more distal parts and perhaps less able to resist the dissolving influence of the sea water. A group of fossils (Pl. II, fig. 7) which are attached to the poorly preserved cast of a *Trochonema* shell, on account of the strong distortions of the wedge-shaped appendages presents appearances differing most widely from those of *Conularia*. In this case the appendages are identical with the leaves of Hall's *Sphenothallus angustifolius*.* The extensive destruction of the faces of the pyramids in both specimens, as well as the very poor preservation of the gastropod, is proof enough of the destructive influences to which they were subjected and which may also have distorted the slender pyramids before they were covered by sediment. On the other hand, both contain a sufficient number of nearly straight shells (cf. especially Hall's figure) to warrant the statement that the pyramids were originally straight. The writer's specimen

* Palaeontology of New York, Vol. I, p. 261, Plate LXVIII, figure 1, 1847. Hall's type, which Professor J. M. Clarke had the kindness to lend the writer and which is figured on Plate IV, not only shows young individuals attached to older "leaves," but also ring-like impressions of the basal cups and the transverse ridges of the grooves. The faces have left smooth impressions only

exhibits besides, in several places, well preserved transverse undulating cross-ribs which are very similar to those of *C. gracilis.*

Another objection, which naturally arises in studying these forms, is this; assuming that other *Conulariæ* were sessile also, why have not any such bases been found among the thousands of specimens of the species already described? Barrande had more than a thousand specimens of certain species without noticing such basal cups in the young, which are generally stouter and better preserved than any other part of the fossil.

In almost all described shells of *Conulariæ* the apex is broken off, either irregularly or along a septum. The irregularly broken shells, which compose by far the great majority, have undoubtedly lost their proximal parts and are therefore not complete and may be considered out of the discussion. Those closed by a septum are most probably not complete either, for as Dr. A. Ulrich* has pointed out, the empty chamber between the imperforate septa must have been more liable to destruction than the other sediment-filled part. It may, therefore, have been lost in most cases, and only that part of the shell beginning at the youngest septum may have been left to us. It remains in the extremely small number of fully preserved shells. Wiman,† on the basis of Holm's paper, estimates their number at less than 5.55 per cent. of all known *Conulariæ.* These few forms again, although tapering down to a very small diameter (the writer does not know of a real "point" having been observed), do not exclude the possibility of having been expanded again into a base. It is true that it does not seem very natural to have a large pyramid supported by such a thin stem, but this was, in fact, the case with rather large shells of *C. gracilis* (Pl. II, figs. 1, 7). Suppose all *Conulariæ* were attached thus, then it would have been just as strange if the pyramids, in becoming covered, had not been broken right over the bases, as it is that not more of the shells, if they were free, should have preserved the apex. It also bears on this question that several cups, among them one with a diameter of 5 mm., have been found which bear only a very small fragment of the pyramid (Pl. III, fig. 2), and that the specimen represented in Plate I, figure 1, bears a great number of bases from which the young *Conulariæ* are broken off. The preservation of the apex not only forbids any positive conclusion as to the mode of life of the *Conulariæ*, but the supposition of their free existence seems to be questionable and will, therefore, be discussed hereafter.

As none of the large specimens of *C. gracilis* have been found attached, the question as to mode of life can not be directly answered. It can, however,

* Palæozoische Versteinerungen aus Bolivien, p. 35, 1892

† Palæontologische Notizen 1 und 2, Bull. Geol. Inst. Univ. Upsala, Vol II, No. 3, p. 7, 1894.

be remarked that the largest specimen in the writer's collection (length 14.3 cm.) is preserved to a breadth of 4 mm. and ends in a deep impression which could be caused by a cup not larger than the largest well preserved one which has been found. Further, it will be noticed that some of the attached shells (Pl. IV, fig. 40; Pl. II, figs. 1, 7) have already reached a size which renders it improbable that the enclosed animals should still have changed their mode of life.

After having presented the general features of the occurrence of a sessile *Conularia*, the writer intends now to describe the most novel part of the fossil, *i. e.*, the basal appendage.

Though an attempt to isolate and decolor some of the appendages failed, partly on account of an obscure cleavage in the rock and partly on account of the consistency of the residuum after the treatment with acetic and hydrofluoric acids, the author succeeded at least in developing, by the application of the same agents, several of the stout chitinous appendages on the slabs (cf. Pl. III, figs. 5 and 16). The defects in the preparation of the material are atoned for by the well-preserved state of the material itself, for several of the bases are preserved in neat natural sections (cf. Pl. III, figs. 2 and 3), a comparative study of which, as well as of the varying aspects of the other bases, allows a fair insight into the structure of this interesting organ. In order to enable the reader to form for himself a picture by a comparison of the different states of preservation, the writer has given as many sketches as possible.

As already stated in the first article, most bases appear at first sight as stout subcircular to suboval chitinous rings* (cf. Pl. III, fig. 1, which is the base of the specimen reproduced on Pl. II, fig. 1). The original form was probably circular, as the elongated forms (cf. Pl. III, fig. 20) are generally found near the edge of the supporting fossil (cf. Pl. I, figs. 1 and 2), where they were more liable to become laterally compressed than those on the inner part of the fossil.

* These rings were observed by A. G. Nathorst as early as 1882 (cf. A. G. Nathorst, "Om förekomsten af *Sphenothallus* cfr. *angustifolius*, Hall, i silurisk skiffer i Vestergötland" in Geologiska Föreningens i Stockholm Förhandlingar, Vol. VI, p. 315, Pl. 15). The same author has published in the April (1896) number of the same journal (Vol. XVIII, No. 4), under the caption, "*Sphenothallus* en *Conularia*," a review of the study of this interesting fossil in Sweden, from which it appears that he, in describing, in the first cited paper, a specimen of *Sphenothallus*, Hall, from the Silurian shale in the neighborhood of Våmb in Westgothland, accepted Hall's interpretation of the fossil as an alga. Some years later, however, another specimen was sent to him by Dr. N. O. Holst, the state of preservation of which was such as to convince Nathorst at once of the impossibility of referring the fossil to the vegetable kingdom. He pointed out this fact to Holst, who afterwards sent the same specimen to J. Chr. Moberg for identification. The latter reached the same conclusion, as appears from an extract of a letter of his to Nathorst: "It seems to remind me somewhat of a *Conularia*, and above all it surely was not an alga." Nathorst himself now accepts the identification of *Sphenothallus* with *Conularia*. Hall's type is not so well preserved as to have been able to suggest a comparison with *Conularia*.

The dimensions of those rings which are found still attached to a *Conularia* are: Diameter from 1 to 2 mm. (original of fig. 1, Pl. III, measures 1.3 x .7 mm.; original of fig. 19, Pl. III, 1.75 x 2 mm.), though a few larger separate ones have been found (one measuring 4 mm.); height .3 mm. (taken from the originals of figs. 1, 2 and 3, Pl. III).

Externally the ring is perfectly smooth and shining (fig. 1), expanded more or less abruptly towards the base (cf. Pl. III, figs. 2, 3, 13, 18). Underneath it possesses a system of regular radial folds (cf. Pl. III, figs. 7, 8, 9, 13, 18). The true nature of the rings is revealed by a few vertical sections which were found on some slabs (cf. figs. 2 and 3). Figure 2, Plate III, is a reproduction of the whole fossil, which is interesting because it demonstrates not only the occurrence of basal appendages detached from the extraneous object, but also the common separation of the pyramid of *Conularia gracilis* from the appendage a little above the latter. As both sections are not quite median, part of the ring is seen from the inside. In both, the ring becomes attenuated toward the top (in fig. 2 abruptly), thus forming a skin which fastened the basal appendage to the pyramid. This skin formed a dome above the ring, as may be inferred from the laterally compressed specimen reproduced in fig. 9, at *a*; *b* is the basal ring, which on account of its bulging out a little more, adheres to the counter part of the fossil. The general form of the appendage may be compared to a bell, which term will be applied in this paper to the exterior chitinous wall of the organ under consideration, as the word does not imply any expression regarding the possible functions of the whole.

Figure 10, Plate III, reproduces a specimen (taken from the original to Pl. I, fig. 2), which gives a view of the inside of the dome of the bell and exhibits irregular radial wrinkles of the skin, caused probably by shrinkage prior to fossilization. In figure 12 a base is seen from above. Here the greater part of the ring is preserved, while the upper portion of the bell left only its impression.

As appears from figure 8, Plate III, which reproduces the view allowed by one of the appendages into the bell from beneath, the latter, or at least its thicker basal part, consisted of concentric layers.

