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HERMAN LEROY FAIRCHILD, Geologist
J. EDWARD HOFFMEISTER

QUANTITATIVE PETROLOGY OF THE GENESEE GORGE SEDIMENTS
HAROLD L. ALLING

THE VEGETATION OF BERGEN SWAMP
I. THE VASCULAR PLANTS
WALTER C. MUENSCHER

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HERMAN LEROY FAIRCHILD, GEOLOGIST

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The University of Rochester

The name of Herman LeRoy Fairchild is a byword in American geology. To a geologist it means many things. It means Master of Glacial Geology, it means active leader and officer of the Geological Society of America, it means inspiring propagator of geological information, it means Dean of American geologists.

Professor Fairchild's influence on geological thought was considerable. His chief love was the fascinating subject of glacial geology. It is only natural that his thoughts should have been in this direction.

Whether he knew it or not, young Mr. Fairchild entered a glaciologist's paradise when he came to Rochester to be Professor of Geology and Natural History at the University in 1888. One of his first tasks was to unravel the local geology. Thanks to the work of James Hall, State Geologist, and others, some progress had been made on the older bed rock history of Western New York as early as 1844. The more recent events, however, those which dealt with the loose, unconsolidated surface deposits left by the continental ice sheets, were still unexplained.

Fairchild tackled the job energetically and enthusiastically. Any time which was not devoted to his duties at the University and his tasks as officer of the American Association for the Advancement of Science, he spent in the field. He travelled by streetcar, railroad, horse and buggy, on foot, uphill and down valley, until he knew the Genesee country better than the Indians before him. The more he discovered, the more fascinating the search became. He found ancient lake bottoms, shore benches and beaches made by waves in bodies of water which had long since disappeared. He found large boulders miles and miles from their native territories. He found hills made of masses of rocks of all sizes, which he knew could only have been produced by the action of tremendous sheets of ice. He found a buried valley running right past our door. A valley filled with from 400 to 600 feet of sand and gravel, an unseen valley to most people. But Fairchild could see it. He traced it for miles to the south of us and so accurate was his work that years later when surveyors, with all their modern equipment and all their information gathered from drill holes, mapped it, their maps were nearly identical with those of the pioneer.

Then came the task of correlating all the separate pieces of information which he had obtained from his field studies; the task of putting together in their proper chronological order the events which produced the present surface. This he did and the story as he originally told it has in all essentials withstood the test of later investigations.

He was not content to limit his work to this region but extended it over the entire state, down into Pennsylvania, up into Canada, and out to the middle west. Today, when a man works on the glacial geology of this broad area, he begins with Fairchild, and frequently ends with Fairchild.

Fairchild was one who not only collected scientific facts but was able to see the larger significance of these facts. In other words he has influenced geological thought. Let me give you a few examples. Geologists used to have exaggerated ideas of the erosive power of glaciers. They believed that moving ice could gouge out the solid bed rock and create large valleys. Some even went so far as to consider the valleys in which our Finger Lakes are located to have been the result of glacial erosion. Fairchild showed that the cutting power of moving ice was distinctly limited, that the valleys were the result of previous stream cutting and that glaciers did little more than remove the soft weathered deposits from the surface of the bed rock. This was a new conception and one which had a profound effect on the interpretation of geologic events.

The Nebular hypothesis of Laplace for the origin of the earth was the accepted one during the 18th and 19th centuries. At the beginning of the present century Thomas C. Chamberlin, professor of Geology at the University of Chicago, and Forest R. Moulton, professor of Astronomy at the same institution, showed that it failed to meet the requirements of a scientific hypothesis because it did not explain all the facts. In place of it they offered an entirely different conception of earth origin, the Planetesimal hypothesis. This was so different from the Nebular hypothesis that it affected the very foundations of geological thought. Previous conceptions had to be severely modified in the light of the more plausible hypothesis. It was a difficult transition. Many were loath to make it. Fairchild had always been a radical. He never found it difficult to discard old ideas and accept new ones if the new ones were closer to the facts. The result is that he, possibly more than any other geologist, can be credited with the successful readjustment of ideas to meet the requirements of the Planetesimal hypothesis.

In 1891 a geologist reported the finding of a huge hole in the ground near Flagstaff, Arizona. The depression was circular and bowl-shaped, 4000 feet in diameter at the top and 600 feet deep. It was known as Coon Butte and its origin was a mystery. The two most plausible explanations were that, first, it was the crater of an extinct volcano, and second, it was made by the fall of a giant meteorite. The latter seemed rather fantastic and many favored the volcanic hypothesis. Professor Fairchild visited the depression in 1906 and made a careful study of it. His reports proved conclusively that the crater actually had been produced by the impact of a meteorite. Today Coon Butte is known as Meteor Crater and is visited by thousands of tourists each year.

He was always active in the work of scientific organizations. Few men were more influential in organized science than he. He reorganized the nearly defunct New York Academy of Science and was its secretary for several years. He was for many years one of the moving spirits of the American Association for the Advancement of Science. In 1888 he was one of the original thirteen geologists who organized the Geological Society of America. He wrote its constitution and by-laws. He was its Secretary for 16 years and its President in 1912. With his passing goes its last surviving charter member.

His name has been closely linked with the Rochester Academy of Science for over 50 years. In 1888 the Academy was weak, inactive, and faced dissolution. Fairchild had just arrived in Rochester and his advice and aid were solicited. He advised a complete reorganization and was largely instrumental in framing a new set of rules which the Society promptly adopted. He became its president in 1889 and the Academy began a new era of prosperity. He resigned the presidency in 1901 but continued as editor of the Proceedings until 1935. In 1918 he was elected a life member and in 1920 was made a patron. In 1932, while Fairchild was still active and in good health, his portrait bust in bronze was presented by the Academy to the University of Rochester. This now stands in the foyer of Dewey Hall on the River Campus.

I believe the people of this area are unusually geologically minded in spite of the fact that there are relatively few products of economic value found in the local rocks. People here are interested in the origin of the Finger Lakes, the Pinnacle Hills, the rocks exposed along the banks of the Genesee gorge. There is no question about it, this interest can be almost entirely traced to the influence of Professor Fairchild. He was a rare teacher whose enthusiasm was always contagious. He was able to make his rocks live; he gave them a personality. Do you remember when the memorial boulder, opposite the entrance to the main quadrangle of the River Campus, was dedicated to Thomas Thackeray Swinburne, composer of "The Genesee"? Professor Fairchild closed the speaking exercises with an address entitled "Personality of the Boulder." He said among other things:

> "The boulder has appropriateness in bearing the name and perpetuating the memory of Thomas Thackeray Swinburne. We have a geologic name for these alien boulders, transported far from their native sites, and often perched in insecure positions. We call them erratics. Tom Swinburne was an erratic of the human species. He had travelled far from conventional thought and belief. He did not pattern his life and purpose after other people. He was individual.

> His poetic imagination had lifted him from the common plane to the pinnacle of near-genius, always a precarious position. Yet, the world sadly needs more of that type of unconformity to the level of unthinking and superselfish humanity. We honor the memory of Swinburne for his moral individualism and courage as well as for his poetic gifts.
>
> "Rock of Ages Geologic! You are to stand here as a noble memorial of a departed being of poetic genius. And from this commanding position you are assigned to keep watch and ward over the University of Rochester. You are to note the goings-out and the comings-in of the future generations of students; and to them you are to be a reminder of the worth-whileness of 'things of the spirit.' And year by year, you will receive, vicariously, the tribute of successive groups of University graduates."

He gave a personality to his rocks.

In 1920, when he was 70 years of age, Professor Fairchild retired from the University of Rochester as Professor of Geology. When most people reach their 70th year they look forward to a little rest, some leisurely travel, and a chance to do things they have always wanted to do but never had the time to do. But not Fairchild. He remained just about as active as ever. To me one of the most remarkable things about him is what he accomplished between the ages of 70 and 90. He published within these twenty years over 100 scientific papers. And many of these are of considerable size, including a history of the Geological Society of America. A man who could do this must have been made of stern stuff.

May we who are his successors be worthy of the rich heritage which he has left us.

QUANTITATIVE PETROLOGY OF THE GENESEE GORGE SEDIMENTS

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ABSTRACT

The Paleozoic rocks of the Genesee Gorge at Rochester, New York, have been studied by stratigraphers and paleontologists but not by petrographers. A petrographic study now has been done. The quantitative mineral composition of these rocks has been determined by using the Delésse-Rosiwal method of intercepts. Grain size, in terms of nominal sectional diameters, grain roundness, and grain sphericity in two dimensions (circularity) in thin sections have been measured. These data have been arranged into the forms of *complementary microlithologies* and *grain modes* and have been plotted beside the stratigraphic column. Mineral phases, in terms of *microphases,* have been recognized and established. These show the details of the sedimentation, its character, its rhythmic fluctuations, and its relation to shaliness. Studies of fossiliferous rocks reveal that the mineralogical composition governs and controls certain specific megascopic fossils much more than previously realized.

Petrographically the boundaries of the formations are artificial. The base as well as the top of the Clinton group is decidedly arbitrary.

CONTENTS

ILLUSTRATIONS

I. INTRODUCTION

The Genesee Gorge at Rochester, New York, has long been known as a superb section of Paleozoic sedimentary rocks. This geologic mecca has attracted numerous stratigraphers and paleontologists, who have drawn up many correlation charts and listed the fossils. Still there are many unsolved problems, because those who have studied these sediments have been content to accept, in the main, the field descriptions of the rocks as satisfactory analyses of their composition and have not emphasized the rock facies.

This study constitutes a petrographic attack on the problems of these sediments. The rocks studied in thin section range from the top beds of the Queenston up through the Lockport. From the beginning I was expectant of new truths; I have not been disappointed.

The purposes of this paper are first, to determine the mineral composition of these rocks and, second, to study the various rock facies. Some aspects of what Payne (1942, p. 1698) calls "the new stratigraphy" was applied through measurements of grain size and grain roundness in thin sections cut from precisely located specimens. It is believed that only with such information can the paleo-environment be satisfactorily determined.

It was necessary to readapt techniques already developed for studying loose grains and fragments of unconsolidated materials based upon three-dimensional measurements. Thin sections provide only two dimensions (Alling, 1941, 1943). This required the development of new techniques.

These new data made it possible to appreciate for the first time the character of the rock facies, the rhythmic nature of their deposition, and the overlapping of mineral phases that cross formational boundaries. This information furnishes quantitative data for understanding the paleo-environment for specific fossils.

ACKNOWLEDGMENTS

The collecting of measured specimens for thin sections began in April, 1922, with the field assistance of Merle K. Alling. Additional specimens subsequently were provided by Bernard H. Dollen, Dr. William L. Grossman, Dr. Tracy Gillette, Dr. Lois Kremer [Sharpe], and Dr. Virginia Hoyt [Jones], former students of geology at the University of Rochester. To these I am truly thankful. Charles M. Reed and Arthur S. Gale, Jr., furnished the results of a plane table survey of the Rochester and Lockport formations, forming the banks of the New York State Barge Canal to the west of Rochester. The stratigraphic column of the Lockport from the canal was supplied by a chart constructed by Professor George H. Chadwick and students. To them I acknowledge my thanks.

Supplementary slides from the Niagara Gorge were provided by Dr. John T. Sanford, for which I am very grateful.

To Dr. Tracy Gillette, whose death in the fall of 1942 removed a leading authority on the New York Clinton, I am especially indebted for many discussions. The master's thesis of Lois Kremer [Sharpe] (1932) on the Thorold sandstone in New York, has furnished many suggestions. Some of her specimens have been thin sectioned and constitute a portion of the slides used in this investigation. Beginning in 1941, Virginia Hoyt [Jones] (1942) undertook a thorough study of the heavy minerals in the Clinton Group of New York State, from the Niagara Gorge east to Clinton. During this investigation I benefited greatly through many discussions.

Petrographic studies by Marguerite Smith [Robertson] (1938) of the Queenston from Niagara to Rochester has been helpful. The thesis of Charles M. Reed (1936) on the insoluble residues of the Lockport has helped me with the composition and subdivision of that formation.

Professor J. Edward Hoffmeister greatly assisted by reading the manuscript. Appreciation is due to Gordon M. Meade, M.D., and David Jensen for preparing the manuscript for publication.

II. METHODS EMPLOYED

Mineral Composition:—The mineral composition of these rocks was determined by the Delésse-Rosiwal method of intercepts, using a Wentworth stage, and the calculation of the intercepts to a weight percentage. The number of runs per slide depended upon the size of grain; for coarse grained rocks five runs were made; for finer grained rocks the number of runs was three. These seemed to be a sufficient number because a thin section provides only a small sample. A high order of accuracy was therefore not justified and should not be expected. Independent runs give fairly consistent results. One of the poorest checks is shown in Fig. 1A. The choice of the specific gravities for calculating these measurements into weight percentage provided some uncertainty. The clay minerals could not be specifically identified in all cases by the microscope alone, and hence the specific gravities are not very definite. Very few textbooks furnish the value of the specific gravity for collophane, for example. The exact percentage of $MgCO_3$ and $FeCO_3$ in the carbonate minerals could not be determined by optical means. Staining methods help but are not quantitative.

Chemical Analyses:—Commercial analyses provide some assistance even though the exact stratigraphic horizons are not known in most instances. These analyses supply the ratio of the calcium carbonate to the magnesium carbonate.

Grain Size:—In contrast to the three-dimensional measurements of loose grains, thin sections provide areas of random sections of grains. Measurements on identical material in the two forms are not comparable (Krumbein, 1935). As the relationship between two- and three-dimensional measurements is not simple and has not as yet been established, no attempt has been made to modify the thin section measurements to three-dimensional values. *All sizes in this paper are in terms of the nominal sectional diameter (Wadell, 1935) in millimeters measured in thin sections.* Size measurements were accomplished by the diaphragm method previously described (Alling, 1936, pp. 189–204). Measurements of seventy-five to a hundred grains per slide were regarded to be sufficient. The data were plotted as frequency-distribution curves. The mode or peak was chosen for plotting on the charts that follow.

Independent parallel runs of grain size measurements of quartz, for example, are not always strictly reproducible. Nevertheless, such results are comparable. An illustration of an excellent check is the data of two slides cut from the same specimen, as shown in Table 1. The number of grains measured was purposely different. The rock contains only 2.1% of quartz by weight, hence the number of grains in such a rock in thin section is not numerous. The check is very close. The modes are the same.

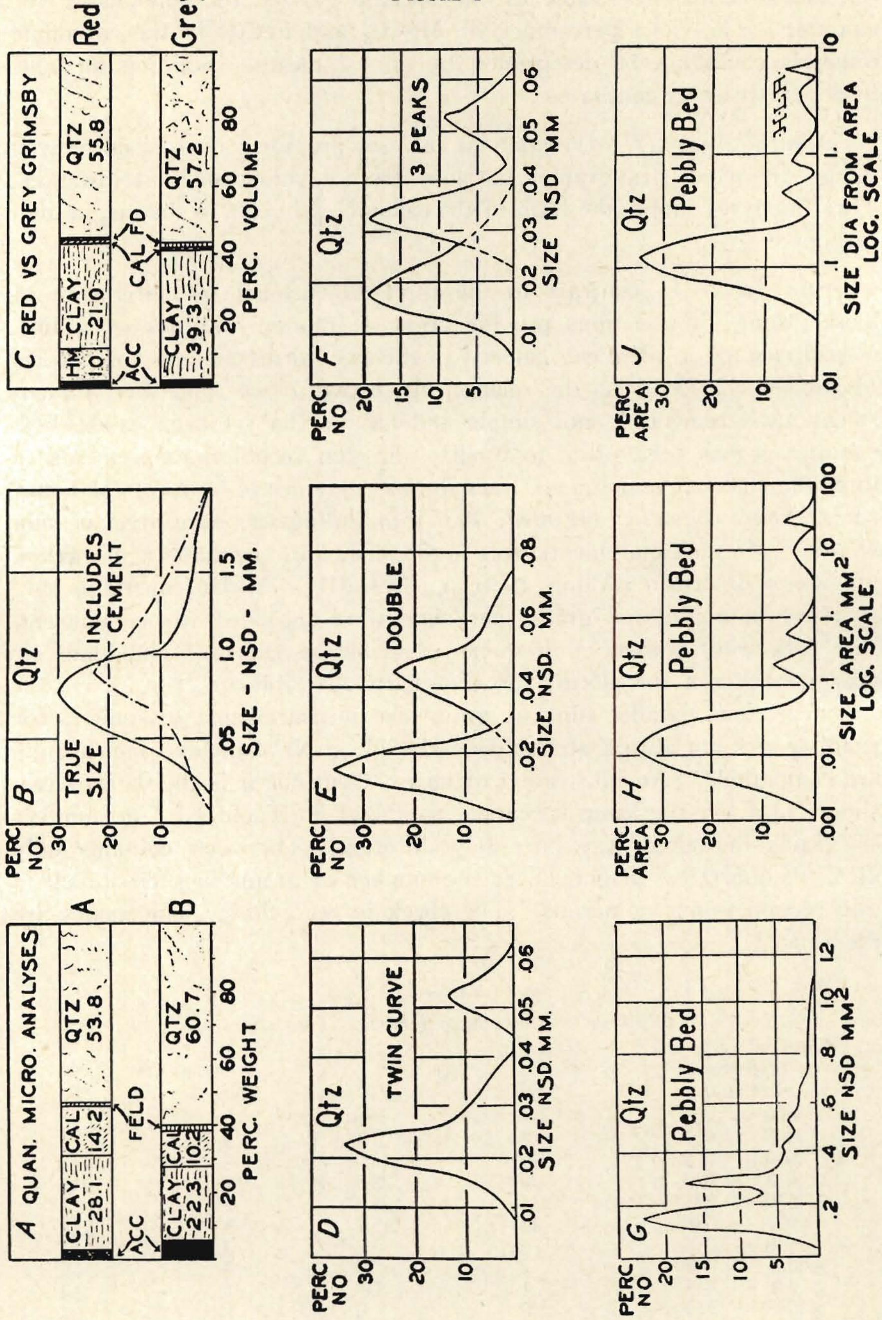
TABLE 1

Grain Size Analysis of Quartz. Two slides

Nominal sectional diameter, Size, mm.	A* No.	A* %	B* No.	B* %
.000 — .005	0	0	0	0
.005 — .010	5	7.1	3	7.3
.010 — .015	10	14.3	5	12.2
.015 — .020	20	28.3	12	29.3
.020 — .025	15	21.4	9	22.0
.025 — .030	11	15.7	5	12.2
.030 — .035	6	8.6	3	7.3
.035 — .040	2	2.8	2	4.9
.040 — .045	1	1.4	1	2.4
.045 — .050	0	0	1	2.4
	70	99.6	41	100.0

* Rochester formation, 2.16 ft. above base, Densmore Creek.

Figure 1


A QUAN. MICRO. ANALYSES
CLAY 28.1
CAL 14.2
QTZ 53.8
A
ACC
FELD
CLAY 22.3
CAL 10.2
QTZ 60.7
B
PERC. WEIGHT
B
PERC NO.
TRUE SIZE
Qtz
INCLUDES CEMENT
SIZE - NSD - MM.
C RED VS GREY GRIMSBY
HM 1.0
CLAY 21.0
QTZ 55.8
Red
ACC
CAL FD
CLAY 39.3
QTZ 57.2
Grey
PERC. VOLUME
D
Qtz
TWIN CURVE
SIZE NSD MM.
E
Qtz
DOUBLE
SIZE NSD MM.
F
Qtz
3 PEAKS
SIZE NSD MM
G
Qtz
Pebbly Bed
SIZE NSD MM2
H
Qtz
Pebbly Bed
SIZE AREA MM2
LOG. SCALE
PERC AREA
J
Qtz
Pebbly Bed
SIZE DIA FROM AREA
LOG. SCALE

Multiple Peak Frequency-Distribution Curves:—In 1935, while studying the rocks in the Niagara Gorge (Alling, 1936), the technique of grain size analysis was not completely developed and the cause of multiple peak frequency-distribution curves was not understood. It was not at all clear whether there was any fault of the method, or of the technique, or the method used in plotting the results. Sanford (1939) was doubtful about the value of the curves. It was believed that an increase in the number of grains measured, the use of a mechanical stage to eliminate the personal element in the choice of grains that serve as samples, repeated runs on the same slide, and standardization of the number of class intervals in plotting, would remove these multiple peaks. These improvements have to some extent done so but did not remove all of them. I am now convinced that many peaks exist and represent something real.

In 1936 (Alling, 1936) it was suggested that these peaks pointed to different sources of the sediment or to a lack of complete sorting during transportation. Many slides of rocks which show multiple peaks frequently show two or more types of rocks, sometimes as alternating layers or as heterogeneous aggregates. It is often possible to actually see the several sets of grain sizes. These give added evidence for the reality of multiple complementary microlithologies. Each microlithology may be well sorted, but the microlithologies together produce a multiple peak curve.

There are all gradations in the graphic behavior of these curves. Some have several separated peaks with no grain sizes in between, and constitute distinct curves independent of one another when plotted on the same graph base (see Fig. 1D). Many are joined together (Fig. 1E).

FIGURE 1

All measurements made from thin sections

A. Quantitative microscopic analyses, Delésse-Rosiwal method by Wentworth stage, of one slide. Two independent runs of 3 traverses each, showing poor agreement. Most of the analyses were much better. Thorold, 3.4 feet above base, Genesee Gorge. Percent by weight.

B. Frequency-distribution curve, percent of number of grains of quartz and nominal sectional diameter size in mm. Shows true size, full line, and size including quartz cement, dot-dash line. Top of Thorold, 2.8 feet above base, Glen Edyth.

C. Quantitative microscopic analyses of red and gray portions, top of Grimsby, Densmore Creek, showing great similarity, except for hematite content in the red portion. Percent by volume.

D. Frequency-distribution curve of quartz grains in the Furnaceville at Densmore Creek. The main peak is characteristic of the Reynales, the smaller peak is of Thorold size, showing overlapping of the two sedimentary types.

E. Double-peaked curve, quartz in the Maplewood at Densmore Creek. 10.5 feet above base.

F. Three-peaked curve, quartz, the Rochester, 52.5 feet above base. Barge Canal.

G. Quartz curve, pebbly bed. Grimsby, Genesee Gorge, 10 feet above base. Percent of number and nominal sectional diameter. 112 grains.

H. Quartz curve, pebbly bed. Grimsby, Genesee Gorge, 10 feet above base. Percent of area of grains, size in areas, square millimeters. Log. scale, 1103 grains.

J. Same as H except size is in diameters, calculated from areas, in mm. Log. scale.

Such joined multiples can be treated as separate curves that overlap (Fig. 1F). Most of the curves consist of one main peak with one or more minor peaks; the composite curve is made of a number of curves of unequal size.

The Grimsby contains many layers supplied with pebbles. The usual field term is pebbly bed. The method of plotting percentage frequency of the *number* of grains against the nominal sectional diameter size results in curves with a number of small peaks tagged on to the end (see Fig. 1G). Such curves do not give an adequate picture of the rock. What are seen in the hand specimen are the large grains and pebbles and not necessarily the small grains of the groundmass in which they are set. It is the *areas* of these pebbles, not their relative number, that is impressive. Consequently the percentage by *area* was chosen as the basis for frequency-distribution curves for the pebbly beds.

The method used in measuring these pebbly beds was to place a grid, engraved on a thin sheet of celluloid, directly over the slide. By means of a camera lucida, the pebbles of each grid square were drawn on paper. A polar planimeter was used to measure the areas of not only the pebbles but that of the groundmass as well. The grains constituting the groundmass were sampled by measuring 50 to 100 grains of each grid square. The data of the pebbles and of the groundmass were combined in a single curve (Fig. 1H). In Fig. 1J the basis of the graph was calculated into diameters, for better but not absolute comparison. It is quite possible that areal basis is preferable to frequency by number.

Grain Roundness:—This matter is one of the most illusive concepts in the field of sedimentary statistics. As Wadell (1935, p. 263) has clearly shown, roundness and shape are independent variables. Roundness is the degree to which corners and sharp edges have been ground off. It is not sphericity or circularity. Many methods have been devised (Krumbein, 1935). Some measure something else besides roundness, however. Extensive trial of all these schemes demonstrated their impracticability as applied to thin sections; they prove too time consuming. The only practical method is one of inspection. Krumbein's (1941) chart of roundness for pebbles was adopted and modified for thin sections. Camera lucida drawings were made and sorted as to roundness and a number, 0.1, 0.2, to 0.9, assigned to them and drawn on a long strip of tracing cloth, mounted on rollers, and viewed by a camera lucida. The image of the standard was matched directly with the image of the investigated grain.

III. MINERALOGY

Carbonates in General:—The microscope readily distinguishes several forms of calcitic minerals in these sediments: (A) fragments and sections

PLATE I

Length of scale 0.1 m. All with cross nicols light, except H, K, L, and M. Ordinary light H, reflected light (Leitz Ultrapac) K, L, and M. All from Genesee Gorge, except E.

A. Grimsby, 39 ft. above base, hematitic-coated quartz grains cemented by quartz. Orig. mag. X174.
B. Thorold, 3.5 ft. above base. Lamellae in quartz grain. Orig. mag. X240.
C. Thorold, 3.5 ft. above base. Quartz grains cemented by added quartz. Orig. mag. X240.
D. Thorold, 2.5 ft. above base. Microcline feldspar grain cemented by calcite (rough surfaced, white). Orig. mag. X174.
E. "Grey Furnaceville", .3 ft. above base, Glen Edyth, east side of Irondequoit Bay. Plume chert (lower half), and recrystallized calcite (rough surfaced white grain). No hematite-bearing rock occurs at Glen Edyth. Orig. mag. X174.
F. Upper Reynales, 7.5 ft. above base. Ring of chert in dusty centered recrystallized calcite. Orig. mag. X69.
G. Brewer Dock, 2 ft. above base. "Blade" of quartz derived from recrystallization of chert. Orig. mag. X48.
H. and J. A pair. H, ordinary light, J, cross nicols, Brewer Dock, 2 ft. above base. Collophane with inclusions of quartz and recrystallized calcite. Orig. mag. X48.
K. Thorold, 1.2 ft. above base. Reflected light. Pyrite (white).
L. Furnaceville, .35 ft. above base. Goethite (white) replacing fossil calcite. Reflected light. Orig. mag. X94.
M. Furnaceville, .88 ft. above base. Goethite (white) replacing fossil calcite. Reflected light. Orig. mag. X94.

of fossils, some of which can be specifically identified, (B) large clear homogeneous grains, many of which are twinned and which have experienced recrystallization, and (C) small, dirty, anhedral grains usually in large clusters with irregular surfaces and without optical orientation. These have been considered to be largely clastic in origin. Actually the three types frequently intergrade with one another. The classification of the calcitic substances in some slides is consequently somewhat arbitrary. This was especially true of the carbonates of the Rochester and the Lockport formations.

Fossil Carbonate:—The fossil forms are the easiest to recognize and lend themselves well to Delésse-Rosiwal analyses on the Wentworth stage (see Plates IL, IM, IID, IIJ, IIK, IIL, and IIIM). Cross sections of brachiopods like *Coelospira hemispherica* (see Plate IIJ) and *Pentamerus oblongus* are readily identified. The calcite, apparently very high in calcium carbonate, occurs as clear, clean grains and aggregates which under cross nicols are brilliantly colored. Bryozoa are perfectly obvious. Other fossil fragments, not paleontologically identifiable, show spectacular plumes of bright polarizing calcite. It is clear that much of the calcite of the fossil fragments has been recrystallized. This type has not, however, been cataloged with other recrystallized forms for the purpose of compositional plotting.

Netted Calcite:—Apparently closely genetically related with the fossil fragments is "netted calcite." Moderate to high microscopic objectives reveal the presence of a three-dimensional network especially in the center of grains. The visibility of the network varies greatly depending upon the degree to which it has been replaced by other minerals, especially hematite.

The structure of the net is best acquired from the photographs (Plate II, D through H). It is an interlocking, pale yellow-green tubular network. It is organic in origin and probably zooecial tubes of monticuliporoid bryozoa (Hatch, Rastall, and Black, 1938, p. 158). In composition it seems to be either transparent to translucent chitin or collophane or allied substances. It is opaque under cross nicols and is microscopically amorphous. It is easily replaced by yellow-brown collophane, or is easily changed to that substance. In the Furnaceville, hematite replaces it. Even a single slide may show all gradations from a "net" composed of collophane to one composed entirely of earthy hematite. The hematite attacks and replaces the netted calcite both on the margins and at the center of the grain of netted calcite. The iron solutions probably found their way into the interior through a few tubes of the network that extend to the margin of the grains. First the network is replaced, leaving the calcite in the interstices untouched. Then this calcite is gradually replaced until the whole grain of "netted calcite" is composed of solid, earthy hematite. Pyrite sometimes replaces the netted calcite but never to the extent nor as completely as hematite. In the center of some grains the earthy hematite is recrystallized to brilliant red plates of specularite and sometimes to martite.

Recrystallized Carbonate:—Limestones with a low clay content contain a good deal of recrystallized carbonate. This is recognized by its optical homogeneity and freedom from inclusions of clay and dust particles. The grains range from small (.005 mm.) to several millimeters in diameter, and are frequently striped with twinning bands (see Plates IE, IIM, IIIL, IVB). The clay inclusions formerly present have been cleared by being pushed to the margins where they now constitute part of the cementing materials. A good deal of the recrystallized calcite has been enlarged by the addition of calcite; margins have been added (Plate IIB and C). Much of this kind of carbonate deserves the term authigenous calcite and should be considered in the same class with authigenous feldspar. The added margins are, commonly, on top of clay frames. Examples of multiple margins have been noted.

When carried to an extreme, the large clear grains of recrystallized calcite produce a white rock with sparkling luster. These the field geologist calls "crystalline" limestones. The term is unfortunate because it obscures the gradation from fine-grained, recrystallized carbonate rocks to those coarse-grained. The microscope fails to reveal any appreciable amount of amorphous material. Even the collophane, showing dark under cross nicols, reveals a definite crystal lattice by X-ray analysis. Perhaps the field geologist does not desire to imply that other rocks are amorphous; the term "crystalline" carries this implication, however.

The amount of recrystallization has not been as great nor as extensive in the dolomitic rocks, such as the Rochester and the Lockport formations.

No difficulty is experienced in a qualitative identification of the types of calcite but, in quantitative analyses, where each and every grain in the line of the intercept must be assigned to one of the various types, personal opinion enters into the problem. The processes of recrystallization were evidently spread over a long period of time and are a part of those constituting diagenesis (lithogenesis) and probably continued long afterwards (Thiel, 1942). So sensitive is calcite to this reorganization that it is rather surprising that any unrecrystallized calcite occurs today.

The cause of the recrystallization and its irregular distribution is an intriguing problem. In the same way that water is necessary to affect recrystallization of schists, water in these sediments is regarded as the probable medium. The variable permeability of the sediments may have controlled the volume of this circulating water. The amounts of clay are believed to be a factor in making the sediments watertight, even though the amount of recrystallized calcite does not show any clear relation to the amount of clay. The available data when plotted gives inconclusive scatter-diagrams. However, there is some evidence that a high content of clay *between* the grains (Reynales type), in contrast to the clay included within the calcite (Lockport type), seems to make the rocks less permeable to water circulation. But the clay within the grains restricts the recrystallized calcite to small sized grains.

There is no satisfactory way to express the extent of the recrystallization. Even within a single microscopic field, calcitic grains appear in all stages of reorganization from small grains with optical heterogeneity, with many dust inclusions with subround abraded external surfaces, to large clear grains with twinning bands with euhedral borders (Plate IIM).

Clastic Carbonate:—The term clastic carbonate, as used here, may not be one towards which criticism cannot be directed. It is employed, nevertheless, to designate the type of calcite of limestones which consist of small, irregular, subangular grains of calcite and dolomite that are not fragments of fossils and have not experienced recrystallization (see center of Plate IIK). Many of them in all probability are clastic in a true sense; the debris from wear on previously formed carbonate. Some of this material, especially the excessively small grains, may be derived from chemical precipitation, perhaps aided by organisms. Undoubtedly much of the clastic carbonate has lost its specific identity through recrystallization. A few layers of limestone are chiefly composed of clastic carbonate especially if it is abundantly supplied with clotted clay, and is somewhat magnesian in composition. Clastic carbonate enters into the composition of some fine-grained, argillaceous layers with a prominent shaly structure. The source of the clastic carbonate is not directly indicated. These observations suggest that the limestones from the Genesee Gorge are, in part, if not in large part, of clastic origin.

Clay-clotted Carbonate:—Quantitative microscopic analyses of both the Rochester and of the Lockport formations report less clay than the insoluble residues would suggest. High-power objectives reveal that a good deal of the clay is in exceedingly small units within the grains of the carbonates, quantitatively unmeasurable by the Wentworth stage. Chemical analyses suggest that clay-clotted carbonate is magnesian in composition. Certainly the dolomitization restricts the size of the grains in many cases. Some of the white rocks of these formations, such as the Eramosa beds at Lockport, New York, are essentially calcite.

Clay-clotted carbonate is one of the characteristic mineral microphases recognized, and has been called the Lockport clay microphase.

Quartz:—Detrital quartz occurs in nearly every slide, ranging from minute fragments to large grains, to pebbles. Most of it is clear, homogeneous with sharp and uniform extinction under crossed nicols. Others show wavy extinctions, implying internal strain. Gas bubbles are common. Rutile inclusions are relatively rare (see Plate IVC). Fractured grains are present. A few quartz grains show lamellae due to deformation previous to deposition which are similar to those described by Fairbairn (1941) (see Plate IB). In addition to quartz grains composed of single individuals, there are aggregates and pebbles composed of many separate grains. Many are of quartz; some are composed of detrital chert and chalcedony.

Chert:—Chert and associated minerals, chalcedony and opal, occur in the Furnaceville and in the Upper Reynales. It takes various forms and shapes. Bands of black chert are common in the exposures in the gorge. Slides cut from these layers show that the chert occurs in small units as well. It very definitely replaces calcite, more especially the fossils. Under the microscope the chert can be seen in all stages of crystallization from cryptocrystalline, microcrystalline to secondary quartz (see Plate IE, F, and G). The distinction of the latter from detrital quartz is usually possible. The clastic grains usually show some rounding and dust coating and, less commonly, are optically strained.

So perfect is the replacement of the fossil calcite by chalcedonic quartz that none of the structure of the fossil has been destroyed, and the fossil, in favorable sections, can be specifically identified.

There is abundant evidence that the silica was in solution when it replaced the calcite. Circulation of this solution was probably possible because of the permeability of the sediments. The rocks which contain a low but a definite amount of clay were especially favorable for chert. Layers of the Reynales which carry a large amount of clay do not contain chert. It would seem that large amounts of clay prohibit the formation of chert, or the conditions favorable for clay are unfavorable for chert (see Fig. 6D).

The problem of "primary" and "secondary" chert is a ghost that constantly haunts this investigation. The chert is secondary in the sense that it replaces the calcite; it is primary in the sense that it is in a part of the rock as formed. The development of the chert was one of the many processes collectively called lithogenesis.

Feldspar:—Clastic feldspar is very common: very few slides fail to contain some variety. Some limestones contain very small amounts. The large amounts are not, surprisingly enough, in the rocks with a high quartz content, but rather in those with intermediate amounts. A great flood

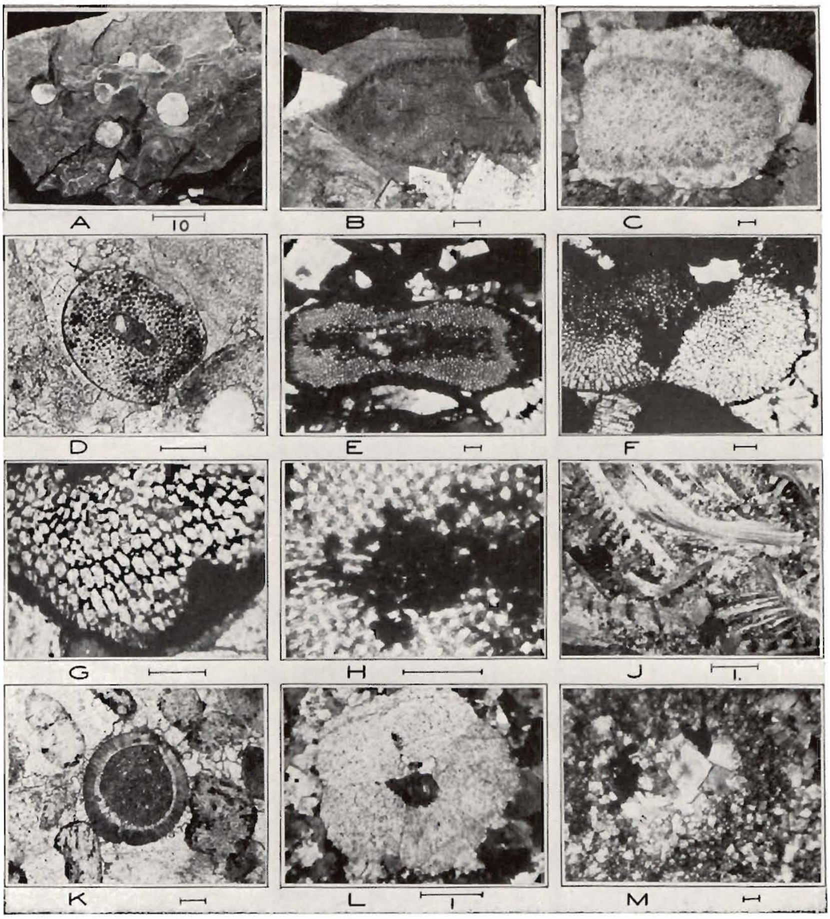


PLATE II

Length of scale 0.1 mm., except A, J. and L.

A. Maplewood, hand specimen, Maplewood Park, Genesee Gorge, showing calcareous discs. Orig. mag. X1.6.
B. Upper Reynales, Genesee Gorge, 5.6 ft. above base. Dusty centered grain of of calcite cemented (enlarged) by calcite. Cross nicols. Orig. mag. X69.
C. Reynales, Niagara Gorge, 12 ft. above base. Dusty centered grain of calcite cemented (enlarged) by calcite. Cross nicols. Orig. mag. X48.
D. Upper Reynales, Genesee Gorge, 11.5 ft. above base. Netted calcite fossil fragment, partially replaced by hematite (black). Ordinary light. Orig. mag. X140.
E. Oölitic ore stringer, 5 ft. below "red flux," Clinton, N. Y. Netted calcite, margined and centered by replacing hematite. Ordinary light. Orig. mag. X48.
F. Furnaceville, Genesee Gorge, .88 ft. above base. Netted calcite partially replaced by hematite. Ordinary light. Orig. mag. X69.
G. Furnaceville, Genesee Gorge, .88 ft. above base. Netted calcite margined and partly replaced by hematite. Ordinary light. Orig. mag. X174.
H. Oölitic ore stringer, 5 ft. below "red flux," Clinton, N. Y. Netted calcite, centered by replacing hematite. Ordinary light. Orig. mag. X240.
J. Lower Sodus, Upper Pearly layer, Genesee Gorge, showing cross sections of *Coelospira hemispherica*. Cross nicols. Orig. mag. X14.
K. Upper Reynales, Genesee Gorge, main *Pentamerus* layer (No. 4). Note clastic calcite within ring of recrystallized calcite, fossil fragments. Cross nicols. Orig. mag. X69.
L. Furnaceville, Genesee Gorge, .8 ft. above base. Calcitic rosette, pentagonal fossil fragment. Cross nicols. Orig. mag. X19.
M. Irondequoit, Densmore Creek, 15.5 ft. above base. Recrystallized magnesian calcite rhombs in limestone. Cross nicols. Orig. mag. X48.

of quartz seems to suppress the amount of feldspar. The amount of feldspar rises with the quartz to a peak and then falls off.

Orthoclase is rare, but microcline is common (see Plate ID). Perthitic feldspars, often in considerable amounts, exhibit all kinds; microclinic microperthite and microclinic antiperthite are dominant over the orthoclasic varieties. Plagioclase is the most abundant of all of the feldspars (see Plate IIID). Many of them are strikingly twinned, some are untwinned. The mode of the frequency-distribution data is oligoclase. Albite, andesine, and labradorite grains are common. Only several grains of bytownite were noted in the Grimsby.

Due to the perfect cleavage in two directions, feldspar grains are usually subangular; sometimes angular and only occasionally subround. The degree of roundness is also dependent upon size. The small grains are less round, the large grains more rounded.