The absence of any carbonaceous film at the base of the bell (cf. figs. 7, 8, 13, Pl. III) would lead to the conclusion that the bell was open there: but the smooth surface of the rock inside of the deeper impression of the ring (cf. fig. 9*d*) in several specimens indicates the former existence of a basal closing film. A very clear view of the latter is furnished by the basal appendage (cf. fig. 15) of the *Conularia* reproduced in figure 14, which apparently was attached to a little fragment of a *Stictoporella.* It appeared at first like figure 15; the dissolving of the enclosed rock, however, brought out the entire base of the organ, namely, the broad, deeply-impressed exterior ring (*a*), the impression of the somewhat wrinkled film (*b*) stretching towards the center of the base and connecting with an internal part (*c*) that appears as a narrower, radially furrowed impression of a ring. The latter can be seen very distinctly at the bottom of the basal appendage reproduced by figure 1. In the remarkable specimen belonging to figure 6, all chitinous parts have been removed by weathering except two stout rings, which strongly contrast with the buff-colored weathered shale, and which are evidently the bases of the bell and of an internal part of the appendage. The original of figure 5 (taken from the group Pl. II, fig. 7) exhibits also a stout, though now, through the action of the acids, somewhat corroded ring. Another reproduction (fig. 7, Pl. III) of the underside of a basal appendage shows the latter removed from the center, apparently by the overturning of the young *Conularia* to which it was firmly attached. It is partly preserved in the original of figure 9, Plate III, and it can be distinctly seen in the basal appendage reproduced in figure 13, Plate III (taken from the group Pl. I, fig. 5), where it stands out in relief, while its system of basal radial furrows can be seen in figure 18 at *b*.

The real form of this internal body is revealed by a fine vertical section through the basal appendage (fig. 3) of a detached *Conularia* (fig. 4, Pl. III). This section shows again a crescent-shaped cleft of a stout chitinous body, proceeding from the converging marginal grooves of the pyramid of *Conularia.* The horns of the crescent can be traced to the chitinous mass of the basal ring of the bell, the inside of which is visible in the section. The original of figure 5 assists in making evident that this crescent is the section of a chitinous cup-shaped body, which is fastened to the apex of the pyramid, while its base is continuous with the basal skin, extending to the exterior bell. The cup itself was not closed basally, as can be inferred from the little node in the center of the impressions of the basal appendages (cf. fig. 9*d*).

It remains to consider the connection of the pyramid of *Conularia* with the basal organ. As the sections figures 2 and 3 indicate, the angular grooves of the pyramid curved in at the basal end. The subquadrangular piece broken out of the dome of the bell in figure 10 suggests that the shell of *Conularia* yet retained its quadrangular section when entering the bell. The counterpart of this fossil (fig. 11) has preserved the broken-out chitinous piece and exhibits on the latter a cross of four ridges, consisting of pyrite. A similar aspect is presented by the node in the middle of the basal appendage of figure 17, Plate III, which is an enlargement of the base of the specimen reproduced on Plate I, figure 4, and which shows two arms and the intersections of the two others on top of the central node. The pyrite in both specimens points to the former existence of canals, or at least to an original difference between the material which has been replaced by pyrite and the enclosing chitine. There can hardly be any doubt that the cross of pyrite represents the basal junction of the marginal grooves of the pyramid, and that the little node in the center of the base (cf. figs. 11 and 17, Pl. III) is the real apex of the pyramid. The direct continuance of at least two grooves is exhibited by quite a number of remains, *e. g.*, by those reproduced in figures 18 and 19, while the original to figure 20 gives a neat section through the four grooves at the entrance of the pyramid into the bell. It is evident from the latter fossil that these grooves, as already demonstrated, were originally covered by a carbonaceous film and filled with phosphate of lime. The supposition is, therefore, not out of the way, that they may have been free from this filling towards their proximal ends and could therefore have been filled by pyrite during the process of fossilization.

The morphology of the whole appendage will be best understood from a diagrammatic section, as given in figure 21, Plate III. The apex of the pyramid (*d*) is enclosed in a stout central cup (*b*) which, in turn, is connected by a thin film (*c*) with the broad basal extension of the exterior bell (*a*). The latter again is fastened to the pyramid a little above the cup.

There can be no doubt that the basal appendage was an organ of attachment. It is further evident that the latter did not amount to a coalescence, but was of a temporary character only; for the not uncommon occurrence of detached specimens with well-preserved basal appendages (cf. figs. 2 and 4) is not consistent with the assumption of a coalescence. The apparatus, therefore, can not be compared to the basal disks, such as certain bryozoans have. On the other hand, it is indicated by the impressions left by the appendages* that their inner parts were flexible or even retractible, while the stout exterior bell, with its broad, radially striated base, apparently served to give stability to the mechanism and to close the interior tightly from the exterior.

An attempt to compare the basal appendages to suckers, such as various gastropods use for purposes of attachment, would lead to the further

* Cf. figs. 9 and 16, which show the ring-like impression (*c*) of the bell to be considerably deeper than that of the wrinkled basal film (*d*).

assumption that their interior was filled with muscular tissue, and consequently connected with the circulatory system of the living animal. The writer was unable to study this question on account of the negative results which followed his attempts to isolate the appendages; neither did he succeed in tracing the confluent canals, indicated by the cross of pyrite at the apex of the shell, which may have effected a connection with the interior of the pyramid and thereby have become instrumental in producing a vacuum by the withdrawal of a fluid, similar to that found in the pedicels of the echinoids. The writer, however, is inclined to suppose that there existed no connection whatever between the interiors of the pyramid and of the appendage, but that attachment was effected by the elasticity of the latter alone, especially by that of the central cup. The organ might then be compared to the chitinous suckers with which the males of certain water-beetles (*e. g.*, *Eunectes*) are provided, and which possess no muscular tissue whatever but adhere to foreign bodies by external pressure and by subsequently resuming the original shape through their own elasticity, thus producing a vacuum much like the India rubber plates which are used to fasten objects to the glass panes of show windows. The shape of the central cup as well as the fact that the appendage consists of a substance which certainly was elastic, could be adduced in favor of this supposition, while there seems to be no serious obstacle in the way of assuming that the animal, which no doubt had a certain power of free moving, had the further power of pressing the apex of the shell and with it the securely fastened cup to the body it wished to adhere to.

The diagrammatic section, figure 21, Plate III, is intended to illustrate the working of the apparatus, the dotted part representing the latter in the state of compression preparatory to attachment, and the striated part shows the same in the state of attachment by suction.

It should be remembered that however erroneous the attempt to explain the special operation of this organ may be, this does not affect the fact that the attachment was evidently only a temporary one and that the impressions left by the appendages show both the connecting film and the central cup bulging inward. These observations can, in the opinion of the writer, be only accounted for by the assumption that the basal appendage was an organ of attachment by suction.

The publication of the concluding part of this article on *Conularia gracilis*, Hall, has been much delayed because of a fortunate discovery, during the past summer (1896) of a locality on the bank of the East

Canada creek, which yields specimens of this *Conularia* not larger than .5 mm. in length, and which, therefore, enables the author to furnish some further details relating to the development of the shell of this interesting animal (cf. Pl. IV). The minute, oval, carbonaceous bodies cover some of the layers in astonishing multitudes.

While the great majority of the tiny fossils are found promiscuously scattered over the slabs, some of the latter, otherwise poor in such detached specimens, bear linear carbonaceous films, with outlines so straight and well defined as to make it improbable that the film should be the result of an accidental drifting together of shells. One of these bodies has been reproduced in figure 1, Plate IV, on account of the distinctness with which it shows its composition of young shells of *Conularia*. There are others of more regular outline, the most complete of which attains a length of 31 mm. and tapers regularly from a width of 5 mm. at one end to 4 mm. at the other. This film consists of minute shells of *Conularia*, which become especially distinct at both of its ends, where it is more or less lacerated. The shells observable in these films range in length from .5 mm. to 2 mm. A few specimens (cf. fig. 2) have been collected, which indicate that the shells were sometimes regularly arranged and attached to some central body, which, in the original of this figure, is not preserved. Whether these probably originally cylindrical aggregates of spawn of *Conularia* are brought about by the crowded fixation of young individuals around extraneous bodies, as *e. g.*, fragments of seaweed, which are not preserved, or whether it is a case of brood-protection, has not been ascertained with the material thus far collected.

There can, however, be no doubt that the animals, in the infantile condition which comes under observation here, were already seeking attachment to other bodies, in spite of their usual irregularly scattered occurrence on the slabs, which might suggest a swimming habit. This is clearly shown in very youthful stages found attached to little cones (probably belonging to a *Monticulipora*), which project from the slabs (cf. fig. 3), and above all by the possession of the organ of fixation, namely, the basal appendage.

There have been no shells found which did not reach a length of .5 mm., while fossils between .5 mm. and 1 mm. are quite common. This smallest stage obtainable (cf. figs. 4 to 7, Pl. IV), is characterized by the presence, and relatively large size of the basal cup, which attains half the size of the entire shell; by the apparent greater breadth and by the curved outline of the living chamber, which often approaches a circular shape.

The distal margin of the shells is composed of small denticles which develop into the apertural processes of the adult stage. In all the broader specimens there terminate, between these denticles, longitudinal lines, which are of darker color than the other film and which divide the latter in sections of equal size (cf. figs. 5, 7, 10, Pl. IV). They are, as shown by their position, the first indications of the marginal grooves observable in this early stage. The appearance of several of these denticles and grooves on the broader specimens indicates that the apparent great breadth of the youngest stage is largely due to a complete flattening. This explains also why a few specimens have been found the marginal angle of which is not much larger than that of adult forms (cf. figs. 8 and 9).