The method of measuring roundness of feldspar was based upon the same principle as that for quartz. Krumbein's (1941) method appears to have two limitations, however. First, it was for relatively large pieces of limestone, not individual grains and, second, roundness characteristics of mineral grains are peculiar to each kind. Instead of using a set of drawings of quartz, a collection of sketches of feldspar grains were drawn and used. The relationship between the roundness of quartz and feldspar has not been investigated; they are not the same. The character of the cleavage of two minerals is part of the difference.

The grain-size range of the feldspar follows closely that of quartz. While the number of grains of feldspar per slide is much less than those of quartz, a sufficient number were found to construct satisfactory frequency-distribution curves that can be set alongside those of quartz. Commonly the mode size of the feldspar is slightly less than that of the quartz and it usually consists of one peak, while the curve of the quartz may show several. Since the grain sizes of quartz and feldspar are so nearly alike, the latter have not been plotted on the charts to avoid confusion.

The feldspar grains appear to be remarkably fresh and unaltered. Only occasionally paragonitization appears on the plagioclase blebs in perthite. Clay derived in situ from the feldspars could not be identified.

The Clay Minerals:—Nearly all of the slides show some form of clay or closely allied minerals. The clay minerals proper are difficult to study and many members of the important clay groups cannot always be identified by optical means in thin section. Nevertheless the kaolinite and montmorillonite types were recognized. The potash-bearing clays, called illite, are very common. The term "illite" is used in the sense of Grim: it "is not the name of a mineral species, but . . . a general term of the clay mineral constituents of argillaceous sediments belonging to the mica group. . . . The dominant . . . species present is [probably] bravaisite . . . " (see Fleischer, 1943). In addition there are pale green, flaky aggregates that are micaceous in habit which are transitional products due to decomposition of primary minerals to which definite names may not be appropriate. These are uralitic hornblende, bleached micas, both muscovite (see Plate IVA) and biotite, as well as a host of chlorites. It is the last that colors the Maplewood bright olive green and gives the gray-green tint to the Thorold and to the green portions of the Lower Sodus, and the Lower Irondequoit.

The red colorization of the Queenston, the Grimsby, and the purple parts of the Lower Sodus are due to hematitic stained clays. The hematite is in submicroscopic units, adsorbed by the clay.

Three clay microphases are recognized: the Queenston type that continues up to 38 feet above the base of the Grimsby, the Maplewood type which extends from this zone of the Grimsby upwards to the base of the Irondequoit, and the Lockport type of clay as clots within the magnesian calcite and dolomite, ranging from the base of the Irondequoit up into the base of the Vernon. These clay microphases are described beyond.

The Queenston especially contains abundant detrital muscovite and bleached biotite. Some flakes show authigeneous additions.

The orientation of the clay minerals is an interesting problem. The flakes are too small for satisfactory Federov Universal stage analysis. The use of the mica plate demonstrates that most of them are optically parallel to the bedding; there are other flakes at right angles to the bedding. Measurements are insufficient to indicate in exactly what planes the latter are chiefly concentrated. Unquestionably their orientation is governed by the presence of quartz grains.

Among the various chlorites, whose iron content is relatively high, is the interesting mineral chamosite which is important in the formation of the oölitic type of Clinton iron ore. In the Rochester region chamosite is rare and is not entirely confined to the Furnaceville. It has been found in the Brewer Dock and above the Furnaceville, as spherulites with polarization crosses. In the Furnaceville a few oölites of chamosite similar to those at Clinton have been found, but they are not as common nor as spectacular.

There are other chlorites involved with the hematites that are not chamosite. These occur as a core or nucleus of oölitic masses of hematite into which blood red specularite has grown. These have royal blue interference colors under crossed nicols.

The shaly character of many of the rocks of the gorge are in part dependent upon the amount of the clay, the kind of clay, the place of it in respect to the calcite and to the fabric or orientation of the flaky substances, and to the looseness of the interlocking of the constituent minerals.

The shaliness of the Genesee Gorge rocks is discussed later under the term, Preferred Compositional Ranges (see Fig. 6F).

Collophane:—Sanford (1936, pp. 799–801) was much interested in the phosphate nodules that occur in these rocks. He hoped that their presence marked definite horizons. Perhaps they do, but this was not substantiated by this study. In the field they are seen as shiny, rounded, dark brown to black pellets, frequently with pitted surfaces, ranging from pea to bean in size. The microscope reveals that collophane, the essential mineral of these nodules, is common, especially in rocks with an appreciable carbonate content. In thin section they are pale brown to straw in color, and opaque under crossed nicols, justifying the expression amorphous; the modern term should be perhaps pseudo-amorphous, as X-ray studies have revealed an apatite crystal lattice (see Plate IH and J). There are usually many inclusions within the masses. Detrital quartz is common but the universal mineral is a black opaque. The surface of this is dull as seen by reflected light and appears to be without any pattern. It is suspected that it is a ferrous sulphide common in sediments, known as hydrotoilite.

The collophane masses occur in two ways: as obvious pebbles, which have experienced considerable rounding and attrition; others are an essential part of the rock and have replaced fossil fragments. Usually the process of replacement is complete and none of the original carbonate remains. A few transitional stages, however, have been found to demonstrate the process. The source of the phosphate is regarded as organic, which is consistent with its occurrence in calcite-rich rocks.

Collophane is also recognized as constituting, at least in part, the network in many fossil fragments.

Collophane seems to be especially susceptible to replacement by compounds of iron, both of yellow-brown goethite and by earthy (cryptocrystalline) hematite.

Hematite:—Naturally hematite plays an important role in the Clinton. It takes many forms and possesses many degrees of crystallization. The two principal forms are the hematite of the Furnaceville and the adsorbed stain of the red Queenston and Grimsby. In the Furnaceville there are several varieties: (A) the powdery or submicrocrystalline, (B) microcrystalline, (C) specularite, and (D) martite.

Goethite:—The use of reflected light, such as obtained by the Leitz Ultrapac, reveals many grains of an opaque, bright yellow mineral in the slides of the Furnaceville. In spite of many attempts to affect a positive identification, there is considerable uncertainty regarding its true nature (see Plate IL and M). It occurs solely in the Furnaceville and at the same time white leucoxene is lacking in this member. These yellow grains could be iron-stained leucoxene. This seems reasonable, but what is the yellow stain? In the Furnaceville, iron compounds are available and hence the stain is probably an oxide or hydroxide of iron. Since the hematite is ferric iron and oxidation may have been part of the ore-forming process, the iron stain is likely to be oxidized as well. Goethite is a good guess. These yellow grains are apparently highly susceptible to further adsorption and replacement by hematite, resulting in flat discs with a hematite color which are insoluble in cold hydrochloric acid. Dr. Hoyt [Jones] (1943) reports these in the heavy mineral suites.

Pyrite-Marcasite:—Pyrite and/or marcasite occur in all of the slides. Most of them are in small units which occur either as round pellets showing a radial structure and a dull luster or as small cubical grains with a bright surface (see Plates IK and IVF). Sometimes the two are part of the same larger unit. Some of the larger grains are long stringers parallel to the bedding. Many of these have a core with a different color. This is a bright, metallic, slightly emerald green in color which contrasts with the brass yellow of pyrite margins. The core is probably marcasite. If so, the pyrite is later than the marcasite.

There are also megascopic discs of radial pyrite lying flat along the bedding planes. These have been found as large as a half dollar. Certainly this is a later development.

Pyrite is not evenly distributed. The Williamson and the Irondequoit are especially rich. In the Rochester and the Lockport the pyrite is in very small sizes as pellets and cubical grains.

Iron Sulphides and Carbonaceous Matter:—Closely associated with the pyrite-marcasite, either as separate masses or as marginal coatings, are dull black opaque substances. Their composition is not definitely known. They are believed to be iron sulphides which are known from many sedimentary rocks. Carbonaceous matter is not ruled out, however. Consequently, these black substances are regarded as possible mixtures of ferrous sulphides and carbonaceous materials. The latter is not the type usually referred to as bituminous. As many know, freshly broken pieces of the Lockport have a bituminous odor. Under the microscope, slides of the Lockport reveal cracks sometimes parallel to the bedding and styolites filled with a dark brown, oily material, unquestionably some form of bitumen. The styolites look as though they are the result of subsequent solution, the resulting cracks filled by the hydrocarbon.

Sulphates:—The Lockport has long been known to furnish mineral collectors with many beautiful specimens (Giles, 1920, Jensen, 1942). Many

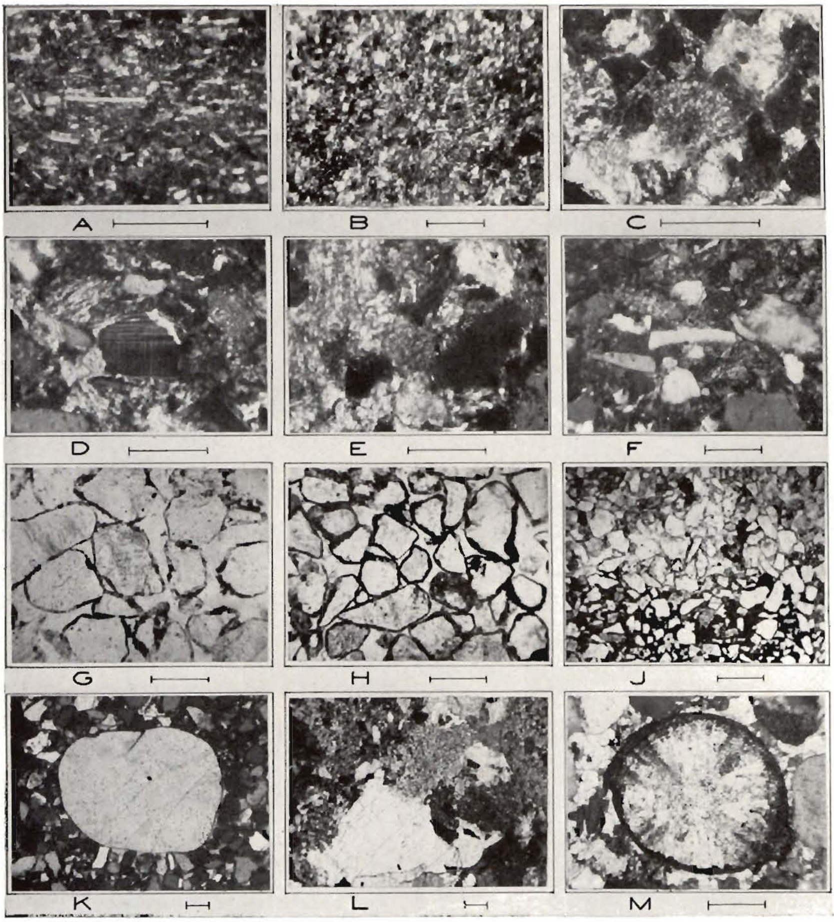


PLATE III

Length of scale, 0.1 mm.

A to E inclusive, Queenston. F to M, Grimsby. All from Genesee Gorge except M.

A. Queenston, .2 ft. below top. Red shaly bed, parallel to bedding, long flake of muscovite. Cross nicols. Orig. mag. X290.

B. Queenston, 6.5 ft. below top. Green shaly bed. Maplewood clay microphase. Cross nicols. Orig. mag. X174.

C. Queenston, 15.2 ft. below top. "Red Greywacke." Grain of glauconite in the center. Cross nicols. Orig. mag. X302.

D. Queenston, 4.3 ft. below top. "Red Greywacke," grain of oligoclase, center Queenston clay microphase. Cross nicols. Orig. mag. X240.

E. Queenston, 4.3 ft. below top. "Red Greywacke." Queenston clay microphase. Cross nicols. Orig. mag. X240.

F. Grimsby, 2.5 ft. above base. Queenston "Red Greywacke" type. Quartz grains. Cross nicols. Orig. mag. X174.

G. Grimsby, 26 ft. above base. Pink Grimsby type. Ordinary light. Note hematite coating quartz grains inside quartz cement. Orig. mag. X174.

H. Grimsby, 50 ft. above base. Red Grimsby type. Ordinary light. Heavier coatings than in G. Orig. mag. X174.

J. Grimsby, 54 ft. above base. Alternating red Grimsby (bottom) and pink layers (center). Ordinary light. Orig. mag. X140.

K. Grimsby, 54 ft. above base. Pebble in siltstone. Cross nicols. Orig. mag. X69.

L. Grimsby, 0 ft. above base. Recrystallized calcite (white) showing cleavage and a twinning striation. Cross nicols. Orig. mag. X69.

M. Grimsby, Densmore Creek, 27 ft. above base. Water-worn fossil fragment coated by hematite. Cross nicols. Orig. mag. X174.

of these minerals have been identified as microscopic grains in thin sections as well. In special slides, prepared without the use of water, little cubes of halite have been identified. All of these clearly indicate the increasing salinity of the Lockport sea.

Both anhydrite and gypsum occur in the Lockport. The microscope shows that the gypsum was derived from the anhydrite by hydration. There is no way of deciding whether the anhydrite was originally formed by dehydration of primary gypsum. In any case the present gypsum occupies more space than the anhydrite and has produced microfaulting and microfolding in similar fashion to that reported in Vernon-Camillus rocks of the Salina. The Lockport contains many geodes and solution cavities which show the corrosive effects of the saline waters.

Leucoxene:—This mineral is very abundant in all the slides. It is sometimes more abundant than quartz. The argillaceous rocks contain many, but small, grains. They can best be studied by reflected and transmitted light, first one, then the other, then both together. The Leitz Ultrapac equipment is very satisfactory for this purpose.

In color the leucoxene varies from porcelain white through straw, buff, yellow, yellow-brown to brown. The margins of many are translucent. The origin of these grains does not appear to be simple. Probably ilmenite is the main source; many of these grains have been sliced in the making of the thin section, and reveal that the transformation from the primary mineral to leucoxene has not always been complete, as many cores of ilmenite still exist. But the cores are not all ilmenite; some are sphene and others are rutile. The white material is largely hydrated titania, as recent analyses show (Coil, 1933, Edwards, 1942). The yellowish leucoxene appears to be stained by ferric iron. Slides of the Furnaceville show yellow opaque masses that are regarded as goethite-stained leucoxene.

Zircon:—One of the most interesting detrital grains of the accessory or "heavy" mineral group is zircon. It was found in almost every slide. "Heavies" are usually studied in loose grains from crushing, with care, a sample from a quarter to a pound of the rock. But it was found that thin sections show many of these minerals and they can be studied and measured in this form. Zircons frequently show crystal outlines, even though the corners have been rounded and a few have been fractured. In color they have a considerable range, from colorless, pale yellows, browns, greens, to opaque. Hyacinth is occasionally found. In shape they are short, stout grains, some with fair terminations to long thin needles. Dr. Hoyt (1943) reports "sawfish" authigenetic additions on some zircons. Only two such grains were found in thin sections of the Thorold. The grains have the appearance of having experienced several erosional cycles.

Tourmaline:—Tourmaline, together with zircon, is the most abundant accessory mineral in these rocks. The ratio of these two varies somewhat, but they are roughly equal in amount.

Perfection of rounding probably is attained by more tourmaline grains than any other mineral; not only are they round but many are circular as well. Certainly the roundness scale or standard for zircon does not apply to tourmaline, and awaits laboratory data for its construction.

For ranges of color and variety of pleochromism, nothing in these rocks equals this mineral. Colorless tourmaline is rare but yellows, browns, greens, and blues are common. Like zircon, tourmaline is one of the most stable minerals and very probably has been through many erosional cycles.

A few grains of tourmaline were found with authigenic additions, which are colorless or pale pink in color, usually in strong contrast with the colors of the core mineral.

Glauconite:—Occasionally small, roundish grains of glauconite are seen in almost every formation, although not in every slide (see Plate IIIC). No relation to known stratigraphic breaks is recognized. They appear to be more abundant, however, at the planes of possible diastems (Goldman, 1921).

Other Accessory Minerals:—Occasionally the following detrital minerals can be identified in the thin sections: hypersthene, diopside, corundum, anatase, rutile, brookite, allanite, garnet, magnetite, ilmenite, andalusite, and spinel.

The Absent Minerals:—These rocks are especially interesting in the minerals that are absent. Garnet is comparatively rare and when found is usually corroded. Hypersthene and diopside were the only pyroxenes found, but no amphibole. The feldspathoids and the olivines are conspicuous by their absence. Many minerals have been removed from these rocks since their deposition; many have been added. Sedimentary rocks are not closed systems. Diagenesis and leachings consist of many processes that seemingly never cease operating. Sedimentary rocks are complex, worthy of careful study.

IV. MICROLITHOLOGIES

Stratigraphers recognize that rocks intergrade horizontally, shales into sandy beds, marine sediments into continental rocks, gray sediments into red beds, etc. These are rock facies. Caster (1934) has crystallized our thinking by proposing two effective terms: magnafacies for rock types spanning more than one formation, and as a subdivision, parvafacies, limited to one formation. The boundaries of facies are not always parallel to the formational limits nor are they necessarily parallel to the planes of contemporaneity. Chadwick, in his studies of the Upper Devonian of New York, has used facies and has made extraordinary progress. He has done the science of stratigraphy a great service in recognizing that the Chemung is Portage, for example. But perhaps he did not always distinguish between formational units and parvafacies.

The term microlithologies (Alling, 1945) was developed and proposed through the observation that many of the formations in the Gorge are in reality composed of several distinct types of sediment. The term is essentially a microscopic one. An illustration of microlithologies is the Reynales formation. The lower beds are calcareous with a fluctuating argillaceous content. The latter are relatively thin shaly partings. These are not composed solely of argillaceous matters, but of carbonates, chiefly calcite, diluted (the word is used deliberately) with argillaceous substances. The expression "shaly limestone" would be a common one to use but the term is sterile. The formation is composed of at least two rock types: a limestone with the various types of calcite, a narrow range of quartz, feldspars, and accessory minerals, each with a characteristic modal grain size, and a finer-grained argillaceous rock with clay minerals and its own limited range of quartz, calcite, and accessories, each with its own grain size. The siliceous microlithology is a minor constituent. It is chiefly the relative *percentage* of the rock microlithologies that makes the formation. For this it is proposed that it be given formal expression in the *principle* of *complementary microlithologies.*

The microscope clearly shows that the multiple types were often deposited together; not a sudden cessation of one at the expense of the other. It is not the case of either limestone or "shale", but a mixing of the two in different proportions. The igneous petrographer is familiar with hybrid rocks. Much of the Reynales is one. The principle furnishes a clue to the manner in which limestones change into shales; it is the *percentage* of the microlithologies that changes, not necessarily a profound change in the composition of each microlithology.

Delésse-Rosiwal analyses by the Wentworth stage provide the percentage mineralogical composition of the rock as a whole. Each specimen can be further analyzed. The total composition can be subdivided in order to recognize the composite nature of the sediments. The calculation of the complementary microlithologies into the basic rock types, calcareous, argillaceous, and siliceous, was based upon the following procedure.

Calculation of Microlithologies:—The rocks which are largely composed of a single microlithology, argillaceous, for example, were selected as the basis for the computation of this particular microlithology. The composition of other specimens in the same formational unit were subdivided on the basis that the composition of the microlithology was similar even though other microlithologies are present.

1. All the clay minerals were assigned to the argillaceous microlithologies.

2. The frequency-distribution curves of quartz were divided into two parts: the small grains were allocated to the argillaceous, and the large to the siliceous microlithology. The point along the size scale that bisected these curves was based upon the size of the quartz of the standard sample. In the case of many of the formations this was close to .032 mm. The area of the two parts of the frequency-distribution curves was measured by a polar planimeter. The ratio of these two areas was used to divide the percentage of the total quartz. The basis of these frequency-distribution curves was geometric and not logarithmic in character.

3. The feldspar content was allocated by the same method as the quartz.

4. All of the recrystallized and fossil calcite was assigned to the calcareous microlithology.

5. The clastic calcite was divided between argillaceous and calcareous microlithologies on the basis that argillaceous rocks with a high clay content rarely contain more than 10% of clastic calcite. Consequently 10% of the clastic calcite was arbitrarily allocated to the argillaceous and the rest to the calcareous microlithologies.

6. The bulk of the accessory minerals were allocated to the siliceous microlithologies; a little (.1 to .3%) to each of the other two.

7. The clay content of the argillaceous microlithology of some rocks, especially of the Rochester and Lockport formations, was slightly increased over that measured by the Wentworth stage, because chemical analyses and insoluble residues showed a higher amount. The grain size of the clay of the Lockport is too small for Delésse-Rosiwal analyses. The clay content was increased ten per cent by subtracting that amount from that of the clastic carbonate as determined microscopically.

In some thin sections the reality of these multiple complementary microlithologies is amply substantiated by simple inspection alone; in other rocks, however, microlithologies become somewhat theoretical or artificial. These microlithologies are exactly comparable to the "normative minerals" used in calculating norms of igneous rocks from chemical analyses. The theoretical nature of some of these microlithologies in no way invalidates the usefulness of the concept, as the diagrams in this paper will show.

The results of these calculations were plotted alongside the geologic column, in three columns, one for each of the three microlithologies, argillaceous, calcareous, and siliceous. The width of these columns was scaled to permit the plotting of one hundred per cent of any one microlithology.

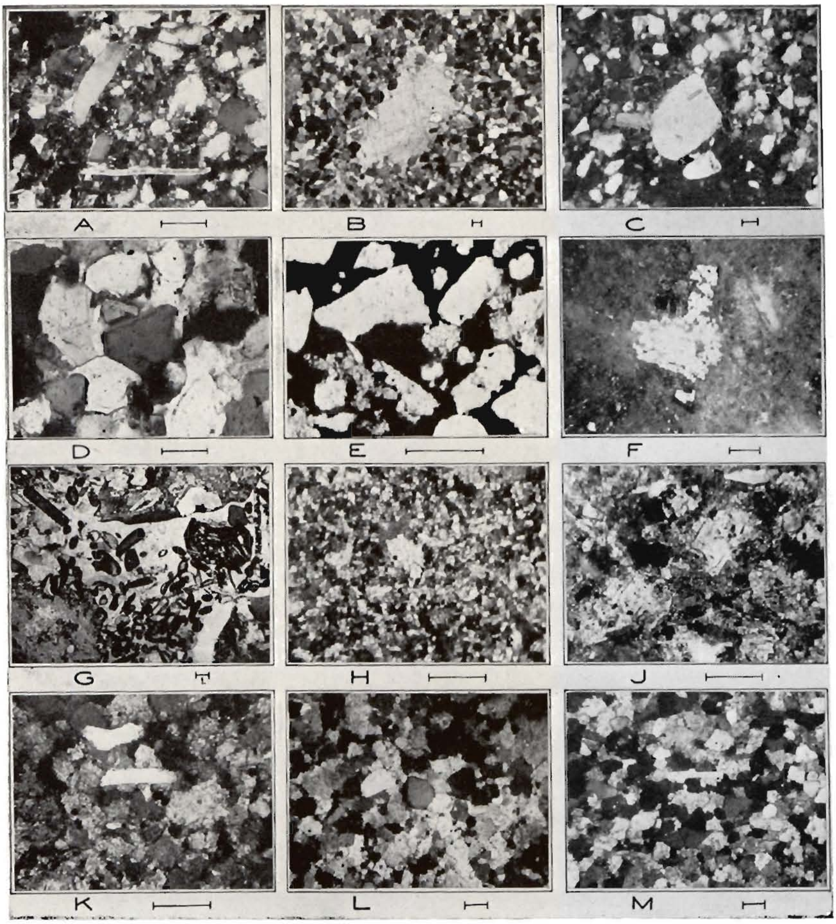


PLATE IV

Length of scale, 0.1 mm., except G, which equals 1. mm. Cross nicols, except E, F, and G.

A. Thorold, Albion, N. Y., 2 ft. above base, showing Maplewood clay microphase "framing" quartz grains. Near bottom, long flake of muscovite. Orig. mag. X140.

B. Thorold, Genesee Gorge, .1 ft. above base, showing crystoblast of recrystallized calcite, exhibiting twinning striations. Orig. mag. X26.

C. Thorold Genesee Gorge, .1 ft. above base, showing rutile needle in sand grain of quartz. Note Maplewood clay microphase framing quartz grains. Orig. mag. X48.

D. Thorold, Genesee Gorge, 2 ft. above base. Quartz grains cemented by added quartz. Orig. mag. X140.

E. Thorold, Genesee Gorge, 1.2 ft. above base. Clinton type of hematite (black) replacing calcite (rough grains) cementing quartz grains (grey). Ordinary light. Orig. mag. X240.

F. Thorold, Genesee Gorge, 1.2 ft. above base. Pyrite (white). Reflected light. Orig. mag. X94.

G. Furnaceville, Densmore Creek, .7 ft. above base. Entire slide, fossil fragments replaced by hematite (black) in calcite (grey) groundmass. Ordinary light. Orig. mag. X4.

H. Lower Sodus, Densmore Creek, 13.5 ft. above base. Just below upper pearly layer, showing very fine-grained limestone. Orig. mag. X174.

J. Rochester, Barge Canal, 5 ft. above base. Fossiliferous zone. Leucoxene and iron sulphide grains, black. Orig. mag. X174.

K. Rochester, Barge Canal, 63 ft. above base. Upper zone, "Gates limestone" quartz, splintery grains in limestone. Orig. mag. X174.

L. Lockport, Barge Canal, 78 ft. above base. Dolomite with quartz grains. Orig. mag. X69.

M. Lockport, Barge Canal, 88 ft. above base. Dolomite with quartz grains. Probably Lower Shelby zone.

In draughting these charts each microlithology was plotted along the central line (50% by weight) so each plot is bilaterally symmetrical.

The varying thicknesses of the formations and the distribution of available thin sections made it desirable to vary the vertical scale from chart to chart.

V. MICROPHASES

The listing of the names of minerals present in these rocks does not express at all what there is to see. There were various fabric, textural, and structural relationships that are characteristic of certain formations. This is not simply composition alone for it involves size, shape, roundness, and orientation, etc. of many minerals. Since minerals by themselves are not rocks they do not constitute rock microlithologies but rather mineral *microphases.* This distinction is patterned after Shand (1942). He applied this principle to a study of the igneous Cortlandt series on the Hudson. He used the term "species" in the same sense as "lithologies" is used here. This change in nomenclature does no violence to Shand's principle, however. The application of this method of attack has resulted in recognizing a number of characteristic microphases.

Maplewood Clay Microphase:—This type consists of clay minerals as fine, feathery shreds with a preferred orientation, some of which, however, lie in planes at right angles to that of the bedding. In oriented thin sections the latter are seen on edge up against the detrital quartz grains, "framing" them (see Plate IVA and C). This gives the illusion that the roundish grains are angular. It gives them the appearance of being rectangular and square cornered.

The Maplewood clay microphase was found in the Neahga of Niagara, in the Thorold of many localities. In the Genesee Gorge it was found at the top of the Grimsby, in the Thorold, in the shaly partings of the Reynales, in the Lower Sodus, and in the Williamson. It is, of course, the dominant microphase of the Maplewood. In the other formations it is significant even though it does not necessarily bulk large. Its presence shows that the conditions and processes that were responsible for it began in the top of the Grimsby and continued with diminishing quantity up to the base of the Irondequoit.

Other microphases were recognized: (A) the Queenston type of clay, (B) the Reynales type of calcite, and (C) the Lockport type of magnesian carbonate. Descriptions of these are given in the appropriate places.

VI. NOMENCLATURE OF SEDIMENTS

The common field terms—sandstone, limestone, and shale—are utterly inadequate for today's needs. This is not a new thought, however, for Grabau in 1917 (p. 743) stated that: "if we stratigraphers insisted on a more refined classification of our sediments, instead of being satisfied with conglomerates, sandstones, shales, limestones, and some minor types, we would make more rapid progress." A satisfactory classification of sediments presupposes a thorough knowledge of them. However, paradoxically, a classification of rocks is not a classification of rocks but a classification of ideas about rocks. Ideas about rocks change. We need ideas before we can have a classification. Instead of reviewing a host of terms and proposing new ones, as Grabau did, a simple way out of the difficulties has been adopted: to refer to the carbonate, the argillaceous, and to the siliceous rocks when composition and composition alone is intended.

Shaly beds, usually referred to as "shales", are abundant throughout the geologic column investigated; some of them, like the Maplewood, are entirely of this character. Many of the others consist in part of thin beds of stratified rocks, usually referred to as "shale partings." The ability of a shale to split parallel to the bedding is not necessarily the direct result of its mineralogical composition. The relationship is not that simple. To be explicit, the word "shale" is not used in this paper but instead the adjective form "shaly", as advocated by Wentworth (1922), is employed. Etymologically "shale" is not a compositional term. The amount of the clay minerals, as well as the kind, is a factor, but these are not the only, or even the essential, characteristics of shaly rocks. The fundamental cause is the orientation or fabric of the minerals which possess basal or flaky cleavages and the lack of effective interlocking of these layers. It takes only a small amount of the oriented flaky substances to produce a shaly rock.

Not all minerals which produce such a structure are clays even in a broad sense. Uralitic hornblende, the chlorites, and even leucoxene are important in producing foliated rocks. The orientation was apparently due to primary deposition and to subsequent compaction.

VII. THE FORMATIONS

The Queenston:—Of the 900 feet or so of the Queenston in the Rochester meridian, only the upper 26 feet have been sampled. The usual field description, "red shale", means very little. Some, however, have recognized the minor beds within the Queenston by referring to cherry red and green shales, and green to gray sandstone (Wilmarth, 1938), or red sandstone and shales, thin gray and green shales. Other expressions are red sandy shales and red arenaceous shales. The Queenston is a composite rock with heavy-bedded argillaceous siltstone layers with thin-bedded to fissile, fine-grained siliceous, argillaceous seams, and "shale partings", purple-red in color. There are also thin, massive to heavy-bedded, gray-green siltstones, not unlike, in a superficial way, the Thorold, and thin, bright green shaly beds.

On the outcrop much of the Queenston appears red in color but in thin section there are narrow streams that are not red at all. I cannot escape the growing impression that some of the red is either due to weathering or to added red stain from wash from indigenously colored members on exposure to the atmosphere. Here field observations have given a false impression which the thin sections clarify. The color is due to hematite and probably not due to ferric hydrate (Raymond, 1942). It is in submicroscopic units and is essentially a red stain on the surface of the micaceous minerals, there by adsorption. As it is very difficult to measure the amount of hematite present by the Wentworth stage, a few chemical analyses were made. The amount of ferric oxide in the red beds ranges from 2.67 to 5.13%. In the green types the ferrous iron is only slightly less. Oxidation of ferrous to ferric iron would account for the change of color from green to red. But there is more to this problem. The hematite is on the margins of the quartz grains, usually *beneath* the quartz content, as well as between the enlarged grains, and especially on the flakes of the clay minerals. In spite of the masking of many details of the characteristics of the clay by the hematite stain, the red Queenston seems to lack in large degree the chlorite possessed by the green and gray members. Was the iron of the hematite derived from the decomposition of ferrous iron-bearing chlorites, such as leptochlorite or penninite, and oxidized to the ferric condition? An affirmative answer seems reasonable on the basis of the present information. But why is the chlorite decomposed in some layers and not in others? Or was the iron introduced from the outside?

In the Niagara Gorge, Grabau (1901, p. 88) reported that "the shale is seamed by whitish or greenish bands, both parallel with or at . . . angles to the stratification plane . . . often extending to an inch on either side . . . due to percolating air or water, the latter probably carrying organic acids in solution . . . along lines of greater permeability."

The implications are that the rock was originally red and the organic acids have reduced the ferric iron to the bivalent condition. This can be carried a step further. This is based upon the observation that the green shaly layers carry the Maplewood clay microphase which is characterized by thin parallel strings of clays, not the bunched illitic types prevalent in the red argillaceous siltstones or greywackes. The microscope suggests that the green types were more permeable between the leaves of clay. Grabau reports slickensided surfaces on joint faces which show discoloration. The movement along these planes provided a channelway for the acid solutions.

In addition to these green bands, there are the perplexing gray-green spots. This phenomenon is not confined to the Queenston. They occur in many red beds. The Grimsby, the Vernon, and the Catskill of New York contain them as well. The position and arrangement of these does not seem to fit any pattern. Perhaps they represent spots due to leachings or, on the other hand, they are spaces not yet stained by hematite.

Quantitative analyses and grain-size measurements, etc., reveal no essential differences between the red and green areas except for the presence of red hematite. The presence or absence of carbonaceous matter, which has been often suggested for non-oxidation and oxidation, respectively, has not been established for these rocks.

Petrographically the Queenston is a red bed (see Plate III, A through E). Slides of some of the Catskill megafacies from New York State are very similar and cannot, except with thorough examination, be distinguished from it. The quartz grains are universally angular and many are splintery. Feldspar grains, while not abundant enough to justify the term arkose, are common.

The clay substances are distinctive. The low birefringence types are in the minority, the bulk being illite, hornblende, uralite, and various chlorites.

Muscovite flakes are very common but many show authigenetic marginal additions of illite and green chlorite materials. The micaceous minerals have not arranged themselves like frames around the quartz grains, as is the case with the Thorold. The clay masses are irregular in shape and occur in patches, not in thin streaks. This is the Queenston clay microphase.

Slides of siliceous flagstones in the upper portion of the Genesee Group of the Upper Devonian of New York, in the Keuka Lake region (Grossman, 1944), are comparable to the Queenston, except for color. Thus there exist two names, "shale" and "flagstone", for much the same kind of rock. Both of these possess many characteristics of relatively fine-grained representatives of the "Flysch" type of sediment, implying sources undergoing gradual uplift. They are continental in character with poor sorting, angular grains, and with interformational shaly beds with a dominant to predominant cementing matrix composed of various chlorites, illitic type of clay, and minor carbonates. In the case of the Devonian sediments, interfingerings of thin calcareous beds with a shaly structure, containing marine fossils, occur. These rocks I call greywackes, departing from the definition given by Twenhofel (1939, p. 289), because it does not fit the rocks described by geologists as greywackes. It is the amount of the cementing matrix that distinguishes them from "shales" on one hand and "sandstones" on the other. The use of the term "greywacke" recognizes the tectonic factor in the sedimentation, which is usually ignored. The work of Krynine (1941) is a notable exception. He called the Queenston a "red greywacke", colloquially. The shale partings of the Queenston alone deserve the name "shale."

Contact of the Queenston with the Grimsby:—The question of the age of the Queenston need not be rediscussed here.* Williams (1919, pp. 47–8) states that at Niagara the Cataract beds rest on the uneven, worn surface of the Queenston. A similar break repeatedly has been looked for in the Genesee Gorge. There are a large number of diastems within the mass of the red Queenston and Grimsby, any one of which, from field scrutiny alone, could be the plane of demarcation. The lack of continuous bedding, with obvious to obscure cross bedding, ripple marks, channel flutings, etc., make it impossible to draw the line. Perhaps no line should be drawn. As a practical measure, the dividing plane has for years been assumed to be at the base of the first heavy bedded siltstone layer; above is the Grimsby, below is the Queenston. It may well be that there is an unconformable contact at Niagara and in Maryland (Ulrich, 1911, pp. 252–257), but it cannot be located at Rochester. If the Whirlpool was recognized at Rochester, the unconformity probably could be found. From what can be seen in the field and under the microscope, the sedimentation was fairly continuous in the ordinary sense. This was the view maintained by Sanford in his classes at the University of Rochester. The gradation from one to the other is well shown in Fig. 2. The demarcation has been drawn at the customary plane assumed at Rochester. There is no assurance, however, that it has been correctly placed.

Paleontologically the distinction between the two formations is unsatisfactory. *Paleophycus tortuosum* occurs in the Queenston and *Arthrophycus alleghaniensis* is found in the Grimsby. It is reasonable to suppose that these worm burrows are in reality facies fossils, dependent upon the type of sediment (see Fig. 6F).

The Grimsby:—The excellent summaries of Schuchert (1914) and of Wilmarth (1938) make it unnecessary to present a lengthy discussion of use of the terms "Medina", "Albion", "Grimsby", "Cataract", etc. I have followed the example of Gillette (1940) in recognizing that the Medina (in its original sense) is divisible into two formations, the Grimsby above and the Cataract below. These are equivalent beds of different facies, that is, they are complementary units. The Grimsby is continental and the Cataract marine in character.

Since the rock at Rochester is chiefly a red siltstone possessing the facies characteristics of the Grimsby at Niagara, it is assumed that the Cataract facies is missing. The term Grimsby is used here.

The lower beds of the Grimsby at Rochester are very similar to the

* The United States Geological Survey accepts the Ordovician age for it.

underlying Queenston (see Plate IIIF). There are some slides that cannot be properly assigned unless recourse to the labels is made. Field and microscopic observations lead to a five-fold list of lithologic types: (A) heavy-bedded red siltstones, (B) heavy-bedded greenish gray siltstones, (C) red greywackes, (D) thin-bedded to fissile red argillaceous shaly partings, and (E) thin fissile green argillaceous rocks. (A) makes up the bulk of the Grimsby.

In terms of total composition, the Grimsby has slightly less clay and more quartz than the Queenston. The carbonate content, however, is about the same.

A study of the microphases shows that the clay in the lower half of the Grimsby (up to 26 feet above the base) is that which prevails in the section of the Queenston sampled. In other words it is the Queenston clay microphase. In the upper zones, however, the Maplewood clay microphase begins to appear. In the zone between 38 and 41 feet above the base there are two green shaly partings, the clay of which is largely that of the Maplewood type. In the red siltstones near the top of the Grimsby both the Queenston and the Maplewood types are present; at first the Queenston phase dominates, and then at the top, especially at Densmore Creek, the Maplewood kind is in the majority. This overlapping of the clay microphases stresses the interlocking and sedimentary intergradation of the two formation units. These microphases could well be studied more as they may prove of assistance in better understanding the sedimentation of these rocks.

The zone 38 to 41 feet from the bottom of the formation represents conditions of abrupt compositional changes. Not only do two green shaly partings occur within it but also six thin red shaly beds as well, separated by red siltstones. There is, in addition, a curious contorted layer with *Daedalus archimedes* and *Arthrophycus alleghaniensis,* pebbly beds approaching conglomerates and some layers with clay balls (Robertson, 1941). This zone is one of several of intraformational shale pebble conglomerates (Schuchert, 1914). All of these changes within 3 feet of sediment occur at the same zone as that of the maximum quartz content. This is graphically shown in terms of microlithologies in Fig. 2. It was necessary to omit some details due to the small scale. The composition of the microlithologies shifts somewhat but the large changes were brought about by the shift in the percentage of the argillaceous and siliceous microlithologies. The pebbly beds contain large grains of quartz, many of which are worn to almost perfect spheres (see Plate IIIK).

This zone has been recognized by Gillette (1940, p. 25) in the Clyde and Sodus Bay quadrangles. Cross bedding and ripple marks are common throughout the mass.

Fairchild (1901) long ago recognized the beach characteristics of the Grimsby in Western New York.

Sarle (1906) stated that the results of burrowing organisms known as *Daedalus archimedes* occur throughout the upper thirty feet of the formation and that *Arthrophycus alleghaniensis* is restricted to the lower 14 feet of this thirty-foot zone. These are plotted on the chart in Fig. 2.

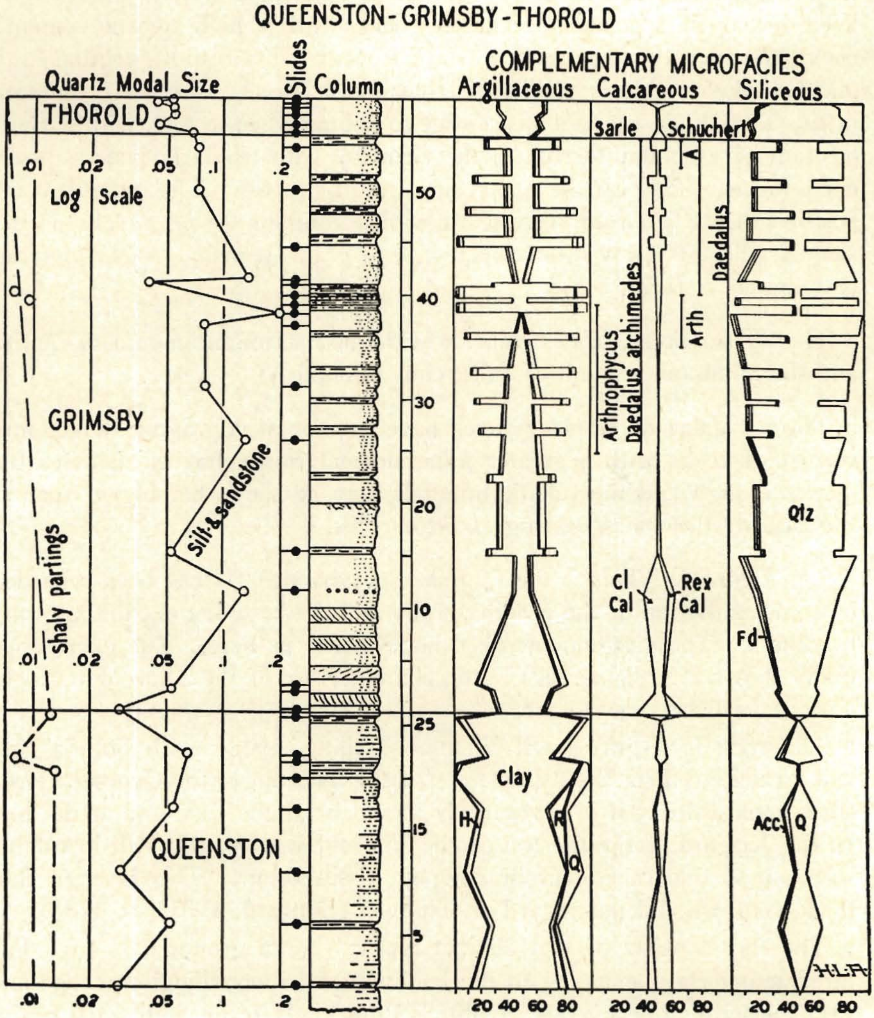


FIGURE 2

Queenston-Grimsby-Thorold Formations

Quartz modal size, measured in thin section, and complementary microlithologies.