Such abruptly broadened shells as that reproduced in figure 6 are a common occurrence. It is obvious that in this case the shell burst at this point and became subsequently more distally unfolded.

Even larger shells, though by far not so common as those of the smallest stage, were subjected to bursting and spreading in one plane. Figures 17, 18, 25, 28 and 31, Plate IV, are taken from such specimens. The crushing sometimes led even to a separation of the faces, as in the original of figure 11. The infrequent observation of adult specimens of *Conularia* which are complete, in comparison to the profuse occurrence of fragments of faces, may be largely due to such separation of the faces before becoming covered by sediment.

A remarkable feature of many of these minute shells is the darker appearance of the basal appendage when compared with the living chamber. Shells where this difference is especially noticeable are reproduced in figures 5 and 7. This difference can, no doubt, be accounted for by the different thicknesses of the chitinous walls, and this is also indicated by the less compressed condition of the basal appendages in more advanced stages (cf. Pl. IV, figs. 12, 13, 14, 18, 22, and especially Pl. I, figs. 2 and 5; Pl. II, fig. 1).

Increasing in length, the shell generally becomes more slender in shape (cf. Pl. IV, figs. 13 to 32), though specimens with oval outlines are by no means rare (cf. figs. 17, 21, 29). In looking over the slabs with the naked eye, it will even seem as if all the tiny fossils consisted of carbonaceous oval bodies with a disc or ring at one end. The glass, however, will in the majority of the specimens reveal straight margins (cf. fig. 26) and a truncated (cf. fig. 21) or acute (cf. fig. 30) distal end.

The relatively large size of the basal appendage in the smallest forms has already been mentioned. Though in these smallest specimens the details of the basal cup could be discerned only in exceptional cases (cf. fig. 12), it at once becomes apparent in somewhat larger specimens that the appendage differed only in size from the organ previously described. Figures 11 to 34 illustrate sufficiently the various aspects, and also the somewhat differing size which the appendages show according to their state of preservation and the direction and amount of their compression. The specimens which exhibit the underside of the base (cf. Pl. IV, figs. 12, 13, 21, 22) show plainly its radiated surface. Others give lateral views of the appendage (cf. figs. 4, 9, 10, 11, 18, 19, 23, 24, 26, 27, 28). Of these the original of figure 10 is especially interesting. This has apparently preserved the protruding interior cup; that of figure 18 plainly shows the ring-like thickening of the basal part of the exterior cup. Some specimens even present sections of the base (cf. figs. 8, 16, 17, 32, 33), while the majority of the appendages, which appear as solid, smooth discs (cf. figs. 5, 7, 29, 30) evidently expose the upper side to view.

While most specimens terminate in triangular outlines, undoubtedly formed by the apertural processes in an expanded state, numerous shells present at first sight a somewhat puzzling aspect by the appearance of a well defined, often darker, and somewhat projecting square plate or of a corresponding impression, at the distal end (cf. Pl. IV, figs. 13, 19 to 22, 32). As in several specimens the composition of this plate of four triangular pieces could be observed (cf. figs. 19, 21, 22), it may be safely inferred that, by an obliquely lateral compression, the summit aspect of the fossil has been preserved and all four apertural processes are visible. A complication of this aspect is often caused by the appearance of a central circular impression which is surrounded by one or more concentric ridges (cf. fig. 20). The writer is disposed to regard the latter as parts of the internal shell-wall which have been pressed through the apertural plates. This assumption presupposes that the interior section of the shell was not quadratic but circular, a supposition which seems to be supported by the occurrence of examples which show a well defined circular spot in the center free from carbonaceous matter (cf. fig. 23).

Indications of a surface sculpture are extremely rare in the great majority of infantile specimens. All that can be seen in the smallest specimens is, now and then, a series of distant transverse furrows (cf. Pl. IV, figs. 6, 14, 24, 25), which would seem to belong to a deeper, transversely fractured layer, such as has been observed in the original of Plate III, figure 4. The original of figure 26, Plate IV, shows a fine longitudinal striation and that of figure 27 exhibits at the distal end distinct longitudinal ridges and slight indications of transverse ridges which suggest a comparison with the surface sculpture of the adult *Conularia*. As these few indications of surface sculpture in the smallest stages are, however, in contrast to the generally smooth appearance of the fossils, they can hardly be regarded as reliable evidence of the existence of a sculpture in this smallest stage, and may be only secondary corrugations. There has, however, been found a specimen, 4 mm. long, which is excellently preserved and which exhibits a system of distinct intersecting longitudinal and transverse ribs (cf. Pl. IV, fig. 35). The sculpture of this fossil differs from that of an adult individual in the appearance of the transverse ribs which are not undulating but straight, and which, towards the base, become more prominent than the longitudinal ones. The same specimen possesses a peculiarity in its four deep transverse furrows. Whether the latter originate from more closely arranged transverse ribs and retarded growth or from the former presence of septa which are broken out, remains doubtful because of lack of corroborating observations.

Adolescent stages ranging in size between the last described and the adult stage, have been described and figured on Plate I. figures 1, 2, 3, 5. They show the sessile mode of life of these stages, the structure of the basal cup, the presence of the surface sculpture which is characteristic of *Conularia gracilis*, and the peculiar transverse ridges of the side walls of the marginal grooves.

All the forms described so far are flattened, often into a mere carbonaceous film and can not be regarded as giving conclusive evidence as to the transverse section and actual general aspect of the infantile shell. This defect in the material has been filled by a single fortunate discovery of a small slab bearing eight young *Conularias* which are either not at all or but slightly compressed. Two of the latter (cf. Pl. IV, figs. 37 and 38) were attached to a shell of *Endoceras*. Most of these shells, as well as the impressions of some which are broken out, are perfectly round (cf. figs. 36 and 38) and remarkably strong. The position of the marginal groove is indicated by a narrow furrow. They are perfectly smooth, but as indicated by one specimen, a sculptured superficial layer existed originally around the thicker interior shell. Figure 37 is taken from a specimen which suffered a slight crushing; as a consequence, the median part is sunken in and the stronger marginal grooves appear as a projecting frame, giving also to this form the appearance of a compressed pyramid. While this specimen explains why even very young shells may appear as pyramids, it is shown by the uncompressed specimens that the original section of the youngest stage was circular. The writer already has had occasion to observe the round section of the basal part of larger specimens before this material was found (see Pl. I, figs. 3 and 4), and the concentric furrows on the apertures of flattened specimens, which were mentioned above (cf. Pl. IV, fig. 20), point to the same fact.

It may be concluded from these observations that the young shell of *Conularia gracilis* consisted not only of the thin sculptured surface layer but also of a thicker carbonaceous interior layer. The interior surface of the living chamber, formed by this latter, was smooth. This can be seen wherever the cast only of the shell is preserved, as for instance in the original of figure 40, at *b*. The cast consists of four smooth faces extended between the marginal grooves.

The uncompressed specimens show further that the young shells were, in fact, much more slender than the compressed fossils would suggest. They often approached at the basal end more to a cylindrical than a conical shape, an observation which is illustrated in the above mentioned figures of Plate I (figs. 3 and 4). The latter figure also shows well the gradual change of the cylindrical young shell into the pyramidal form by the marginal grooves becoming more prominent. There is no doubt that the marginal grooves were present in the incipient shell, for this is proved by the originals of figures 5, 7, 10, etc. (Pl. IV), but they were only part of the superficial layer, as shown by the specimens belonging to figures 36 and 38, and became important only in the thinner later part of the shell.

The writer has added to these illustrations that of a fragment of a shell which plainly shows a convex segment at the apex (cf. fig. 39). It naturally can not be decided from a single specimen* whether this shell accidentally broke at the segment or whether we see the result of a discarding of the basal appendage by the adolescent animal. It is worth mentioning in regard to the latter possibility that the writer made only one other observation which might indicate the existence of septa in *Conularia gracilis*, namely the above mentioned constrictions of the original of figure 35, Plate IV.

Finally, a reproduction of the type of *Sphenothallus angustifolius*, Hall, has been added in figure 40, in order to indicate the traces of basal appendages, which are perceptible, as well as two young shells attached to a larger one at *a*. A part which is of interest in regard to the conception of the shape of *Conularia* is marked *b*. The upper face of the pyramid is here broken away, whereby the crushed lateral faces and the opposite lower face are laid open. The section of the cast is broadly rectangular.

* The apex of the original of Plate II, figure 5, is not distinct enough to be of account.