Legend: Cl Cal = clastic calcite, Rex Cal & R = recrystallized calcite, H = Hematite, Qtz. & Q. = Quartz, Acc = accessory minerals. Plane at top of Queenston is the customary position assumed at Rochester.

Schuchert (1914) gave slightly different zones for these organisms, as is indicated alongside those of Sarle. The chief divergence is that Schuchert found *Arthrophycus* in the upper six feet as well as 15 to 20 feet farther down.

Field observations would suggest that Sarle's *Arthrophycus* zone contains well-developed specimens, while the upper zone of Schuchert is one with fossils less well developed. This is confirmed by the microscope. Well-developed specimens occur in rocks with a high quartz content; rocks in which those poorly developed occur contain more argillaceous microlithologies. It is significant that the relatively rare *Arthrophycus* in the Thorold in the Genesee Gorge is contained in a rock with a composition very similar to that in the Grimsby with similarly poorly developed forms. This can be appreciated in Figure 6B. The mineral composition of the Thorold at Niagara, which contains *Arthrophycus,* is the same as that of the well-developed zones of the Grimsby. *Arthrophycus* is definitely a facies fossil.

The *Arthrophycus* zones coincide with the maximum amount of quartz and the minimum amount of calcareous minerals.

The *Daedalus archimedes* zones have greater stratigraphic ranges and consist of rocks with a greater mineralogical range, but in all cases the quartz is high and the calcitic minerals may be somewhat higher than is the case of the zones bearing *Arthrophycus.*

The Thorold:—This is the familiar "grayband." It has been regarded by some as the top of the Medina group and the base of the Clinton group by others. These arguments need not concern us here. The microscope easily shows a fundamental Clinton characteristic of the Thorold at Rochester, as will be shown later.

The rock is a gray-green siltstone (Alling, 1943) with both a clay and a calcite cement. All the slides of the Thorold in the Genesee Gorge show some calcite; it is particularly abundant at the base and at the top. In the Niagara Gorge the top of the Thorold is especially rich in calcite, so much so that calcareous brachiopod fossils occur. This layer, a foot thick, Sanford did not regard as Thorold (Sanford, 1935a, p. 173).

The clay consists of two distinct types: (A) a groundmass of a low birefracting clay belonging to the kaolinite and montrillionite groups and (B) micaceous phenocrysts of illite. Both kinds frame individual grains of detrital quartz. These flakes produce the illusion that the quartz grains are angular and often square in cross section (see Plate IVA, B, and C). It takes a little experience to observe that the quartz grains are in reality subangular and have been authigenically enlarged by added quartz and thereby cemented together (see Plate IVD).

Grain size measurements were possible in the majority of the grains only after the most patient and careful study, otherwise the measurements would include quartz cement which would have little significance. Curves of the true grain sizes and those which include the quartz cement are compared in Fig. 1B. The grain size of the quartz of the Thorold is, on the whole, slightly smaller and less rounded compared with the underlying Grimsby. If the Thorold is to be regarded as reworked Grimsby, at least in part, these observations are not incompatible. Gillette (1940, p. 40) says "the sediment itself . . . may have been derived from the underlying Grimsby." The Thorold at Glen Edyth, however, shows the same size of quartz as the underlying Grimsby; the clay content is slightly less than is the case in the Genesee Gorge. Here the reworking of the Grimsby may not have been as extensive as at Rochester. The amount of zircon, tourmaline, leucoxene, and so on, appears to be more abundant than in the Grimsby. However, the hematite-stained clay of the red beds effectively obscures the accessory minerals which reduces the accuracy of the Delésse-Rosiwal analyses.

A red band or lens a tenth of a foot thick occurs slightly over a foot above the base of the Thorold in the Genesee Gorge. In the field it was regarded as a red shaly, recurrent seam of the Grimsby interbedded in the Thorold. Such an interpretation would strengthen the opinion that the gray band is closely tied to the beds underneath. I was fortunate to have a chip of this narrow red streak thin sectioned. It turned out not to be a red argillaceous rock but a Clinton type of "iron ore", more siliceous than the Furnaceville, but essentially a limestone which has experienced considerable replacement by the characteristic earthy type of hematite, not the hematitic stain of the Grimsby adsorbed by the clay substances (see Plate IVE). As there is no characteristic so typical of the Clinton as "iron ores", this slide ties the Thorold, at Rochester, to the Clinton group.

Chadwick (1935) has presented a question that illustrates the problem of correlation by paleontologic means without considering the changing rock facies. The Thorold, both at Thorold, Ontario, and at the Niagara Gorge, contains the work burrow *Arthrophycus alleghaniensis*. Chadwick reported that at Rochester this fossil is lacking and on this basis questioned that the "grayband" is Thorold. At Lockport he reported finding *two* sandstones separated by a few feet of green shale. His conception is that there are two sandstones, each of which deserves a formational name: the lower one the Thorold, and the upper one, which he named the "Kodak." Sanford (1935b, p. 1390) reports the presence of *Arthrophycus* in this rock in the Genesee Gorge, and furthermore questions its value as an index for correlation. Sanford is inclined to believe that what Chadwick attempted to explain is best understood as a change in the rock facies in the absence of critical fossils.

The specimens of the "grayband" from the Genesee Gorge in the Museum of the University of Rochester, several of which were collected by Sanford, contain *Arthrophycus* (see Fig. 6B). They are not as striking as those from Thorold, Ontario, nor are they as well preserved, nor as large. Such specimens evidently are rare; these are the only ones I have seen, so Chadwick's failure to find this worm burrow is not surprising. The rarity of *Arthrophycus* in the Thorold at Rochester may well be because of the difference in the composition of the rock from that at Niagara. Gillette reports that *Arthrophycus* is occasionally found in the Thorold to the east. At Rochester, the Thorold is more argillaceous and constitutes a different environment, evidently unfavorable for the organism that made these burrows. The few feet of green shale at Lockport is evidently a band of the same argillaceous substances that constitute the green shaly partings of the Grimsby. Not only is it unnecessary to use the term "Kodak" but its introduction further adds to an already overburdened nomenclature.

The presence of the Maplewood clay microphase in the Thorold is another reason for assigning it to the Clinton Group.

Chadwick's (1918, p. 334) suggestion that the Thorold at Rochester is not closely related to the underlying Grimsby is not fully understood. He gives no reason for this conclusion. Sanford (1935b, p. 1390) says "this is a matter of opinion."

Farther to the east at North Wolcott, Gillette (1940, p. 43) reports that as the Thorold was being pried from the creek bed it broke up into polygonal pieces. Many of these are separated by thin green shale dividers, apparently composed of the same kind of clay as that parallel to the bedding. This suggests that the Thorold was formed in shallow water in which the sediment was covered from time to time with mud which filtered down the sun-baked cracks.

The Maplewood:—The microscope shows that the Maplewood is very different in many ways from the Lower Sodus with which it was confused by Hall, an error which Chadwick (1918, pp. 331, 334) had the good fortune to discover by plotting the well records of Newland and Hartnagel (1908). Chadwick had an excellent basis for the introduction of the term Maplewood. As fossils are lacking in this rock, his basis was chiefly stratigraphic.

The Maplewood contains a higher percentage of argillaceous substances than any other rock in the gorge. It is bright olive green in color, highly fissile, and very unctuous when wet.

The upper portion contains the interesting calcareous flattened pellets which Sanford (1935a, p. 175) compared with the size and thickness of a dime (see Plate IIA). He was puzzled by them. Under the microscope they are seen to be clay pellets, or balls, with a coating of calcite. The calcite appears to be an encrustation acquired by being rolled around in a lime mud. By compaction the balls became flat pellets.

Calcite occurs in every slide, as small rhombs. In contrast to the low birefracting clays, the calcite under cross nicols is brilliantly lighted and has been recrystallized. The rhombs are usually framed by illite flakes. Some of the calcite acts as cement.

Clastic quartz is always present. The percentage is naturally low with the high clay content. The quartz grains are universally small in size and very angular. With the low amount of quartz, the percentage of feldspar is less than a tenth of one per cent by weight. They, like the calcite, are usually framed by illite flakes.

The clays consist of kaolinite, montmorillonite, illite, and chlorite. It is the latter mineral that gives the rock its green color. There is some secondary muscovite, a few flakes of which have an illite core. A few slides exhibit a curious "basket weave" pattern. The pattern is oriented in respect to the bedding; most of the fibrous flakes are parallel to it; some are normal to it. The character of the clay of the Maplewood is microscopically very distinctive. It appears as a minor constituent in the Thorold, Brewer Dock, Furnaceville, and upper Reynales. It does not appear above the base of the Irondequoit.

Further information on the problem of the Neahga-Maplewood relationship was obtained from Cuylerville, 30 miles south of Rochester. Here 5.2 feet of bright olive green shale occupies this position. From hand specimens alone it could well be either Neahga or Maplewood, but on closer examination a 0.2-foot layer, four feet above the base, contains black-brown nodules of phosphate. The interesting thing is that a thin section of this layer shows, in addition to phosphate nodules, which consist of collophane, considerable recrystallized calcite and grains of detrital quartz of Thorold size, cemented with Maplewood type of clay. It was apparent that this rock was very similar to Sanford's (1935a, p. 173) unnamed bed one foot thick at the top of the Thorold (in his sense) at Niagara, which contained *Coelospira* and underlies Sanford's Neahga. If these microscopic discoveries are taken at their full value, it could be argued that at Cuylerville both the Maplewood, below, and the Neahga, above, occur, while only one rock, the Neahga at Niagara and the Maplewood at Rochester, are present. Perhaps too much has been read into this, probably after all it is the same formation, differing slightly in minor facies changes from locality to locality.

The Brewer Dock Member:—Between the green Maplewood and the red Furnaceville are 3 feet of gray calcareous beds with shaly partings. These have been sometimes confused with the underlying Maplewood but their similarity with the Reynales limestone above the Furnaceville has been well recognized. Chadwick (1918, pp. 342–343) called these three feet "Bear Creek." Sanford (1935a, p. 179) believed these do not correlate into the area of Bear Creek and consequently gave it a local name, "Brewer Dock." It serves well for the present.

The usual field expression, "limestone and shale," fails to indicate the true character of the rock. The composition of the Brewer Dock can be appreciated in terms of the three microlithologies: argillaceous, calcareous, and siliceous. This is shown in Fig. 3. The shaly layers are composite of three microlithologies. The two principal microphases present are the Maplewood clay microphase and the Reynales carbonate microphase. The former has been described; the characteristics of the latter consist of clear grains of calcite, many of which have been recrystallized but not to the extent of developing twinning bands. The presence of the clay substances seems to have prevented the formation of large-sized grains except near the top of the Reynales where the clay content is low. There are clastic grains of calcite as well. The microscopic character of the Reynales carbonate phase is shown in Plate IG.

The recognition of these two microphases illustrates the overlapping character of these rocks; the clay is like that below and the carbonate is like that above. It is the carbonates that obscure the green color of the chlorite and consequently the Brewer Dock is gray when fresh and buff when weathered.

Analysis of each of the shaly layers shows how the clay phase enters into the makeup of the rock. It will be noticed (Fig. 3) that the lowest shaly layer does not contain the maximum amount of clay but is rather low, while in the next higher layer a large amount occurs. From this point upward to the top of the member, the clay content diminishes at a fairly uniform rate and becomes the lowest in the Furnaceville. Of course, in percentage, the amounts of carbonates are complementary, greatest when the clay is lowest in amount.

In the limy layers the same story is repeated in somewhat the same manner; the lowest layer is relatively high in calcite. In the second layer the carbonate is very low only to increase to nearly 100% at the top, which in the next member above became the relatively clay-free lime rock which was the Furnaceville originally, before partly replaced by hematite.

The same pattern prevails in the Upper Reynales as will be shown later.

The thickness of these shaly layers likewise follows much the same pattern: thick at the bottom and thin at the top. The size of the recrystallized calcite in the limy layers, in the form of the mode, is small at the bottom and large just below the Furnaceville. These relations may be determined only through microscopic measurements.

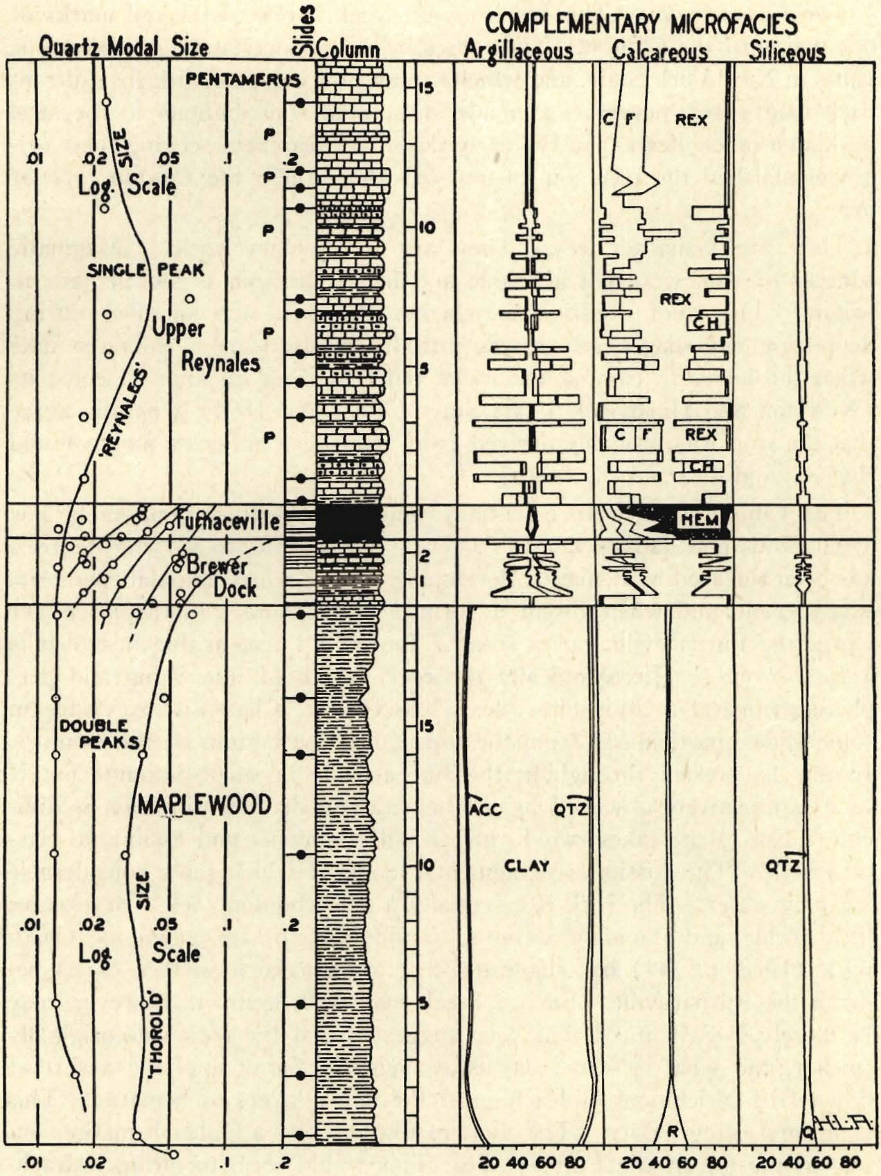


FIGURE 3

Maplewood, Brewer Dock, Furnaceville, Upper Reynales

Quartz modal size, measured in thin section. The frequency distribution curves of quartz grains of the Maplewood are double peaked. The larger size is called "Thorold size", the smaller, "Reynales size." The Brewer Dock and the Furnaceville show multiple peaks, showing mixed conditions. The Upper Reynales shows single-peaked curves.

Legend: C = clastic calcite, F = fossil calcite, Rex, R = recrystallized calcite, Ch = chert, HEM = hematite, Qtz. Q = quartz, P = *Pentamerus* layer.

The Furnaceville:—This hematite-rich rock is one of the red marks of distinction of the Clinton. These ores, while not outstanding in economic value in New York State, and which cannot now compete with the Adirondack magnetites, nevertheless made substantial contributions to the steel backbone of civilization in the early days. Researchers seeking their origin established the common custom of calling these the *Clinton type of ore.*

They are hematite ores. They are sedimentary rocks. Magmatic sources of iron were not available and hence the iron is sedimentary in origin. The chief question is whether the iron was supplied during deposition and diagenesis or was introduced afterward. It is the date when the hematite painted the rocks red that is in dispute. Geologists (Newland and Hartnagel, 1908; Smyth, 1892 and 1894) generally agree that the iron was probably derived from lateritic weathering and polluted the seas and dwarfed the fauna.

The Clinton ores were essentially limestones, with a remarkably low argillaceous and detrital quartz content. The calcite, to varying degrees, has been replaced by hematite, developing oölites, when colloidal chamosite was present, and when absent it formed "fossil" ore. In the Rochester Gorge the Furnaceville varies from .7 foot to 1.4 feet in thickness. It is a fossil "ore". Microscopically the rock is full of interesting and perplexing mineral relationships (see Plate IVG). Chamosite is visible in some slides, particularly from the top and at the bottom of the member. It may be present throughout the Furnaceville in small amounts but if so it is effectively obscured by the hematite so that identification is difficult. The calcite takes two forms: fossil fragments and as minute clastic grains. The fossils are fragments, many of which show considerable wear by water. The rock is essentially a paleocoquina rock. Bryozoans, little corals, and abundant sections of crinoid stems are common. Chadwick (1918, p. 344) has suggested that a wave-worn surface exists beneath the Furnaceville. Such a break may well occur; it, however, may be merely a diastem. It has been suggested that the rock was originally thicker, and what is seen today is a condensed form, implying a sort of downward enrichment by leaching of the upper layers of hematite. This is an interesting theory. The chart in Fig. 3 shows a higher hematite content at the top of the Furnaceville. This would seem to mean, if leaching occurred, that the downward enrichment did not enrich the bottom layers to the same extent as the top. The concentration of fossil fragments in the Furnaceville is not any greater than in other non-hematite zones in the Reynales. The dwarfed forms, however, make more fossils per unit volume.

The two major theories of the origin are: (A) that the ores are primary, deposited essentially in the same condition as they occur today except for compaction and diagenesis, and (B) that they were formed by replacement of original limestones by downward percolating waters which secured the iron in some form from areas of laterization. That is, the ore would be secondary. The implication is that one or the other of these theories, not both, is true. These statements are clear and distinct, but they are too definite to fit the facts.

There are implied concepts in these statements which may not be fully realized but that have an important bearing on the clarity of thinking. To an economic geologist "primary" and "secondary" mean more than first and second, more than a mere order of events. They have come, through usage, to convey something more. They are almost synonyms for syngenetic and epigenetic, respectively. The real obstacle is the word "replacement." It has an important place in the second theory. The word "replacement," apparently conveys the added thought that it can only occur as a secondary process. This is not necessarily so.

This investigation has proved that the earthy or cryptocrystalline hematite in the Furnaceville at Rochester has replaced to a large degree calcite formerly constituting fossil fragments, but it does not follow that the epigenetic hypothesis is thereby substantiated. There is much objection to referring to the second theory as the "replacement theory." The difficulty seems to be that replacement can well have been contemporaneous with and, indeed, may have been an essential part of the diagenesis of the rock. If so, the hematite is syngenetic in the sense of the first theory but it was brought about by replacement as well, an expression which is an important thought in the second theory. Smith * recognizes this syngenetic replacement in a slightly different manner by saying: "The ferruginous waters came in contact with calcareous shell fragments; . . . the iron was precipitated partly by reaction with the lime carbonate, yet mostly by oxidation, while the lime was carried off in solution by the aid of the carbon dioxide set free . . . This method of replacement is widely different from the other process of replacement that has been applied to the ores . . . The iron is a secondary product as regards the individual particles of ore, it is primary in relation to the ore bed itself."

There are therefore four aspects to the problem:

(1) Precipitation of the iron.
(2) Reaction with the calcite.
(3) Replacement of the calcite.
(4) Oxidation of the ore (if it occurred).

There is some danger in this separate listing as it gives the impression that all are independent events. They probably occurred together and are merely aspects of one and the same interlocking process.

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*Smith, C. H., Jr., quoted in translation by Newland (1908, p. 52).

The iron solutions or colloidal suspensions derived from areas supposedly distant, containing both potential hematite and chamosite, stabilized by organic acids would, in contact with the electrolytes of sea water, be precipitated. Reaction with, and replacement of, the calcite liberated lime which neutralized the organic acids, further promoting precipitation. If some of the iron was originally in the ferrous condition, oxidation occurred as well.

Twenhofel (1939, pp. 390–391) says: "Perhaps a combination of the view of original deposition and replacement shortly after deposition best meets the conditions to be explained. The fossil ores are certainly replacements."

From the occurrence of the ostracods, Gillette (1940, p. 49) reaches the conclusion that "the Furnaceville is a lithologic designation and carries no time connotation. It simply represents a condition . . . under which 'iron ore' was forming. It is highly probable that all the ore did not form contemporaneously."

It seems that the essential conditions for the formation of the Clinton iron ores were that they were limestones and at the same time iron-rich solutions were precipitated. The combination seems to have been necessary; neither factor alone was capable of producing them.

The hematitic beds are low in argillaceous substances and usually contain chert. When the clay content approaches ten per cent, or the chert is about twenty per cent, hematite does not occur. Iron, however, is not necessarily absent; it is in the form of pyrite, but not to an equal amount.

At Glen Edyth there is no hematite-bearing rock. There is about 1.4 feet of a cherty bed with pyrite, in the Furnaceville position. Hematite is absent, but is the Furnaceville absent? If it is, then what is called "Furnaceville" is a facies. If the Furnaceville is present then it is what Caster called a "stage" or perhaps, since it is a member of the Reynales formation, it is a "substage." This little problem subtends a major one for stratigraphers to straighten out some time. Gillette (1940, p. 49) comments that the Furnaceville is a "designation" which implies that it is a facies. I have called the rock at Glen Edyth "the gray Furnaceville." But the red ore reoccurs six miles further east at Fruitland. The ore is "pinched out" between Densmore Creek and Fruitland. Is the high clay or chert content sufficient to explain the absence of the hematite? The present investigation would suggest this as the cause.

The Upper Reynales:—Chadwick (1918, pp. 334–5) has shown that the limestone carrying *Pentamerus* in the Rochester Gorge is not the Wolcott as long supposed, but rather the Reynales. The name comes from Reynales Basin, eight miles east of Lockport. Miss Goldring (1931) regarded the Reynales formation as a tripartite limestone. Sanford (1935a,

p. 179) agreed but substituted the term "Brewer Dock member of the Reynales" for Chadwick's "Bear Creek." This is the basis for using the expression "Upper" Reynales.

In the Rochester Gorge it is not all limestone. Approximately the lower two-thirds of the upper Reynales contains shaly partings. These shaly beds are hybrids, best appreciated in terms of microlithologies. Field observations and studies of the thin sections have resulted in recognizing four lithologic types: (A) shaly partings, (B) non-*Pentamerus*-bearing limestones, (C) cherty beds, and (D) *Pentamerus* layers.

Gillette (1940, p. 51) has pointed out that there are six *Pentamerus* layers in the Genesee Gorge. However, they do not correlate from section to section but merely represent similar ecological conditions. Gillette, therefore, did not accept Sanford's (1935a, p. 177) attempts to show by the presence and absence of *Pentamerus* that the Reynales formation varies in age from place to place (Gillette, 1940, p. 53).

The Shaly Partings:—Thirteen shaly partings were recognized and measured in the Genesee Gorge. They do not consist solely of argillaceous matters; they are essentially mixtures of argillaceous and calcareous rocks. The percentage of the argillaceous microlithology in these shaly partings is low at the base, rapidly assumes large proportions, and then tapers gradually to extinction at about 10 feet above the base; theoretically at 12.4 feet (see chart, Fig. 3). The uppermost shale parting (9.7 feet above base) contains only 27%. There are no more such beds above this. The trend of the percentage of the argillaceous microlithology from that point upward is towards zero.

However, not all of the 27% is clay; the latter constitutes only 8%. This shows, unmistakably, that the term "shale" is not solely a compositional one. The amount of the shaly producing factors is the amount of clay, the kind of clay, cleavage, orientation, and grain size, and they are not gradational in their effects but sudden. Unfortunately the relations of these factors are not completely known.

The Non-Pentamerus-bearing Limestones:—These beds consist essentially of one microlithology composed of large amounts of recrystallized calcite, very small amounts of quartz, and accessory minerals. Fossil calcite makes its appearance 10.6 feet above the base. These fossils are not necessarily *Pentamerus*. Fossil calcite continues to the top of the formation. This new element in these limestones coincides with the reduction of the amount of the argillaceous microlithology. Of equal interest is the presence of clastic calcite in fair amounts co-existing with the fossil calcite. This indicates that some clastic calcite was derived from wear on the fossils themselves, probable due to wave abrasion in situ.

The Cherty Beds:—These cherty beds are confined to the lower two-thirds of the Upper Reynales, coinciding with abundant argillaceous microlithologies. The calcareous microlithology, even though the chert has been assigned to it, constitutes only eighty per cent. In other words, the cherty beds, in addition to the chert, contain up to 20% of the argillaceous microlithology. Chert and a definite amount of clay always go together, a relationship not revealed by the usual field observations. Has the clay provided the conditions favorable to the presence of the chert? Is it a case of providing just the right amount of permeability and adsorptiveness? Silica as a gel apparently was able to penetrate the rock in spite of the clay, became adsorbed and partially dehydrated, being trapped by the clay. The exact amount of clay seems critical. Either below or above 20% argillaceous microlithologies, or 4 to 5% clay, there is no chert.

The Pentamerus Layers:—Of course, paleontologically, these are the most interesting. Here the emphasis has been on attempts to decipher the paleoenvironment. Gillette's thesis is that they represent the same ecological conditions. In the first place they are nearly mono-microlithologic, composed of 95 to 100% of the calcareous microlithology. The amount of clay is always less than 3% in these beds.

In thin sections, in contrast to the impressions acquired from hand specimens, fossil fragments, chiefly those of *Pentamerus,* range consistently between 18 to 26% by weight of the rock, for the bulk of the calcite is recrystallized and clastic. Only in two cases is there more fossil calcite than clastic. The calcite inside two valves of a complete *Pentamerus* specimen is clastic. The same conditions obtain in the pearly layers of the Lower Sodus (see Plate IIJ).

There is no chert. The amount of quartz and accessory minerals is always low and fairly consistent in all six of the *Pentamerus* layers.

In the clay we apparently see the major controlling factor. It is less than 3%. Beds above this amount do not contain *Pentamerus.* Consequently, with a slight increase of clay, the correlative value of this brachiopod disappears.

Chadwick (1918, p. 345) says "Westward the Reynales . . . is persistent . . . but eastward it grades into shale, and finally [is] indistinguishable . . . from the Sodus shale above it." This relationship would become very striking in terms of complementary microlithologies, especially in graphic form.

The Lower Sodus:—Hartnagel (1907, p. 13) applied the name Sodus, but Chadwick (1918, p. 341) amended it to fit the proper unit in the Genesee Gorge, as Hartnagel, through Hall's error (1843), applied the name to the Maplewood; a case of mistaken identity. Ulrich and Bassler

(1923) divided the Sodus into two parts, largely on the basis of ostracods. To the upper part they attempted to restrict the name Sodus; the lower part they proposed to call the "Bear Creek." Gillette (1940, p. 54), however, believed that the choice of the latter name was unfortunate for several excellent reasons. Hence, to avoid "adding another name to the already overcrowded terminology," he proposed "Lower and Upper" Sodus. Only the Lower Sodus is present in the Genesee Gorge.

The Lower Sodus, like the Upper Sodus as well, consists of three lithologic types: (A) purple shaly beds, (B) green shaly beds, and (C) thin beds rich in *Coelospira hemispherica,* which are pearly layers. Unfortunately for clear thinking, (A) and (B) have been called "shales" and (C) limestone, giving the impression of great compositional differences between them. In terms of the actual composition, however, as plotted in terms of microlithologies in Fig. 4, the Lower Sodus is essentially a limestone. Thin sections of the Upper Sodus from the Clyde and Sodus Bay Quadrangles, acquired through the kindness of Dr. Gillette, suggest a slightly lower carbonate content. As can be seen, the chart shows quantitative data for understanding the cause of the shale structure; that is, there is sufficient clay to give the limestone a shaly structure.

The Purple and Green Layers:—The cause of the difference in color between the purple and green layers is somewhat obscure. Chlorite is undoubtedly the cause of the green tint, and dusty hematite adsorbed on the surface of the flaky clay minerals is the reason for the purple coloring. How much is original and how much, if any, is due to subsequent weathering is uncertain. This is another illustration of the same problem: red versus green color in sedimentary rocks.

The Pearly Layers:—A common expression found in the descriptions of these layers is that they are "composed entirely of *Coelospira hemispherica.*" (Gillette, 1940, p. 57). Certainly hand specimens give this impression. The microscope shows otherwise. Fossil calcite, definitely assignable to this brachiopod, constitutes only from 21 to 32% by weight. Both recrystallized and clastic calcite are present in considerable quantities. Much of the latter occurs inside bivalves and is packed around them (see Plate IIJ). The layers are lenses and do not have any horizontal continuity. Certainly they do not correlate from section to section. They are similar in composition and clay content to the *Pentamerus* layers of the Reynales.

The Pearly Layers contrast with the *Pentamerus* Layers of the Reynales, of course, in the fossil content. Here the question is raised, are there sufficient differences to suggest the ecological reasons for the differences in the organisms? The *Pentamerus* layers are lower in the argillaceous microlithology and in clay. *Coelospira hemispherica* does occur in shaly beds as well as in the Pearly Layers, while *Pentamerus oblongus* does not. The critical argillaceous microlithology content that separates the two is evidently about 12% (see Fig. 6C). The other major difference between the two is that there is more fossil calcite in the Pearly Layers, 21.3 to 31.8%. This is due to the closer packing of the smaller shells of *Coelospira.*

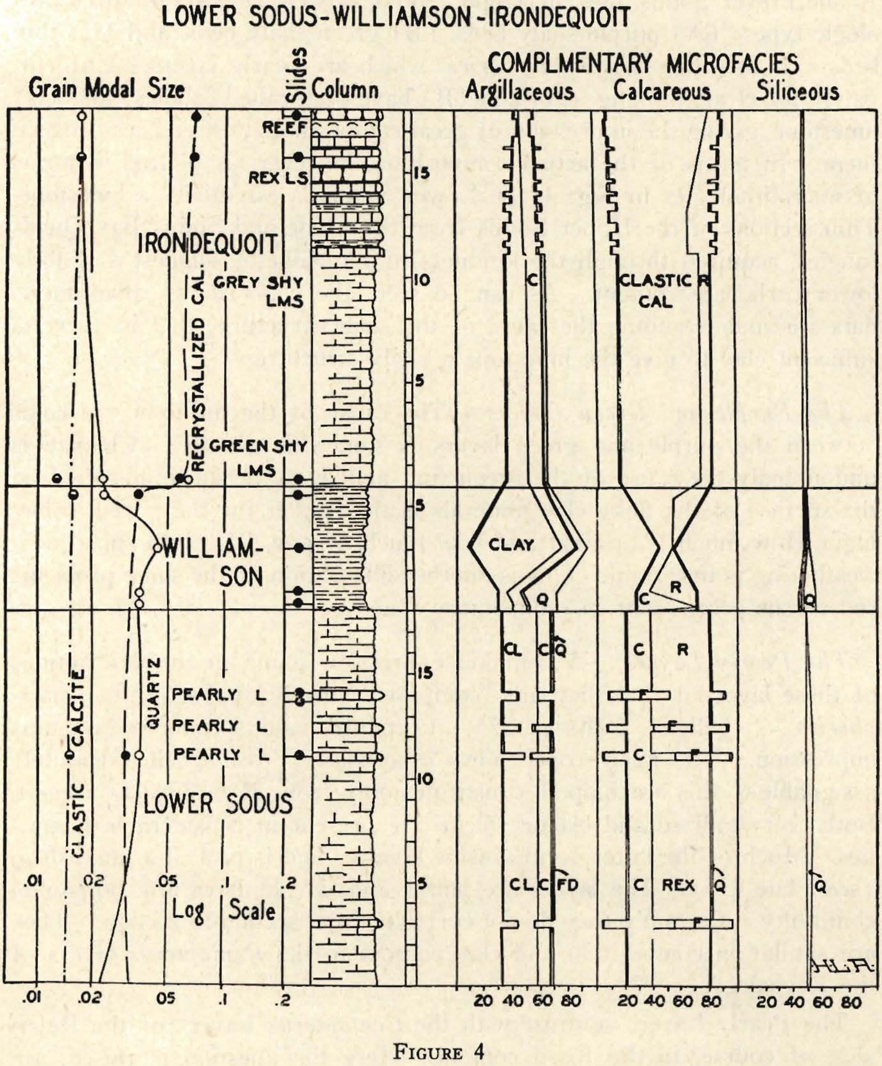


FIGURE 4

Lower Sodus-Williamson-Irondequoit Formations

Grain modal size, measured in thin section. Quartz size is that of the Reynales.
Legend: Cl, C = clastic calcite, Rex, R = recrystallized calcite,
F = fossil calcite, Q = quartz.

This shows that *Pentamerus* requires a virtually clay-free environment, while *Coelospira* can endure some. It does not explain why *Coelospira* does not occur along with *Pentamerus* in equal amounts. To be sure, *Coelospira* is found in the *Pentamerus* layer but apparently never to the dominating extent of the latter. Both of these fossils are obviously facies fossils. This is apparently the principal reason why ostracods are regarded so highly; they are more independent of the type rock in which they are found.

The Williamson:—The Williamson, named by Hartnagel (1907, pp. 15–16) and restricted by Chadwick (1918, p. 348), with its graptolites is so strikingly different in color from the underlying Lower Sodus and the overlying Irondequoit, that it comes as a surprise to find that most of the Williamson is essentially a limestone, perhaps not to the extent possessed by the Lower Sodus, as it contains considerable quartz. The presence of so much quartz means that a new element has entered into these sediments. This change in composition coincides with the unconformity at the base of the Williamson; the Upper Sodus, the Wolcott, and the Wolcott-Furnace are absent at Rochester. The Williamson is more variable than is generally apparent. The rock ranges from dark olive green to jet black in color, with very thin, gray-blue limestones with *Plectambonites transversalis,* a rock which is similar to that containing the *Pentamerus* and to the Pearly Layers. Some layers, as above noted, are almost quartz siltstones. There are also some pebbly beds which some call conglomerates. The Williamson apparently represents an unstable and a new phase in the sedimentation of the rocks at Rochester, with very rapid oscillations and pulsations.

The graptolites are in thin, black seams interbedded between the argillaceous siliceous limestones. In composition, the graptolites themselves appear to be chitin stained by black iron sulphides and organic matter. So effective is this stain that the general impression is that the Williamson at Rochester is a "black shale." So conclusive are the microscopic findings, however, that the Williamson is essentially an argillaceous siliceous limestone, dark gray to blue gray in color, that discussions regarding the habitat of graptolites, which ignore the limy nature of the rock, may not be highly significant. The slides of graptolite "black shale" show that the organisms are confined to bands averaging less than 0.2 mm. thick. The rock only splits along these bands because they, and they only, have enough clay to be shaly. Associated with the remains of the graptolites, chiefly *Monograptus clintonensis,* are small grains and aggregates of pyrite, or what are now pyrite. This type of pyrite is usually regarded as "primary". Megascopically there are discs with radiating structures up to 25 mm. in diameter along the bedding planes. These are "secondary". Both appear to have been derived from black iron sulphides.

Under reflected light both types are seen to be heterogeneous in color and in structure. These grains and discs are not solely marcasite nor pyrite, but both in varying amounts. In spite of this change the "blackness of color . . . persists after the black sulphides of iron become marcasite or pyrite." (Twenhofel, 1939, p. 304.)

The Irondequoit:—The 18 feet of rock assigned to the Irondequoit provide six lithologic types: (A) at the base green shaly limestone usually called green "shale", (B) the middle portion of gray shaly limestone, commonly referred to as gray "shale", (C) thin to relatively thick limestone layers, (D) gray shaly limestone partings with much the same composition as (B), (E) the coarsely recrystallized limestone with a lower clay content than (C), inappropriately called "crystalline" limestone, and (F) the Bryozoan reef near the top.

It is clear that much the same kind of rhythmic sedimentation that characterizes the Upper Reynales prevailed in the Irondequoit as well. It began with argillaceous material, rich in chlorite. The clay gradually increased in amount and the rock is gray in color with a loss of chlorite or its submergence by the clay. Beginning at 11 feet from the base, thin limestones separated by shaly partings prevail up to 14 feet above the base. Then the lower, coarsely recrystallized limestone bed occurs. Above this the thin shaly partings are thinner and separated from each other by greater distances. Above 16.4 feet no more shaly partings occur. At 17 feet the interesting reef underlies the upper coarsely recrystallized limestone.

These microlithologies point the way to the concept of two parvafacies: the shaly facies and the limestone facies. But the two are separated by a zone of interbedding or interfingering. This can be seen in the field. On correlating the Irondequoit westward it is found that the limestone parvafacies dominates, while to the east it is shaly parvafacies that is most abundant. It would appear that they are complementary to each other. To the east the shaly parvafacies increases in thickness at a faster rate than the thickening of the limestone parvafacies. Each parvafacies appears to contain its own faunal characteristics.

Microscopic examination reveals traces of sulphate minerals, such as anhydrite, gypsum, barite, and celestite. These have been identified with difficulty. Galena was suspected in one slide. All of these minerals are in traces and not as abundant as they are in the overlying Lockport. The small grain size of the clay constituents suggests a slight increase in the saline character of the Irondequoit sea, which shows more abundantly in the Rochester, and even more so in the Lockport. The slightly magnesian content of the Irondequoit is regarded as in conformity with this suggestion.

In the field the contact between the Williamson and the Irondequoit is difficult to draw because of the shaly nature of the base of the latter. Especially to the east, "most of the workers in the past have considered that the Irondequoit included only the limestone," (Gillette, 1940, p. 77) and hence included the gray shaly beds with the Williamson. Gillette, however, assigns the gray shaly beds, which contrast with the dark olive-green beds, to the Irondequoit. These gray shaly beds are "transition" beds. Many stratigraphers at times seem to be reluctant to admit that such beds exist. It is as though the classification must be maintained; the boundaries between formations must be made sharp and clear, in spite of the field facts. The Irondequoit is an illustration. The common practice of a dual nomenclature, "Irondequoit limestone", often leads to the confusion. It will be noticed that this paper does not use dual names.

The Lockport Clay Microphase:—These lower beds contain a new phase, not before encountered. From the top portion of the Grimsby to the top of the Williamson the clay content is the Maplewood microphase. In the basal Irondequoit the clay is in very small units, just visible with an oil immersion objective, and is seen inside rather than outside the calcite grains. This is clay-clotted calcite. This microphase, called the Lockport, is characteristic of the Irondequoit, of the Rochester, and of the Lockport formations.

The Irondequoit is allied to the Rochester petrographically. Gillette (1940, p. 85) has shown that the faunal content of the limestone portions of the Irondequoit are in many instances quite different from those in shaly portions. Many of the latter are identical with those in the Rochester. In fact, he assigns the Rochester to the Clinton, differing from Chadwick (1918, p. 354) who excludes it, partly on this basis.