The general conclusions which can be inferred from the preceding observations are the following:

1. The smallest shells are often found aggregated in grape-like bunches and are already attached.

2. The youngest observable stage consists of basal appendage and living chamber.

3. The basal appendage reaches about half the size of the living chamber and is stouter and more resistible than the latter. The relative size and strength of the two parts suggests, not only the question after their relative age, but also the possibility that the basal appendage was the preceding one of the two. Though this problem can only be solved conclusively by the finding of still younger shells, it may be permissible to point out some facts which would seem to support the supposition of the earlier appearance of the basal appendage. Its relatively great size and thickness in the youngest stage have already been mentioned. But it is soon outgrown by the living chamber, for while it begins with a length of .3 mm. (cf. Pl. IV, fig. 4), it reaches only 4 mm. in the largest cup observed, which was found in a detached state, and none were found in connection with the shell broader than 2 mm. The living chamber, on the other hand, grew from a length of .3 mm. to one of 14 cm. and perhaps still more. As it is obvious that the basal appendage began relatively large but did in no way keep up in growth with the living chamber, it is probable that it was an organ of importance only in the youth of *Conularia gracilis*. Moreover, as it appears to be in the later stages so strangely out of proportion to the size and supposed weight of the animal and as it is absent in all known adults of the various forms of *Conularia*, it may have been dropped entirely at adult age. Perhaps it was the first hard tegument appearing on the embryo, and the suggestion of A. E. Verrill* that the appendage is "the initial secretion of the shell gland of the veliger-like young" seems to be not inappropriate. It should, however, be remembered that the appendage also grows and does not remain stationary as do the embryonic chambers of the *Cephalopods*, to which one might feel inclined to compare it.

As the general trend of development is from sessile to slowly moving and from these to faster moving animals, it seems reasonable to regard the presence of the appendage in youth as a true palingenetic character indicating the derivation of *Conularia* from sessile forms.

*American Journal of Science, Vol. II, July, 1896, p. 80.

4. It becomes further evident from the study of the minute shells that the latter were round and that the marginal grooves were only part of a superficial layer. The fact that such multitudes of the youngest shells could be so well preserved while the more advanced stages become rarer in proportion to their size, as well as the excellent state of preservation of the former, can not but suggest that the shells were relatively much stronger in the younger stages than in the later ones. On the other hand, a comparison between the young and old forms impresses upon the observer the greater relative stoutness of the marginal grooves in the latter. They are for the most part hardly noticeable in the infantile stage, and when the specimens are flattened they have often no effect upon the outline which is then curved (cf. Pl. IV, figs. 5, 10, 14, 17, 18, 21, 28, 32). It can, therefore, be said that while the younger stages of growth had stouter walls and less prominent marginal grooves, with advancing age the walls of the faces became relatively thinner and the walls of the marginal grooves stronger. This gives the impression that there had been a tendency to make the shell lighter and at the same time to preserve its strength; a tendency which would be only of advantage in changing a sessile mode of life either to a creeping or swimming one. Thus it seems that the well-known fact of the thinness of the shells of most species of *Conularia* which suggest a swimming mode of life, and the observation of the attachment of the rather stout shells of our species in its infantile and adolescent stages, can be made to harmonize by assuming that *Conularia* represents a group of animals which were in the process of adapting themselves from a sessile to an errant mode of life. It is probable that in most forms, especially those of the Devonian and Carboniferous ages, the ontogenetic course of development was materially shortened; hence the absence of such developmental stages as *Conularia gracilis* has furnished.

It has already been shown by the structure of the basal appendage and the mode of occurrence of the growth stages possessing it, that these youthful forms were also capable of some change in place of attachment.

The slight development of the surface sculpture in the young shells and the preponderance of the transverse ribs over the longitudinal ones in some of the best specimens (cf. Pl. IV, figs. 32 and 35) are perhaps also characters of some phylogenetic significance.

Granted, then, that the described features of the young of *Conularia gracilis* are of a palingenetic character, it would follow that this *Conularia* took its origin from animals with slender, conical, little sculptured, chitinous shells, which were attached by basal, cup-like appendages.

The marginal grooves and pyramidal shape would appear to be of secondary acquisition.

Bearing in mind these supposed characters of the ancestors of *Conularia*, the suggestion of A. E. Verrill in the above-mentioned paper that *Conularia* represents a very primitive genus belonging to the *Cephalopods* appears quite reasonable. The *Pteropods*, to which *Conularia* has been so long referred, are claimed by zoölogists to be a very late class, while the *Cephalopods* are recognized among the fossils of the Cambrian and were, probably, at the beginning only sluggish or even sessile animals which acquired the power of fast motion later. The chitinous material of the shell of *Conularia* seems to the writer to be no ground for objection, for there still exists to-day a group of *Cephalopods* with chitinous shells, viz.: the *Chondrophora* of P. Fischer. Further, the suggestion made in regard to other classes of shell-bearing animals, that chitine was probably the original shell-material which has been replaced later by other materials, probably holds also true for the *Cephalopods*. There are a few observations which point to this supposition. Hyatt* and Holm† observe that the protoconch of *Endoceras* (*Nanno*) *belemnitiforme* and of other *Nautiloidea* is represented by a cicatrix only and hence was fragile and easily destructible. Hyatt concludes from this observation that the protoconch of some Nautiloids was chitinous; others, as shown by Clarke,‡ possessed already a calcified protoconch.

The occurrence of septa in certain species of *Conularia*,§ though of no great significance, indicates at least, that the animal advanced in the shell. The *Cephalopods* did the same, but in a manner which proves their higher development also in this regard.

If the genus *Conularia* indeed represents a group of transitional forms, it would seem appropriate to recall the fact that progress from slower to faster swimming was attained among certain *Cephalopods* (the *Belemnites*) by reducing and enclosing the shell, and to consider the possibility that the *Conularia* did not become extinct, but taking part in the general progress of the class, developed into *Cephalopods* with an internal shell and became thus less liable to be preserved in a fossilized state.

Referring to this possibility, it should be borne in mind that the above-mentioned *Chondrophora*, which are characterized by a chitinous gladius, have not yet been linked phylogenetically to any group of the fossil *Cephalopods*.

* Genesis of the Arietidae, 1889.

† Geologisk Förenings Förhandlinger, Vol. XVII, 1895.

‡ American Geologist, Vol. XIV, October, 1894, p. 205, pl VI.

§ As many as three septa have been observed in the same specimen (cf. A. Ulrich, Palæozoische Versteinerungen aus Bolivien, 1892, p. 32.)

while they appear at the same time (Lias), when *Conularia* makes its last appearance in a single species,* after it had furnished only one other specimen in the Trias.†

* *Conularia cancellata*, Argéliez, Middle Lias of the Dep. Aveyron. Bull. Soc Géol. France, 2 sér, Tome XIII, 1856, p. 187.
† *Conularia triadica*, Bittner. Hohe Wand bei Wiener Neustadt. Verhandlungen der K. K. Reichsanstalt, 1878, p. 281, 1890. p. 177.

EXPLANATION OF PLATES.

Plate I.

Figure 1. *Conularia gracilis*, Hall, Utica slate, Dolgeville, N. Y., with attached young. *a*, wall pressed out; *b*, transverse striation of groove; *c*, apertural process of wall; *s*, sculpture of surface discernible. × 2.

Figure 2. *C. gracilis*, with attached young. *s*, fragments of sculptured wall. × 2.

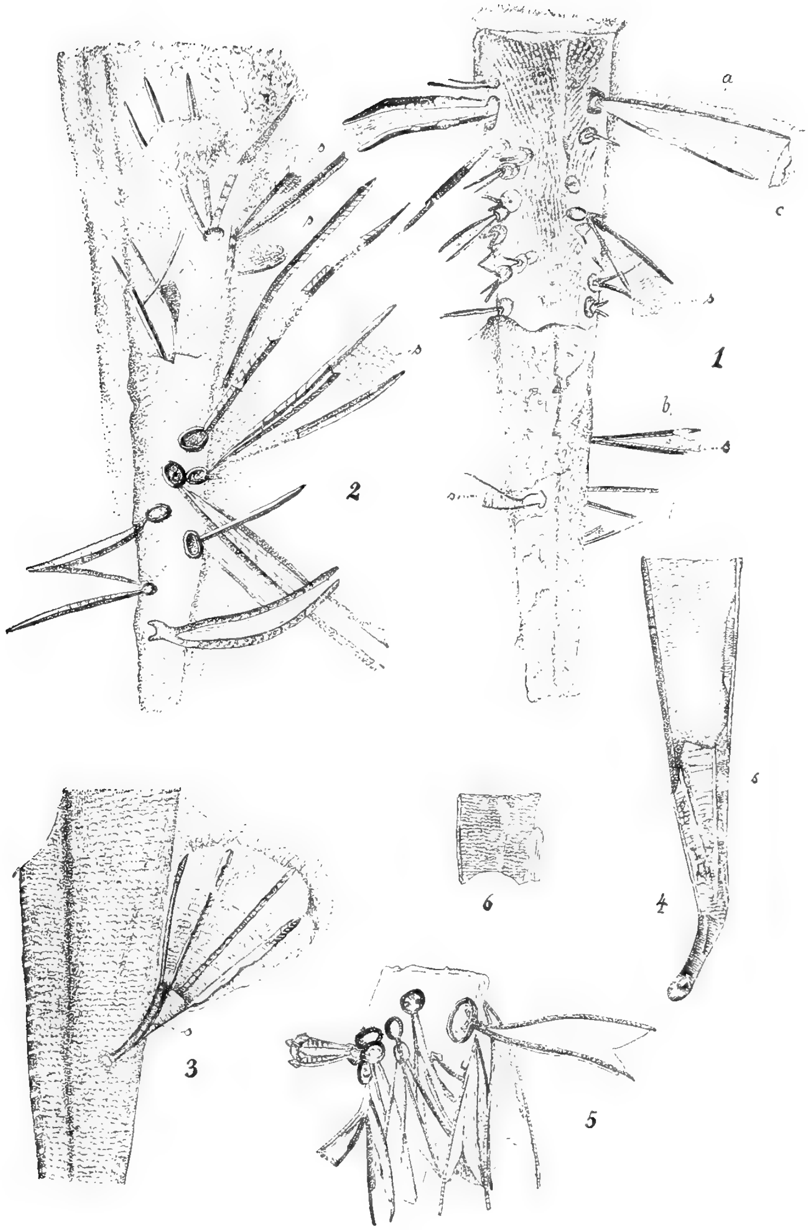
Figure 3. Young *C. gracilis*, with four distinct edges, attached to an older shell. × 2.