The Lower Irondequoit:—The Delésse-Rosiwal analysis of slides of the 13.7 feet of green and gray shaly beds of the lower Irondequoit are similar to the shaly partings in the upper part of the Reynales.

The calcareous minerals are finer-grained in the Irondequoit and contain the internal form of clay (Lockport clay microphase). The clay of the shaly Reynales is of the Maplewood type which is dominated by the white mica (illite), while the clay of the Irondequoit is chiefly of the kaolin and chlorite groups.

It will be noted that the amount of the argillaceous microlithology in the shaly Irondequoit, 29.9%, is nearly the same figure as that of the argillaceous microlithology content of the uppermost shaly partings of the Upper Reynales.

In terms of the amount of clay, however, the two are somewhat different; 19.1% for the shaly Irondequoit and 9.0% for the shaly partings

TABLE 2

Microlithologic Analysis of Lower Irondequoit and Shaly Partings in Upper Reynales

	Argillaceous Microlithology						Calcareous Microlithology							Siliceous Microlithology			
	Qtz	Fd	Clast Cal	Clay	Acc	Total	Qtz	Fd	Rex	Clast Cal	FF	Acc	Total	Qtz	Fd	Acc	Total
Shaly Irondequoit ..	.5	1.	10.	19.1*	.2	29.9	.2	–	6.	59.	2.8	.1	68.1	1.4	.1	.5	2.0
Shaly Reynales	8.0	.5	10.	9.0°	.7	28.2	1.0	.2	6.7	62.4	0	1.0	70.4	1.0	.1	.3	1.4

* Lockport clay microphase type
° Maplewood clay microphase type
Fd=Feldspar, FF=Fossil Fragments

Qtz=Quartz
Rex=Recrystallized calcite
Acc=Accessory minerals

of the Reynales. A greater similarity actually exists, however, when it is realized that there is a very different type of clay in the two rocks; the "internal" type in the shaly Irondequoit, and the "external" type in the shaly partings of the Reynales. The 19.1% of the former, because it is inside of the calcite, is not in a position to be as effective in producing the shale structure, hence it takes more of it to accomplish this. Both rocks have about the same degree of shaliness even though the clay content of the two differs. Consequently the physical environment for the organisms may have been essentially the same. Gillette (1940, p. 85) says: "In lithology the highest shale layers [of the Irondequoit] resemble the Rochester."

The Upper Irondequoit:—The upper portion of the formation is not all limestone, as the gray shaly beds continue to near the top as shaly partings. The limestone beds are fine-grained. The mode size of the recrystallized calcite is .07 mm., while that of the clastic calcite is .0175 mm. The small grain size of the former is in great contrast to the very large grains of recrystallized calcite in the non-*Pentamerus*-bearing Reynales, the mode of which is .325 mm. However, there is a light-colored limestone .4 feet thick near the top of the Irondequoit, with abundant recrystallized calcite, which has been referred to as "crystalline", that contains recrystallized calcite with a mode grain size of .225 mm.

The Bryozoan Reef:—Sarle (1901) pointed out that the bryozoan reef near the top of the Irondequoit is composed almost entirely of *Fistulopora tuberculosa* and *F. crustula.* Under the microscope the rock is very fine-grained. The mode of the clastic calcite grain size is less than .005 mm., which serves as a groundmass in which are set occasional phenocrysts of recrystallized calcite and fossil forms. The groundmass is what Grabau called a calcilutite. These reefs arch up the overlying beds of the Irondequoit and of the Rochester as well.

The Rochester:—Petrographically the Rochester and the Lockport are much alike. To obtain quantitative results with the microscope has been difficult because the clay content is not readily discernible. Examination with high magnifications reveals that the clay is in such small units that much is suspected as being submicroscopic in size and not measurable. Hence chemical analyses were resorted to but they were not completely satisfactory because they needed recalculation into probable minerals before comparisons could be made.

A chemical analysis of the Rochester formation from Rochester, presumably from a publication of the United States Geological Survey, was recast years ago as follows:

TABLE 3

Recast of Chemical Analysis of the Rochester *

Quartz	11.6
Microcline	4.0
Plagioclase	2.5
Calcite	36.0
Magnesite	8.5
White Mica	23.2
Kaolinite	10.0
Chlorite	2.7
Accessory	1.5
	100.0

* Lantern Slide, University of Rochester, Department of Geology.

On this basis it will be seen that the quartz, the feldspars, and the clays, together with the accessory minerals, total more than half the rock, a finding not revealed by the microscope.

The other two analyses available are from Hamilton, Ontario, which, because of the distance from Rochester, are of little value to the immediate problem.

TABLE 4

Chemical Analyses of Rochester Formation, Hamilton, Ontario *

	I	II
SiO_2	22.00	22.52
Al_2O_3	12.65	8.12
FeO	1.77	1.13
Fe_2O_3	0.46	1.01
CaO	20.81	21.83
MgO	7.77	10.14
H_2O	7.20	4.00
	72.66	68.75
°CO_2	27.34	31.25

° By difference, added by author
I. 3 feet above base
II. Upper 4 feet.

* Analysis by Mines Branch, Department of Mines, Ottawa. Given by M. Y. Williams (1919).

Attempts to recast these reveal that there are several ways these analyses may be treated. The nondetermination of the alkalies prevents calculation of any feldspars and white micas. Nevertheless the clay content ranges from 35% to nearly 40%. Consequently, insoluble residues were resorted to. Perfectly consistent results were difficult to obtain, probably due to the destruction and partial solubility of minute clay particles and the production of colloid suspensions. This is especially true if there is any beidellite type of clay mineral present and boiling hydrochloric acid is used (Grim, et al., 1937).

The results of measurements of the clay content were consequently increased by deducting 20% from the value of the clastic calcite and adding that amount to that of clay. This was done to the analyses of the fossiliferous and barren zones. In the case of the "Gates" the figure was reduced to 10% as the rock does not possess such a shaly structure.

Under the microscope the Rochester is seen as an aggregate of magnesian calcite, usually small, with modes ranging from .03 to .09 mm., in size, dirty and clotted by kaolinite type of clay, black sulphides of iron and ferric oxides from decomposed pyrite (see Plate IVJ and K). Some grains are slightly recrystallized, but the gradation from clastic to recrystallized is so continuous that any division into the two types would be purely arbitrary.

Pyrite and leucoxene are very abundant but as they are small grains they do not bulk large.

Paleontologically the Rochester can be divided into three parts: a lower, fossiliferous portion, a middle barren section, and the upper part with some fossils. This upper portion has received the local designation of "Gates limestone" by Chadwick (1918, pp. 335–364).

Petrographically the Rochester is a dolomitic limestone with a shaly structure. In detail it consists of thin to heavy-bedded layers of dolomitic limestone separated by numerous shaly partings. These two types are somewhat similar to each other, both in appearance and in composition.

In terms of the three complementary microlithologies, as in the chart, Fig. 5, the similarity of the three paleontological divisions is obvious. The lower fossiliferous portion has a slightly lower argillaceous microlithology content than the barren zone, with 24% recrystallized calcite and about 6% fossil calcite. The barren zone possesses a slightly higher argillaceous content, the fossil content falls off to zero.

In the upper portion the argillaceous microlithology is low, ranging from 10 to 14%. This permits the calcareous microlithology to increase from 75%, average of the barren zone, to about 85%.

So potent is the effect of the argillaceous microlithology in producing a shaly structure that the slight decrease from that in the barren zone to that in the upper zone results in sufficient differences so the rock has been regarded as distinct from the underlying barren zone. Chadwick (1918, p. 360) says it is "separated from . . . [the beds] below by a perfectly clean cut line or clay seam" and gave it the name "Gates limestone." He says it is apparently missing at Niagara. Gillette does not mention it. Chadwick's "clay seam" is one of the many shaly partings that are characteristic of the whole of the Rochester.

The upper zone is somewhat similar to the top limestone zones of the Upper Reynales and the Irondequoit. If the top limestone of the Rochester formation deserves a special name, why not the others as well?

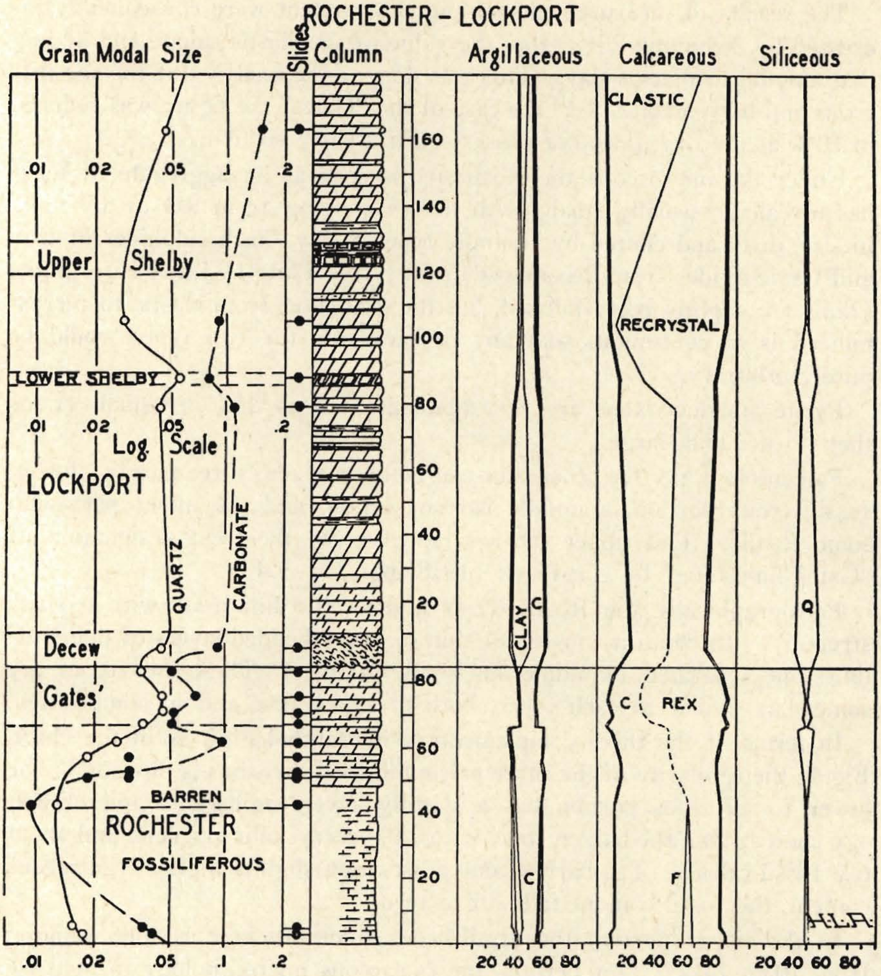


FIGURE 5

Rochester-Lockport Formations

Grain modal size, measured in thin section. Quartz and carbonate. Position of the Shelby zones only approximate.

Legend: C = Clastic carbonate, F = Fossil carbonate,
Rex = Recrystallized carbonate, Q = Quartz.

The term "Gates," in the sense proposed by Chadwick, is a formation, for he says it is "separated from the Rochester shale [restricted] below," that is, he wants to restrict the term Rochester to the fossiliferous and to the barren zones in order to erect a new formational unit. His reason for advocating this is that the rock is really a limestone which has been quarried and sold as such (Schuchert, 1914, p. 304). It has in years past been used for lime. But so is the rest of the Rochester a limestone, with a shaly structure. A more practical method would be to regard the "Gates" as a member of the Rochester.

Actually the "Gates" is a rock facies. The retention of the name "Gates", as a formation or as a member of the Rochester, is deemed inadvisable.

The Lockport:—The Barge Canal, west of Rochester, provides an excellent exposure of the Lockport. The structure of the rocks, which involves two anticlines and a fault, necessitated a plane table survey in order to accurately place the collected specimens in the geologic column. For this I am indebted to C. M. Reed and A. S. Gale, Jr. The base of the Lockport is represented by the Decew member, named by Kindle (1914), which varies from 2 to 10 feet in thickness. It is a dark gray, argillaceous, cross-bedded, dolomitic limestone with a churned or "curly" structure. Williams (1913) reports that it is difficult to separate it from the Rochester. On the other hand, Chadwick has long emphasized the unconformity at the base (Swartz, 1942, p. 535), even granting that some of the material of the Decew may be reworked Rochester. That such a break does occur here, I am convinced, but as to its magnitude, I have no new contribution to make.* Schuchert (1914, p. 304) says "Time break, if any, [was] short." In the winter the ice on the surface of the Barge Canal provides an excellent vantage point to see a wide exposure of the contact. It is unquestionably undulatory. The Decew sags down into slight hollows in the uppermost Rochester ("Gates"). A narrow outcrop does not reveal it. Gillette could not see the unconformity at Lockport, although he made a special trip to that locality. Petrographically the Decew is much like the underlying Rochester and the overlying Lockport. The sedimentation was, essentially, continuous. Slides of the Decew reveal more quartz than most of these rocks; except for this mineral the rock is very similar.

The classification of the 175–180 feet of rock calls for a brief review. As long as the Clinton was recognized as a "formation" then the Lockport is one also. As the Clinton is now recognized as a "group," the question arises, to what group does the Lockport belong? This is an old problem. The term "Lockport group" is rejected by the United States Geological Survey. Gillette (1940, p. 97) says many authors do not consider it necessary to use a group name. This is satisfactory as long as the Guelph is considered to be a part of the Lockport. But some geologists regard the Guelph as a separate formation overlying the Lockport, particularly in Ontario (Shaw, 1937), but in New York State the United States Geological Survey assigns the beds containing the Guelph fossils

* This is an old problem, to which many have contributed. It need not be rediscussed here.

to an indivisible portion of the upper part of the Lockport dolomite. Still this does not answer the fundamental question: Is the Guelph a fauna only? Or is it a member of the Lockport? Or is it a rock facies in which the Guelph fauna exist? Hartnagel (1907) says the Shelby dolomite in the Guelph dolomite "is to be regarded both as a faunistic and a lithologic Guelph element in the succession of the strata." Swartz, et al., (1942) say: "The typical Guelph fauna has not been observed east of Wayne County, New York. Whether this means a hiatus or simply a change in facies cannot here be affirmed." Arey (1892) was the first to recognize the Guelph in the Rochester region. Clarke and Ruedemann (1903) noted that these fossils occur in two beds, called the Lower and Upper Shelby, respectively. They gave the following section from Oak Orchard creek, south of Shelby village, in the southwest township of Orleans County, New York:

(Top)		
4. Upper Shelby dolomite	8–10	feet
3. Lockport dolomite	32	"
2. Lower Shelby dolomite	3	"
1. Lockport dolomites	62+	" (largely covered)
(Base)		

This section is some 37 miles west of Rochester. Hartnagel (1907, p 20), however, gave the above section as probably similar to that of the Rochester region, and stated (1907, p. 24) that the total thickness of the Lockport, including the Guelph, "is not far from 130 feet," which is probably too low a figure. Chadwick (1917, p. 172) has furnished additional measurements. From the top down, 90 feet of Guelph, which includes six feet of Eramosa beds; below this are "60 feet plus possibly 15 feet, as yet unexcavated." He gives 10 feet to the Decew beds. These figures total 175 feet, a value very close to that measured by him aided by students along the Barge Canal and given on a chart in the University of Rochester. Reed and Gale, by their plane table survey, measured 180 feet.

I have used the figure of 180 feet and have approximated the positions of the Guelph fauna-bearing beds on the chart, Fig. 5. There is still much uncertainty regarding the exact position of these paleontologically interesting beds in the Rochester region.

Reed's (1936) microscopic studies of the insoluble residues of the Lockport furnished his basis for dividing the Lockport as a whole into four divisions: the lower two corresponding to the "undivided Lockport"; division III is the Eramosa member of Williams (1919) and number IV is the Guelph, which conformably overlies. The Eramosa is Williams' top member of the Lockport in Ontario; the Gasport member of Niagara underlies. Reconciliation of Hartnagel's and Reed's sections can be effected by regarding the 62 feet of Hartnagel as only a portion of the thickness of the Lockport below the lower Shelby. The true value is about 85 feet.

In terms of complementary microlithologies, the Lockport is quite similar to the underlying Rochester. It differs in a slightly lower argillaceous microlithology content, dropping below the critical amount for producing a shaly rock. The rock contains more magnesia and is essentially a dolomite. Van Tuyl (1916) has expressed the view that the dolomite of the Lockport is primary and directly connected with the increased salinity that culminated in the Salina salt deposits.

Slides of the rock in which the lower Guelph fauna occurs show some chert; otherwise the rock is about the same as the upper portions of the Lockport.

VIII. PREFERRED COMPOSITIONAL RANGES

The quantitative microscopic analyses of these rocks provide some information regarding the physical environment prevailing at the time the various organisms, now preserved as fossils, inhabited these seas. The microscope cannot provide all the information desired, however, any more than the fossils themselves furnish all we would like to know. The rocks are not photographs of these vanished conditions for they have been changed by additions and subtractions. Sedimentary rocks are not closed systems.

Thin sections have been cut from rock specimens containing fossils. The composition of these rocks, when analyzed and plotted, clearly shows that there are *preferred* compositions. In Figure 6 the three-fold complementary microlithologies are plotted on equilateral triangular graphs. More could have been accomplished with this method if paleontologists were in the habit of reporting the exact horizons from which fossils were collected. An exception is the data of Sarle (1906) and of Schuchert (1914).

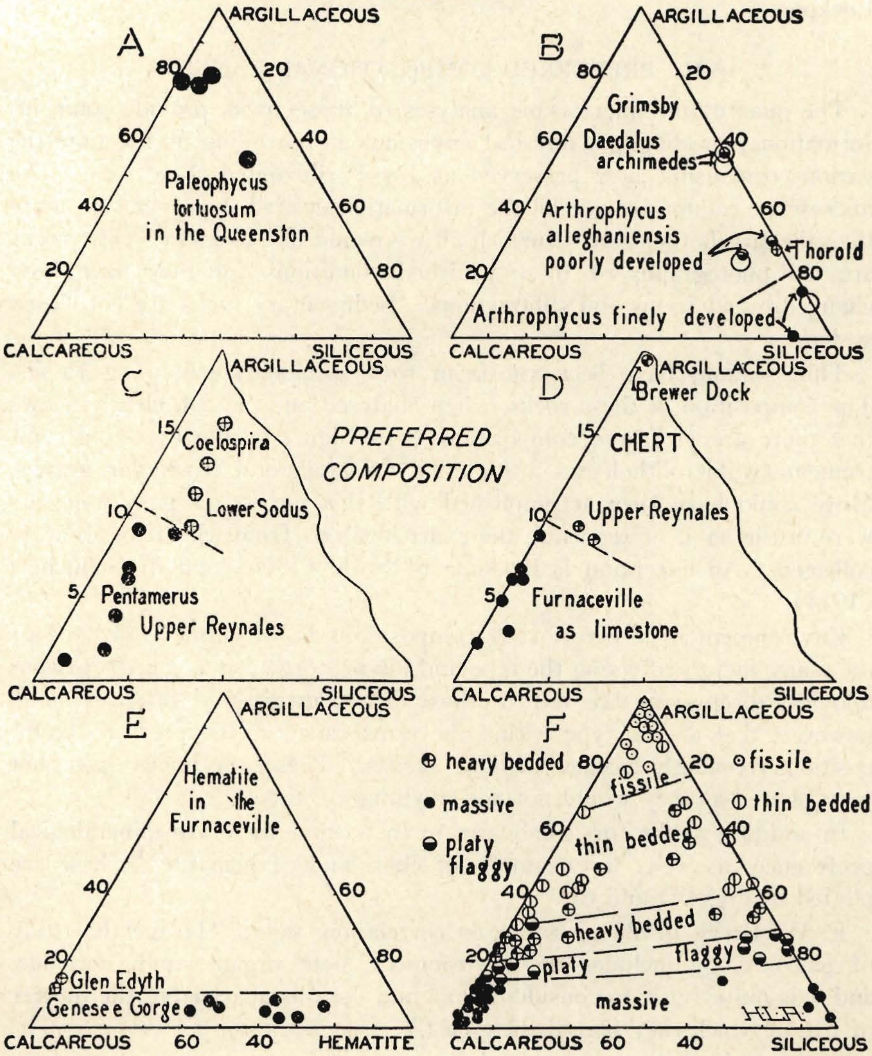
Environment in terms of rock compositions is, of course, only one of the many factors affecting the type and kind of organism. Purely paleontological discussions are left to those better qualified. It was found, however, that a rock type within the same range as the preferred composition frequently occurs without fossils. These specimens have not been plotted as they would not add anything of value.