Figure 4. Detached specimen of *C. gracilis*. *s*, surface film. × 2.

Figure 5. Group of very young specimens of *Conularia* cf. *gracilis*, Hall, attached to a shell fragment. × 2.

Figure 6. *C. gracilis*. Fragment of the wall. × 2.

PLATE I



CONULARIA.

Plate II.

Figure 1. *C. gracilis* on *Trochonema* cf. *ammonius*, Hall. Natural size.

Figure 2. Sulcus at the edge of *C. gracilis*, exterior view. *a*, surface film; *b*, second film *c*, filling prism; *d*, side walls of groove. × 4.

Figure 3. The same, interior view. × 4.

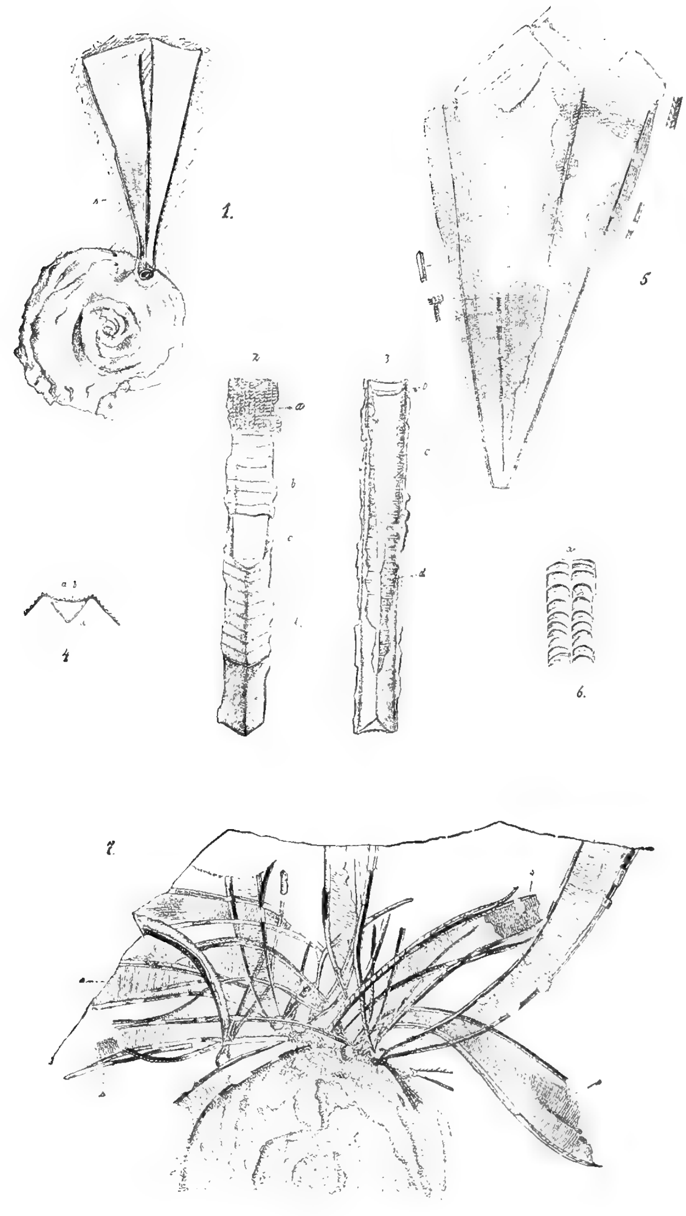
Figure 4. The same, transverse section. × 4.

Figure 5. *C. gracilis*. Natural size.

Figure 6. Enlarged sculpture. × 13.

Figure 7. *Conularia* cf. *gracilis*, Hall, (*Sphenothallus angustifolius*, Hall). *s*, sculpture of surface discernible. Natural size.

PLATE II



CONULARIA.

Plate III.

Conularia gracilis, Hall. Utica slate, Dolgeville, N. Y.

Figure 1. Dorsal view of basal appendage. Enlargement of the appendage of the specimen reproduced in Plate II, Figure 1. $\times 10$.

Figure 2. Vertical section through appendage. Whole specimen as found. $\times 10$.

Figure 3. Nearly vertical section. *a*, basal ring of exterior bell, seen from inside; *b*, dorsal part of bell; *c*, interior cup. $\times 10$.

Figure 4. Detached specimen of *Conularia gracilis*, bearing the appendage reproduced by Figure 3. Natural size.

Figure 5. Underside of appendage. *a*, base of exterior bell; *b*, base of interior cup. $\times 10$.

Figure 6. Ventral view of appendage, only the bases of exterior bell (*a*) and interior cup (*b*) being preserved. $\times 10$.

Figure 7. Ventral view of appendage. *a*, base of exterior bell; *b*, base of interior cup. $\times 10$.

Figure 8. Ventral view of appendage, showing the radial furrows of the base of the exterior bell and the concentric structure of the latter. $\times 10$.

Figure 9. Lateral view of basal appendage. *a*, dome of bell; *b*, basal ring of bell; *c*, impression of base of bell; *d*, impression of basal skin; *e*, node in centre, cast of central cup. $\times 10$.

Figure 10. Interior view of bell from ventral side, shows wrinkled dome of bell and subquadrangular entrance of pyramid of *Conularia*. $\times 10$.

Figure 11. Counterpart of the preceding. Shows the apex of the pyramid. $\times 10$.

Figure 12. Dorsal view of appendage. Dome of bell broken away. $\times 10$.

Figure 13. Ventral view of appendage. Shows radial striation of base of bell. $\times 10$.

Figure 14. *Conularia gracilis*, Hall, attached to a fragment of *Stictoporella*. Natural size.

Figure 15. The same. Basal appendage as found originally. $\times 8$.

Figure 16. The same. Matrix removed by acetic and hydrofluoric acids. *a*, interior bell; *b*, impression of connecting basal skin; *c*, impression of central cup. $\times 8$.

Figure 17. Ventral view of appendage. Exterior bell seen in section. Exhibits apex of pyramid. $\times 6$.

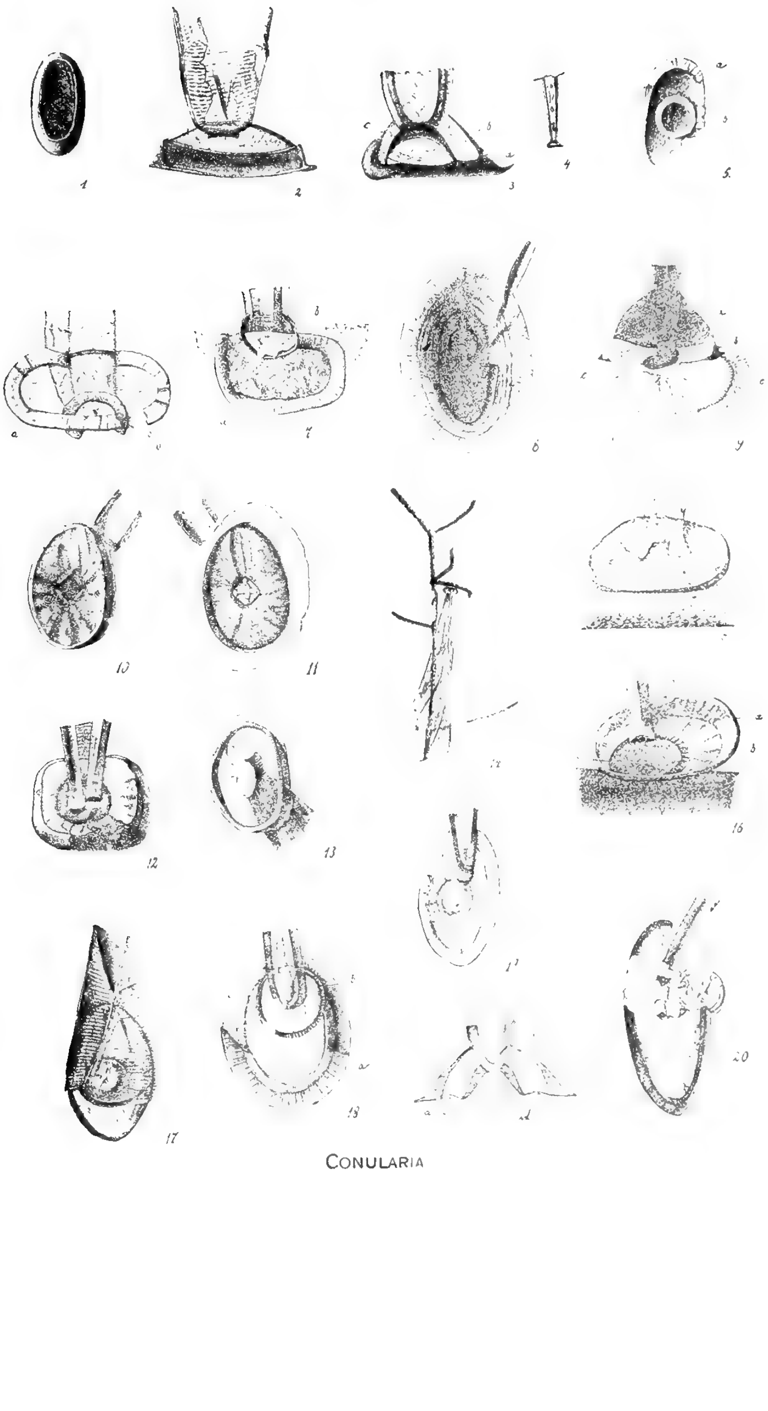
Figure 18. Ventral view of appendage. *a*, base of bell; *b*, base of central cup. $\times 10$.

Figure 19. Impression of basal appendage. Junction of two marginal grooves of pyramid preserved. $\times 10$.

Figure 20. Transversal section through appendage. Shows the four marginal grooves of the shell of *Conularia* in section. $\times 10$.

Figure 21. Diagrammatic section through basal appendage. The dotted part is a section through the basal appendage in the state of compression, the striated through the same in the state of attachment. $\times 10$.

PLATE III



CONULARIA

PLATE IV.

Conularia gracilis, Hall, Utica slate, Dolgeville, N. Y.

FIGURE 1. Group of young. Natural size.

FIGURE 2. Group of young. Natural size.

FIGURE 3. Young attached to a small projection. Natural size.

FIGURES 4 to 35. Various growth stages. × 4.

FIGURE 36. Uncompressed specimen. × 4.

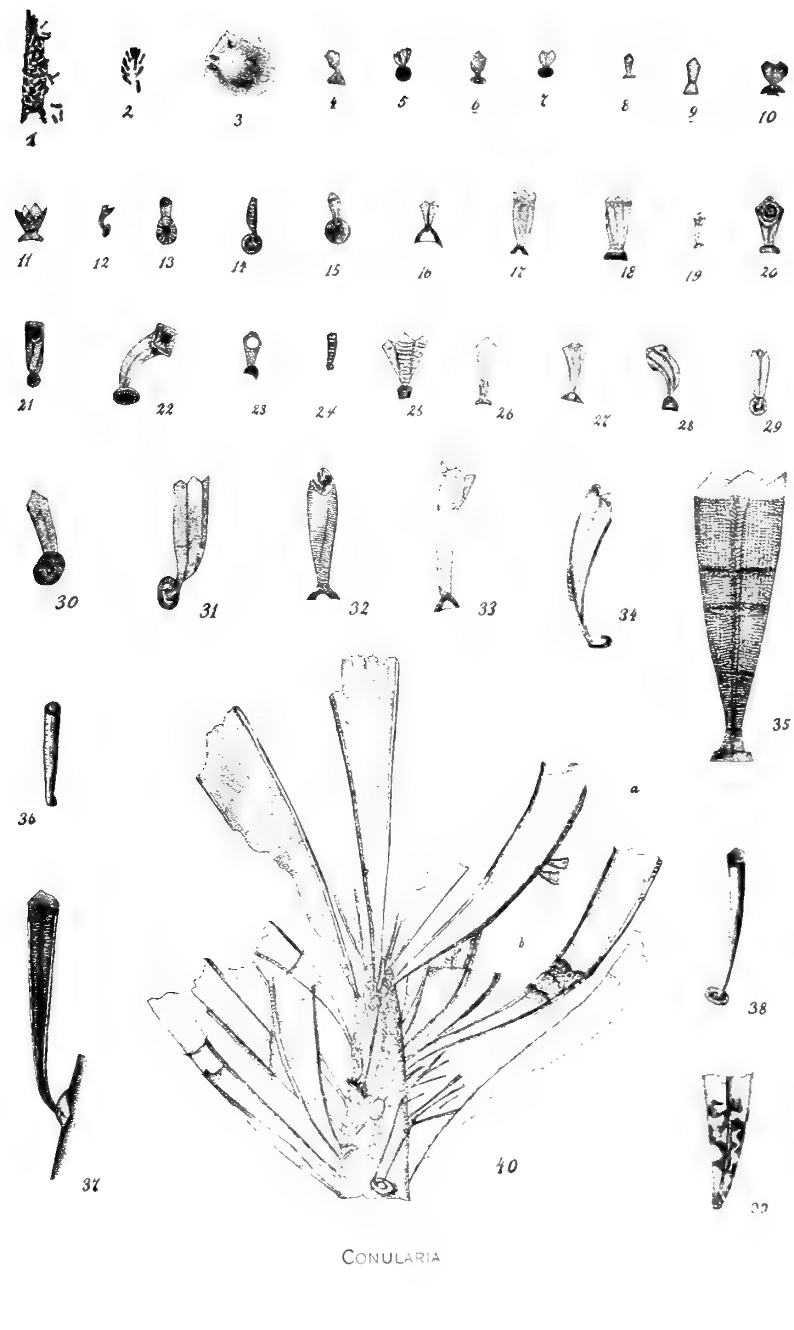
FIGURE 37. Slightly compressed specimen. × 4.

FIGURE 38. Uncompressed specimen. × 4.

FIGURE 39. Specimen terminated by septum. Natural size.

FIGURE 40. Type of *Sphenothallus angustifolius*, Hall, Canajoharie, N. Y. Natural size. *a*, young specimens attached; *b*, natural section, showing the composition of the pyramid of four faces.

PLATE IV



CONULARIA

NOTES ON SOME CRUSTACEANS FROM THE CHEMUNG GROUP OF NEW YORK.

By JOHN M. CLARKE.

Notes on Some Crustaceans from the Chemung Group of New York.

By John M. Clarke.

I. A Singularly Ornamented Phyllocarid Genus, Pephricaris.

By the courtesy of Professor A. R. Crandall, of Alfred university, Alfred, N. Y., and the kindness of Mr. Charles Butts, of the same place, I have been permitted to study specimens of a new crustacean allied to *Echinocaris*, but noteworthy for the extravagant nature of its armature. Of these specimens, two in number, the more complete belongs to the museum of Alfred university and is a sculpture-cast of essentially the entire test, the valves of the carapace being expanded without distortion and the abdominal segments showing, in part, in the posterior hiatus of the carapace valves and thence normally protruding behind. The second specimen, the property of Mr. Butts, is only the echinate margin of one carapace valve.

The general aspect of the carapace is not unlike that of some species of *Echinocaris*, yet it is devoid of the curved sigmoid carina which characterizes typical species of that genus.

The carapace valves are broad, their margins curving rapidly outward for about one-half of their length, slowly recurving near the middle and thence more rapidly receding to the posterior extremity. The expanded valves lie with a moderately broad anterior or rostral cleft, but there is no evidence of a separate rostral plate. They are in contact just back of the apex of this cleft, but for only a short distance, as the underlying abdominal segments are partly exposed, a fact which may be due either to this being the normal attitude of the valves, or to casual separation of them, or again to a breaking of the edges of the cast which is not altogether clear at this place. The surface of each valve is divided into two convexities by an oblique depression beginning at the dorsal edge just back of the middle and extending backward with gentle obliquity. This groove does not reach the margin

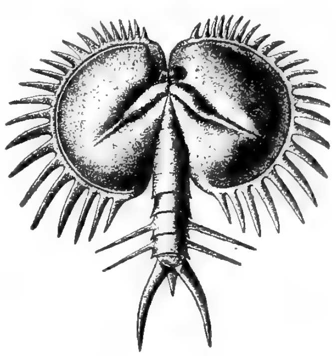


Figure 1.
Pephricaris horripilata, Chemung sandstone, Alfred, N. Y.

of the valve. The anterior convexity is much the larger. Usually, in *Echinocaris*, there is a number of paired nodes and tubercles grouped about the cephalic extremity of the carapace, but in this fossil there is only a single pair, represented by two deep pits situated close upon the hinge and at the apex of the rostral cleft. It is possible that these are remains of ocular nodes, but their depth suggests the probability of their having been basal attachments of the larger legs. Behind these nodes begins an oblique and strong ridge, thickest and most elevated at the hinge, where the anterior edges of the ridges on the two valves meet. This ridge departs backward into the median groove, passes down its anterior slope, then, with a slight change of angle, along the groove and rises slightly on its opposite slope, terminating with the groove itself. The margin of the carapace is somewhat thickened and elevated.

Nowhere in *Echinocaris* do we find a carapace structure like this, even among the species of the Chemung group. The lateral curved carina is one of the constant characters of the genus and may even be duplicate in later species. The median sinus exists there, normally, only as a depression between nodes, and no species is so free of cephalic nodes as this.

As to the abdominal segments, we find that three and a portion of a fourth, protrude beyond the carapace; between the carapace-valves we make out traces of two or three others, estimating the entire number at seven. The posterior segments are unusually short and have short spinules at their post-lateral extremities; there may, also, have been such spinules elsewhere along the posterior edge as in *Echinocaris*, but such are not seen. The caudal plate is short and triangular, with a short telson and two long curved cercopods.

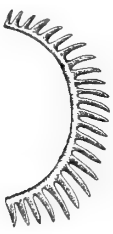


FIGURE 2.
Pephricaris horripilata, margin of left valve.

The fossil bears a striking ornamentation or armature. The entire outer margins of the carapace valves carry a single row of broad, strong, erect and slightly recurving spines. These are shortest at their commencement on the anterior margin, gradually increase in size posteriorly, their greatest length being reached on the post-lateral curve, and thence to the posterior angle of the carapace they become shorter. The maximum length attained by these spines is not less than one-half of the greatest diameter of a carapace valve. That these processes are spinous extensions of the chitinous test substance, and not bundles of setæ, or of other nature, is shown by the aspect of the imprints they have left in the matrix, these being sharply defined and clean-edged throughout their extent; and again by the presence of similar but straighter and more slender spines upon the final segment of the abdomen. Of the latter, two pairs are visible, the penultimate pairs appearing to be somewhat longer than the ultimate; there are traces also of a similar pair on the antepenultimate segment.

This description presents all the known characters of this peculiar crustacean. Its essential structure is nearest to *Echinocaris* and yet not in harmony with that genus, and its extravagant decoration emphasizes that generic difference. For this reason the generic term *Pephricaris* is adopted for the fossil, and the species may be known as *Pephricaris horripilata.*

Both specimens of the species were found in loose blocks of compact Chemung sandstone at Alfred, N. Y. Neither shows associated fossils.

II. The Chemung Trilobite, Bronteus senescens, Clarke.

In the Report of the New York State Geologist for 1888, the writer described the trilobite above named.* The single specimen upon which the description then published was based, was but a very imperfect fragment of a pygidium and the only justification for drawing attention to the fossil was the extreme rarity of all trilobites in the Chemung faunas. At the date of that writing the presence in the Chemung of the species *Phacops rana,* Green, common in the Hamilton rocks beneath, and not of infrequent occurrence in the Ithaca fauna immediately below the Chemung formation, was suspected, and had been announced. Later evidence has not confirmed this statement, and we know to-day only two described species of trilobites from this fauna; the *Cyphaspis lævis,* Hall (sp.), the original and only known specimen being a cephalon, and *Bronteus senescens.* The presence of the genus *Homalonotus* is shown by a fragment from the higher beds in Alleghany county. Since the description of *Bronteus senescens,* founded on a specimen from the lower Chemung strata in the town of Prattsburgh, Steuben county, additional material has been obtained which sets forth the characters of the species in its entirety and also shows that from the fragment previously figured and the restored outline at that time given to the pygidium, it might prove difficult to recognize the species when at its best. A restatement of the characters of the fossil drawn from our amplified knowledge of it, will therefore serve to clearly define the value of this species.

* The Genus Bronteus in the Chemung Rocks of New York, *op. cit.*, Figure 1; also published in Forty-second Annual Report Trustees State Museum, pp 403 405.

Soon after the publication of the article above cited, the writer located the horizon at which this fossil occurs, on Bardeen's farm in the northern part of the town of Prattsburgh, finding here several nearly entire pygidia. This horizon is well characterized by the constant association of this trilobite with the crinoid *Arthracantha depressa;* a species recently described by Wachsmuth and Springer from specimens collected at this locality where its spinous plates are very common. It is the zone of *Rhynchonella* (*Pugnax*) *pugnus*, Sow., and is an eastward extension of this zone from its somewhat more prolific manifestation at High Point, in the town of Naples. More recently two essentially entire specimens of the trilobite have been obtained from higher strata of the Chemung group, near Avoca, Steuben county, through the agency of Mr. Clifton J. Sarle, both excellently preserved though lacking a few details, but presenting us with a really striking exemplification of the late continuance of this genus.

Figures of these specimens are here given and the description of the characters of the species is as follows:

FIGURES 3 and 4. *Bronteus senescens;* two nearly entire individuals from the Chemung group, near Avoca, N. Y.

GENERAL PROPORTIONS. The outline of both of these extended individuals is quite regularly ovo-elliptical, the shorter curve being at the posterior extremity. In length the larger measures 54 mm., the smaller, 46 mm., while the greatest width of the animal is about one-half this dimension in both cases. The specimens have been subjected to slight, if any, vertical compression though the heads are somewhat askew; the lines of the margin may, therefore, be regarded as normal.

CEPHALON. The head is short and subsemilunar in outline, the posterior margin being quite direct. Its length is slightly more than one-half its width. The genal angles are somewhat produced into short and broad spines. The margin is elevated, while the border of the head is broadly concave, rising on its proximal limb to a genal ridge. The eyes are small, well back on the cheeks and moderately elevated, the surface between the palpebrun and the dorsal furrows being notably convex. The *facial sutures* are normal. The *glabella* is elongate and clavate, its width at the anterior extremity where it reaches but does not overhang the margin, being twice that just in front of the occipital ring. In contour it is depressed convex, though its elevated median portion attains greater elevation than any other part of the cephalon. The dorsal furrows are deep and narrow; starting from the posterior margin they approach each other rather abruptly; the curve changes at the level of the posterior part of the eyes and thence forward the furrows diverge outward rather gradually, broadly recurving near the anterior margin. The lateral furrows are short but distinct, the first and third pairs being most clearly defined, a median pair making but a gentle depression upon the surface, while the occipital groove is broad and shallow.

The occipital ring is likewise broad and distinct, but its prolongation to the cheeks is narrower and much more faint.

In one of the specimens the removal of the part of the glabella has exposed a portion of an elongate *hypostome* with an oval central depression, surrounded by a narrow regular groove and bordered by a narrow flattened margin.

THORAX with the normal number of ten segments. The axis is very broad, having fully one-third the entire width of the thorax, and its margins curve outward, approaching each other posteriorly. On the axis the segments are moderately broad and flat, distinctly elevated along the median line with general longitudinal depressions on the lateral slopes and a slight anterior bend at the sides. On the pleuræ, the segments are narrow and soon become free of each other, tapering rapidly to slender, recurved, acute extremities.

PYGIDIUM semielliptical, flabelliform; length and width about equal. Axis very short, extending for not more than one-fifth or one-sixth of the plate; triangular, elevated medially and with an obscure central lobe and depressed lateral slopes. The pleuræ are broad, flat, separated by sharply defined flat grooves. They broaden rapidly outward and finally become merged into the grooves near the periphery of the plate, so that the margin of the latter is smooth. These ribs are fifteen in number; the median rib being somewhat broader than the rest and, in the larger specimen, showing a tendency to division along its distal portion. The margin of the pygidium is without evidence of spines. In general contour this plate is broadly depressed within the slightly elevated periphery, convex over the central region and again sharply depressed about the axis.

ORNAMENTATION. The entire test is pretty uniformly pustulose, the pustules varying somewhat in size and being coarsest on the glabella and the ribs of the pygidium. About the enfolded margins of the cephalon and pygidium the surface is marked by the usual incised inosculating lines.

OBSERVATIONS. This species is noteworthy not alone for the rarity of all trilobites at this horizon. It is, in all probability, the latest representative of the genus, making its appearance in this later division of Devonian time, subsequent to the first intrusion of *Spirifer disjunctus* and long after the only observed occurrence in this country of *Clymenia.* It appertains to a fauna which, considered in its local relations and in correlation with faunas of other countries, characterizes the final stages of the Devonian, and in these we have no other record of the occurrence of *Bronteus.* In this late survivor of the genus, therefore, we may expect to find structural traits indicative of, or in harmony with its late appearance. We observe that between the earlier (upper Silurian and early Devonian) and the later Devonian representatives of this genus there are contrasts in the form of the glabella, the outline of the pygidium and the nature of its ribs. Thus, the glabella (or we should rather say the cranidium, as the distinction depends on the varying distance between the facial sutures) is very wide anteriorly, the dorsal furrows being highly concave within the ocular nodes (compare *B. palifer*, Beyr., Lower Devonian, Zittel's figure, Grundzüge der Palæontologie, p. 473, fig. 1,279a; Katzer's figure, Geologie von Böhmen, p. 1,023, fig. 498-4; *B. campanifer,* Beyr., lower Devonian, Beyrich's figure, Einige böhmische Trilobiten, Plate, fig. 6; *B. Partschi*, Barr., upper Silurian, Katzer's copy of Barrande's figure, *op. cit.*, p. 937, fig. 377-2; *B. viator*, Barr., lower Devonian, Novak's figure in Katzer, *op. cit.*, p. 1,036, fig. 548-1; *B. acamas*, Hall, Niagara group, Twentieth Annual Report New York State Cab. of Natural History, Pl. II, fig. 19; *B. lunatus*, Billings, Trenton limestone, Geology of Canada, p. 188, fig. 187, and Clarke's figure, Geological Survey of Minnesota, Vol. III, Part 2, p. 725, fig. 43). In all of these and numerous other recorded examples the feature referred to is strongly manifested. If on the other hand, we turn to species of the middle Devonian, the narrowing of the glabella and the interval between the facial sutures becomes evident (see *B. flabellifer*, Goldfuss, System. Uebersicht, Pl. VI, fig. 3; *B. meridionalis*, Trom. and Grasset, Barrois's figure, Calc. à Polypiers de Cabrières, Plate I, figure 2a; *B. thysanopeltis*, var. *Waldschmidti*, v. Koenen, Waldschmidt's figure, Zeitschr. d. d. Geol. Gesellsch., Vol. XXXVII, Pl. XXXVIII, fig. 2; *B. senescens*, etc., etc.). This feature appears to be one which, irrespective of other variations in structure, has gradually passed through the change noted, and it is, naturally, to be observed that lower Devonian faunas embrace species, some with the wide, some with narrower glabella, while thereafter, the earlier type of glabella has disappeared.

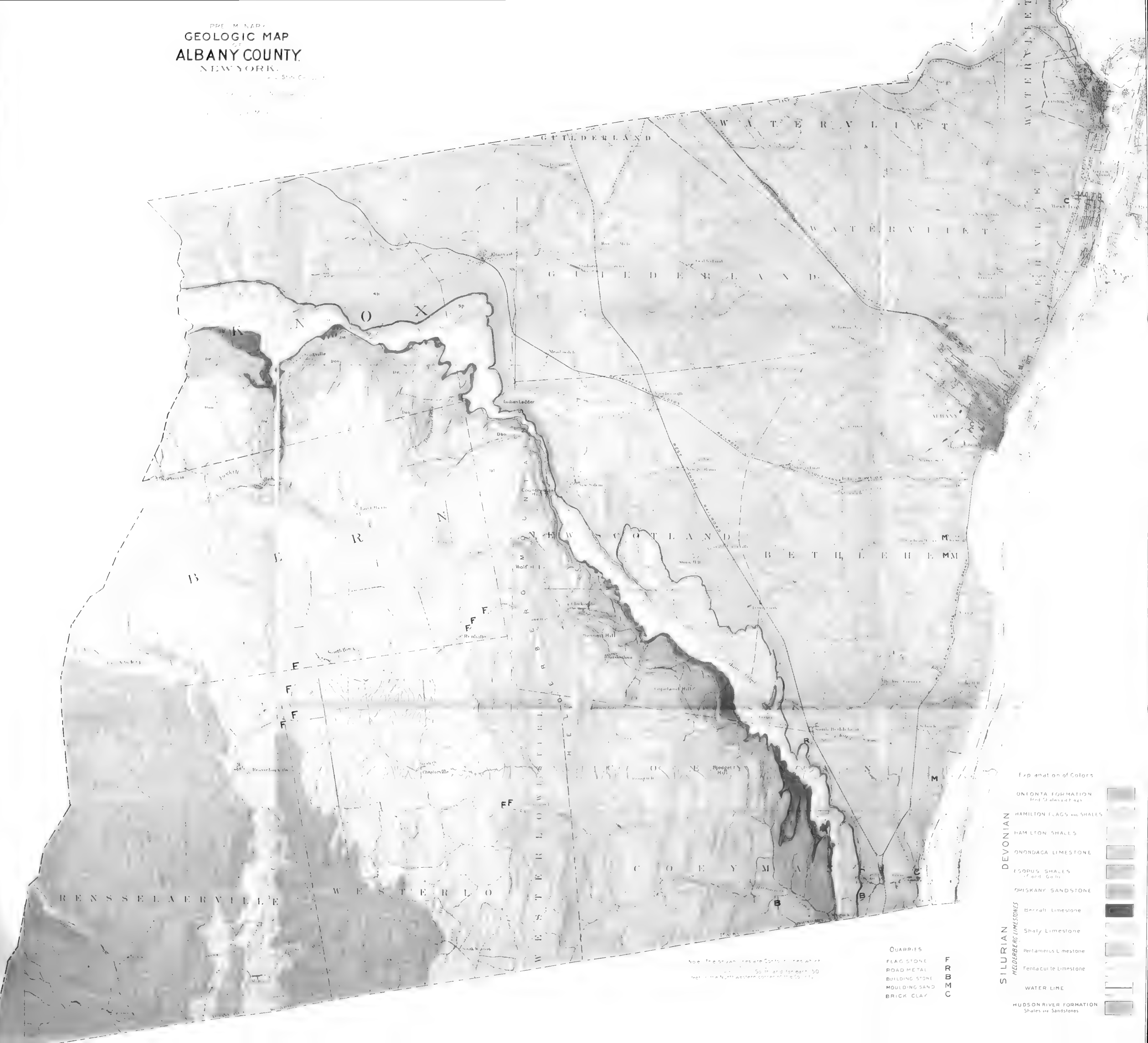
With reference to the characters of the pygidium in this genus it may be remarked that the only really useful, tenable subdivision of the group is founded upon the presence of spinules upon the pygidial margin. This is *Thyanopeltis*, one of the names introduced by Corda and designed by its author to include species of this character; it has proven to possess a definite stratigraphic value. In matter of outline there is considerable variation, from the subsemicircular shape in the earliest species like *B. lunatus*, Bill., of the Trenton, *B. laticauda*, Wahlenberg, of the lower Silurian of Sweden, and *B. hibernicus*, Portlock, of the Caradoc, to the elongate-elliptical curve presented by the species of the Devonian. In this feature *B. senescens* is extreme, surpassing the elongate, narrowing tail-plate of *B. Kielcensis*, Gürich, of the lower upper Devonian (Cuboides horizon) of Poland. Corda (Prodrom einer Monographie der böhm. Trilobiten, pp. 58, 59, 1847), attempted a further division of the genus on the basis of the simplicity or duplication of the median rib of the pygidium, proposing for such species as show a bifurcation, the name *Dicranactis*, and for those in which it is simple, *Holometris*. It has long been evident, and is shown in the species in hand, that the duplication of this rib is of such minor significance that it can be regarded only as an individual character and we can not safely infer values from this trait.

Barrande observed (Système Silurien, Vol. I, p. 840) that a division of the species of *Bronteus* might be founded upon the number of ribs on the pygidium, which are either six, seven or eight on either side of the median rib. By far the greater number of species possess seven ribs, while six such ribs are present only in the earliest species, *e. g.*, *B. lunatus*, *B. hibernicus*, *B. laticauda*. Herein *B. senescens*, having seven ribs, perpetuates the structure of the normal representatives of the genus.

The definite time value of the subgenus *Thysanopeltis* has been set forth by Barrois, Kayser, Frech and other writers. The only representative of this division yet known in American faunas is the species *B. tullius*, from the

Tully limestone (Cuboides horizon) of New York. Though the group is well represented in lower Devonian horizons, there is no record of its perdurance beyond the Cuboides horizon, and we notice that in this late representative of *Thysanopeltis* the marginal spines are minute and hair-like. Within the limitations of this group we find the glabella passing through variations in dimensions quite similar to those which characterize the genus as a whole.

Bronteus senescens is devoid of marginal spines and reproduces the characters of the normal middle Devonian type. We look upon this species, therefore, as distinctly progressed in the character of its glabella and pygidium and as having escaped entanglement with the early Devonian divergence into *Thysanopeltis;* a survival, with appropriate time modifications, of the proper expression of the genus.


GEOLOGIC MAP
ALBANY COUNTY.
NEW YORK.
GUILDERLAND
WATERVLIET
KNOX
NEW SCOTLAND
BETHLEHEM
BERNE
RENSSELAERVILLE
WESTERLO
COEYMANS
Indian Ladder
Explanation of Colors
DEVONIAN
ONEONTA FORMATION
HAMILTON FLAGS AND SHALES
HAMILTON SHALES
ONONDAGA LIMESTONE
ESOPUS SHALES
ORISKANY SANDSTONE
SILURIAN
HELDERBERG LIMESTONES
Becraft Limestone
Shaly Limestone
Pentamerus Limestone
Tentaculite Limestone
WATER LIME
HUDSON RIVER FORMATION
Shales and Sandstones
QUARRIES
FLAG STONE F
ROAD METAL R
BUILDING STONE B
MOULDING SAND M
BRICK CLAY C