In addition to the fossil habitates in this sense, there are mineralogical preferences as well; for example, of chert and of hematite. These are plotted in Figs 6D and 6E.

E. W. Berry (1925), writing on correlation, says: "To me the study of paleontology includes the environment, both organic and inorganic, and it is quite futile to consider fauna and flora as apart from the theater of life in which they played their part."

The biologic effect of these preferred ranges upon the organisms themselves is beyond the scope of this paper. However, certain conclusions are possible. The effect of the environment as reflected by the mineral composition of the rocks is much more important than formerly realized. In other words, the rocks, or rather the conditions under which these rocks were made, governed and controlled the kind of megascopic fossils. All the fossils included in this study are facies fauna. They can be used to correlate similar facies. Their value as index fossils for the correlation of contemporaneous formations is consequently not high. Microscopic forms, especially the ostracods, are not affected by their en-

FIGURE 6



vironments anywhere to the same extent as the larger forms, hence they are of much more value.

IX. SUMMARY

The rocks investigated and discussed in this paper range from the summit beds of the Queenston up through and including the Lockport. Sanford (1939) says: "The formations fall into three divisions: the first, in which a terrestrial influence is strongly felt, includes the Queenston, Cataract, and Albion; the second, which is marked by variability, is composed of formations lying between the top of the Thorold and the top of the Williamson; and the third, which is made up of the Irondequoit, the Rochester and Lockport, is dominated by a marine influence." This threefold division is based upon paleogeography in terms of uplift, transgression, and regression.

The microscopic studies emphasize a tripartite division as well. The bases for these three divisions are the complementary microlithologies and the microphases. This is given in Table 5.

A comparison of the two classifications shows them to be the same. This identity is more significant when it is realized that they were constructed entirely independently and on totally different bases.

There are two cases that lack clean separation in Table 5, the Thorold and the Irondequoit. The former belongs to Division I as seen by the x's in column 2. But note the x's in columns 6 and 8 which characterize Division II. The Thorold therefore has some properties of both. The Thorold is placed in the Clinton by some and excluded by others. The finding of the little stringer of "ore" is a petrographic discovery which tips the scales to a Clinton age. The Thorold is, however, transitional.

FIGURE 6

Preferred composition in terms of three complementary microlithologies measured in thin section.

A. *Paleophycus tortuosum* in the Queenston, Genesee Gorge, occurs in highly argillaceous rocks ranging from thin-bedded to fissile in shaliness.

B. *Daedalus archimedes* and *Arthrophycus alleghaniensis* in the Grimsby and Thorold, Genesee Gorge.

C. *Coelospira hemispherica* in the Lower Sodus and *Pentamerus oblongus* in the Upper Reynales, Genesee Gorge. Truncated triangle. The *Pentamerus* layers are lower in the argillaceous microlithology.

D. Chert-bearing beds, Furnaceville, Brewer Dock, and Upper Reynales. Truncated triangle. The Furnaceville calculated as limestone.

E. Hematite in the Furnaceville. Specimens from the Gorge contain hematite, and less than ten percent of argillaceous microlithology. Those from Glen Edyth contain no hematite and more than ten percent of the same microlithology.

F. Plot of 90 specimens of sedimentary rocks from the Rochester region in terms of shaliness as determined by inspection of hand specimens. The dashed lines are "contours of shaliness." 85 percent of the area of the triangle are "shales." Siliceous content reduces shaliness as is shown by the slant of the "contours" towards the calcareous corner.

TABLE 5

Tripartite Division by Petrologic Analysis

	1	2	3	4	5	6	7	8	9
	Tri-partite division	Essentially silic. and argill.	Essentially calcitic and argill.	Essentially dolomitic and argill.	Queens-ton type of clay	Maple-wood type of clay	Lockport type of clay	Reynales type of calcite	Lockport type of dolomite
Lockport	III			x			x		x
Rochester	III			x			x		x
Irondequoit	III		x				x	x Minor	x Minor
Williamson	II	x	x			x		x	
Lower Sodus	II		x			x		x	
Reynales	II		x			x		x	
Maplewood	II		x			x		x	
Thorold	I	x				x		x	
Grimsby	I	x			Lower Portion	Top only			
Queenston	I	x			x				

The boundary line, whether on top or at the bottom of the Thorold, is arbitrary. An alternative plane of demarcation would be the unstable zone near the top of the Grimsby, 38 to 41 feet above the base. The Queenston clay microphase is limited to beds below this zone. The Maplewood clay microphase occurs only above it. This zone may prove to be more significant than it appears to be at present.

The Irondequoit is likewise transitional. Sanford goes further and names three divisions: I, Medina group, II, Clinton group, and III, Niagara group. But excluding the Irondequoit and the Rochester from the Clinton group satisfied neither Chadwick (1918) nor Gillette (1940), each for different reasons.

All agree that drawing the upper limit of the Clinton group is difficult. It is concluded that it, too, is arbitrary. The limits to the groups are in reality artificial. The rocks are gradational.

The name "Clinton" is satisfactory in a general way, however. To the writer there are many problems of greater importance than discussing the exact arbitrary limits of the group.

An igneous rock petrographer studying thin sections of these sediments is tempted to apply methods and nomenclature with which he is familiar. To him shaly rocks are foliated rocks possessing a depositional fabric but carrying no connotation as to composition.

These rocks possess compositional, structural, textural, and fabric characteristics that, if they were igneous, could be called by such terms as "Queenstonite", "Thoroldite", "Reynalesite", etc. Heaven forbid! But the rocks *themselves* deserve study, and thin sections provide the means.

Discussions regarding the diagenesis of these rocks must be tentative. Much has been removed from these rocks. Among the missing minerals are garnet, the clinopyroxenes, the amphiboles, the olivines, etc. Recrystallization has affected a good deal of the carbonate and the hematite. Silica has been added and now occurs as quartz cement in the siliceous siltstones, as chert in the limestones. Hematite has been added to form the Clinton ores. Many minerals have been autogenously "enlarged." In a narrow sense these rocks have been anamorphosed. They are immeasurably more complex than igneous rocks. Much more remains to be done. The sedimentation of these rocks shows gradational changes that cross the formational boundaries. Sudden changes, such as a shaly parting, occur only after a slow and gradual "build up." In the Grimsby the unstable zone occurs at the point of maximum quartz content.

The limestone units, the Brewer Dock, the Upper Reynales, the Irondequoit, and the Rochester have summits of limestone, bases of argillaceous substances, and middle zones of interfingering of the facies types, each one of which may carry a distinctive fauna.

X. CONCLUSIONS

1. The study of petrographic thin sections of consolidated sediments reveals much that is obtainable in no other way. A satisfactory study of heavy minerals is also possible by this means.

2. Thin sections provide adequate samples for Delésse-Rosiwal analyses, measurements for grain size, grain roundness, and grain circularity in two dimensions.

3. The mineral composition of these rocks is best understood by calculating the three complementary microlithologies: argillaceous, calcareous, and siliceous. These can be plotted on triangular graphs.

4. The plotting of these complementary microlithologies alongside the geologic column reveals the true nature of the rocks.

5. The usual nomenclature of sedimentary rocks is inadequate. The term "shale" does not express the mineral composition, but is a structural characteristic. The composition of these sedimentary rocks is here expressed by referring to them as argillaceous, calcareous, and siliceous rocks. "Sandstone" is a textural term, implying size only. Many of the rocks, including most of the Grimsby and Thorold, are siltstones.

6. The frequency-distribution curves of quartz grains, measured in thin section, commonly are multiple peaked. The peaks are regarded as corresponding to different complementary microlithologies.

7. Certain minerals and their fabric relations and distribution constitute microphases. The following were recognized: (A) the Maplewood clay microphase, (B) the Queenston clay microphase, (C) the Reynales calcite microphase, (D) the Lockport dolomite microphase, and (E) the Lockport clay microphase. These cross formational boundaries.

8. Petrographically, the sedimentary rocks in the Rochester area are gradational. The formational boundaries are to a certain extent artificial. Formations are very convenient but not fundamental.

9. Several of the microscopic fossils have been found to be confined to rocks with a very limited range in mineral composition. These are facies fossils, the correlative value of which is restricted to similar facies. The ostracods are a notable exception as emphasized by Gillette.

10. Shaliness of rocks is expressed by the terms massive, platy, flaggy, heavy-bedded, thin-bedded, and fissile, as related to the composition in terms of three complementary microlithologies, as plotted in Fig. 6F. Eighty-five percent of the area of the triangular plot are shaly.

11. The erection of more "formational" units, such as the "Kodak" and the "Gates", is not encouraged until more is known about the facies. These appear to be parvafacies, not formations.

12. The percentage of feldspar rises with the amount of quartz to a

maximum of 57% of the latter and then falls off. A flood of quartz depresses the feldspar content.

13. The rocks here studied are notable for the minerals that are absent. Garnet is rare, the clinopyroxenes, the amphiboles, and the olivines are missing. These rocks must have been subject to long leaching since the Paleozoic. The permeability varied from layer to layer, consequently this leaching was selective.

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THE VEGETATION OF BERGEN SWAMP

I. The Vascular Plants

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BERGEN SWAMP

A place where one may still see Nature at work and learn some of her lessons and secrets.

A small wilderness of quiet recesses, copses and canopies where one may sojourn in undisturbed solitude for inspiration and stimulus for the future.

An heritage from the past with the possibility of linking the present with the future until both shall have become a part of the dim past.

A small group of pioneers who recognized an obligation of the present generation, a few years ago organized the Bergen Swamp Preservation Society to save Bergen Swamp for future generations.

This brief account of the results of some explorations of its rich vegetation was stimulated by the efforts of these pioneers.

If it interests new recruits to join their ranks, future generations will be grateful.

CONTENTS

INTRODUCTION

Bergen Swamp has been known and tramped through by naturalists for nearly a century. With the early history of its exploration are associated the names of C. M. Booth, G. T. Fish, G. W. Clinton, J. H. Paine, Jr., S. M. Bradley, D. F. Day, C. H. Peck and others.[3, 6] Among the later botanists who explored and collected in the swamp are W. H. Lennon, M. S. Baxter, H. D. House, W. D. Merrill, F. W. Johnson, E. P. Killip, and P. A. Stewart.

In 1864 Paine[1] mentioned 38 species of plants from Bergen Swamp. These were again listed in 1925 by Baxter and House[4] who added 67 less common species from the swamp not included by Paine. Day, 1882,[2] recorded plants from Bergen Swamp in *The Plants of Buffalo and its vicinity* and commented upon some of its rare plants.

Beckwith and Macauley, 1896,[3] listed a number of plants from Bergen Swamp and vicinity in the *Plants of Monroe County and adjacent territory.* They also gave an extensive bibliography of papers mentioning plants of the Genesee Region for the period 1687–1895. Only a few mention Bergen Swamp. Zenkert, 1934,[6] included a description of Bergen Swamp and listed the "more noteworthy" plants of the wooded zone and open marl areas. In his general catalogue he also recorded a number of species based largely upon collections and records from the swamp made by Clinton, Day and Johnson.

Stewart and Merrill, 1937,[7] published the first intensive treatment of Bergen Swamp. Although primarily an ecological study, these authors also included the most complete catalogue of plants of Bergen Swamp published to date. This catalogue was based upon the species recorded by Beckwith and Macauley supplemented by the records published by Baxter and House, 274 species, of which only 106 were seen in the swamp by Stewart and Merrill. These authors added new records of 98 species thus making a total of 372 species in their catalogue.

My own interest in the vegetation of Bergen Swamp began in 1917 when, as a representative of the New York State Food Supply Commission, I was stationed for the summer in Batavia, Genesee County, within about ten miles of the swamp. This opportunity for an intensive introduction to the swamp and many trips in the intervening years have made it possible to visit nearly every part of the swamp, most of them several to many times. Visits have been made throughout the growing season. In one year one or two days were spent in the swamp in every month from April to October. These explorations have added considerably to the knowledge of the flora of the swamp. Although they have not progressed to the point where a complete catalogue of the plants in Bergen Swamp is assured, it seems desirable to bring together the available records of vascular plants in one more steppingstone toward a more nearly complete record. The catalogue here presented includes 780 species, more than double the number of species (372) listed by Stewart and Merrill. Even in its incomplete form may it serve to stimulate further interest in the study and preservation of the vegetation of Bergen Swamp.

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GENERAL FEATURES OF BERGEN SWAMP

Bergen Swamp is usually visualized as a very wild area full of rattlesnakes and a place in which it is easy to get lost. For the preservation of the Swamp this concept may have certain advantages. Ordinarily when several persons enter the swamp together, few larger animals are observed. However, on one trip by myself I noticed two deer, four red foxes, numerous chipmunks, several kinds of snakes including one rattlesnake, several turtles, toads and frogs. Several grouse were flushed, many noisy crows were observed perched in the tops of old white pine trees growing in clumps about the border of the open areas. Various small birds were also observed.

Bergen Swamp is a relatively primitive area in the midst of a highly developed agricultural region. Its close proximity to fields and roads explains the occurrence of many weeds and other exotic plants. Anomalous though it may seem, I have seen wheat, oats, rye, maize and tomatoes growing in openings in the swamp. Trees of exotic species of cherries, pears and apples and seedlings of European mountain ash, Scotch pine and European white birch and bushes of Japanese and European barberry and Tartarian honeysuckle have been found growing in openings in the swamp.

A large number of introduced weeds occur in the swamp. These are included in the catalogue as a record of what grows in the swamp now. Their presence offers witness to the close proximity of the swamp to agricultural areas and transportation lanes and silently attests to the disturbances that man has wrought in the native vegetation. In the future it will be interesting to observe which of these infested scars will be "healed over" by the native vegetation and whether any will become centers of encroachment upon the native plants.

Most of the activities causing disturbances in the swamp center about the cutting of trees around its margin for lumber and making fence posts and poles from the arbor-vitae "cedar" within the swamp. This accounts for numerous openings and cutover areas as well as abandoned logging roads, "trails". Most of this activity takes place in the winter when the swamp is frozen over. At times sphagnum moss has been taken from the hummocks in the marl bogs.

Bergen Swamp is located in the townships of Bergen and Byron in the northeast corner of Genesee County, New York, about 24 miles from the city of Rochester and about three miles west of the village of Bergen. This places it within a few hours ride by car or rail from the principal centers of population, industry and education in western New York. Such a strategic position makes it easily accessible to naturalists interested in the study of its flora and fauna. At the same time it is in grave danger of damage or destruction by others who are interested only in the satisfaction of immediate wants or desires regardless of their effect upon the future of the area.

The particular part of Bergen Swamp that is best known to botanists consists of an open marl bog area surrounded by a forest or swampy thicket. A brief but good general description of Bergen Swamp was published 50 years ago.[3] More recently Stewart and Merrill,[7] in their extensive ecological study discussed in detail many aspects of the swamp and certain of its vegetation types. While the marl bog is an extensive and interesting feature of Bergen Swamp, it represents not a static but a dynamic area the uniqueness and persistence of which is highly dependent upon the physiographic features surrounding the marl areas and the types of vegetation that these support.

Bergen Swamp is situated about 590–600 feet above sea-level. It is about three miles long and one to one and one half miles wide. It occupies an east-west depression on a plain overlying the Salina formation of the Silurian. A few miles to the south is the Onondaga limestone escarpment. The depression itself is rather irregular because of the uneven deposition of large amounts of glacial till. None of the underlying strata are here exposed because of the depth of the till.

A continuous supply of lime-bearing water from the springs flowing northward into the depression from the higher ground on the south is favorable for the formation of marl deposits.

Forming a wide curve near the northwest corner of the swamp, and turning from west to east, flows Black Creek. While it drains Bergen Swamp it is also in part responsible for maintaining it. It has its main source some 20 miles southwest in the hills of the Portage escarpment in Wyoming County. Draining a rather large area, chiefly agricultural land, it picks up a considerable load of silt. From its general northward flow this current is diverted to the east when it strikes the west-east depression with but a slight pitch with the result that much of the silt load is dropped along its banks. The frequent deposition of this silt is responsible for striking differences in the physical and chemical natures of the soils of the north and south sides of the swamp. Whereas, near Black Creek the area of raised alluvial soil which gradually slopes southward toward the lower and northern part of the swamp is subject to periodic flushing or drenching with large volumes of silty surface water, the southern part of the swamp receives smaller but more continuous flows of underground clear water from numerous springs. These differences in the soils are also reflected in the composition of the vegetation of these areas.

It has been stated that the glacial till of the Bergen Swamp region is so heterogeneous and evenly mixed that a uniform soil has resulted which has no effect upon the composition of the vegetational areas.[7] It is also stated that the vegetation of Bergen Swamp is supported entirely upon humus formed by the decay of former vegetation. An examination of the soils around the margin of Bergen Swamp shows that neither the glacial till nor the soils formed by its subsequent erosion and addition of humus from plant remains formerly growing thereon are uniform. The soil map of Genesee County, New York, shows Bergen Swamp (referred to in the accompanying text as "the large muck swamp east of Pumpkin Hill")[5] as an extensive muck area into the south margin of which project at least four distinct soil types within a distance of three miles. Along the north edge of the swamp at least one additional soil type is represented.

These soil types are recorded below. A few of the outstanding properties of each soil, taken from the descriptions by Gustafson,[5] are included.

1. *Granby silty clay loam.*—With poor drainage and a good supply of lime and organic matter. This type is also common in the north and east parts of the swamp.
2. *Mahoning silt loam.*—With good surface drainage and poor internal drainage; low in organic content and rather sour.
3. *Ontario loam.*—With good surface and internal drainage; subsoil well supplied with lime. On the north side this type is represented by Torpy Hill and surrounding base.
4. *Honeoye loam.*—Some gravel on surface; good drainage; well supplied with lime and organic matter. Represented by only a small area on the south border.
5. *Dunkirk fine sandy loam.*—Surface soil fine sandy loam to fine sand, porous; lime content variable. Represented on the north border by a small area, part of which has been cleared.

The existence of these several types of soil indicates at least some basic differences in the glacial till on which they were formed or from which they were derived.

VEGETATION TYPES IN BERGEN SWAMP

Stewart and Merrill[7] have already discussed in some detail the probable origin and early history of the depression in which Bergen Swamp is located, the effect of glacial till on soils in the basin, the formation of marl beds, and the causes and some of the stages of the filling in of the swamp. They have described and discussed the present vegetation of the swamp under five "specific zones and associations" as follows:

1. Open marl association
2. Secondary marl association
3. Sphagnum bog association
4. Pine-hemlock zone
5. Beech-maple zone.

These authors interpret Bergen Swamp as a relatively late stage in succession, attained by the filling in of an open-water area, the earliest stage of which is represented at present by the open marl association, followed in order by the secondary marl association, sphagnum bog association, pine-hemlock zone, and finally the beech-maple zone representing the climax. They state that the region now occupied by the beech-maple zone was undoubtedly at one time open swamp, that if left to its natural development the swamp will in in time become stabilized as a climax forest of the beech-maple type. To them "The presence of the beech-maple climax marks the beginning of the end of Bergen Swamp." A very good reason for preserving Bergen Swamp in as nearly an undisturbed state as possible is to provide opportunity to obtain records and data on the progress of the successions in the future.

My own explorations have resulted in supplementing our knowledge of Bergen Swamp as presented by Stewart and Merrill[7] by:

1. Greatly increasing the inventory of plants known to occur there.
2. Revealing types of vegetation not mentioned by them.
3. Providing a clearer picture of the composition of the vegetation in some of the "associations" previously reported.

As a result some of the assumptions previously made cannot be substantiated and in some instances the observations lead to different interpretations.

The most obvious or striking types of vegetation that can be observed by the visitor to Bergen Swamp today may be indicated as follows:

1. Aquatic plants.
2. Carex riparia swamp.
3. Alluvial soil plants.
4. Open marl bog.
5. Secondary marl bog.
6. Sphagnum bog.
7. Arbor-vitae swamp.
8. Alder swamp.
9. Pine-hemlock forest.
10. Birch-maple-elm forest.

It is apparent that this grouping is not all-inclusive nor are the separate types mutually exclusive. However, each type is dominated by certain species and is limited more or less to a restricted habitat determined on the one hand by the physical factors of the environment and on the other by the stage of succession attained by the vegetation. Since these environmental factors may overlap or are subject to modification it is to be expected that some species may occur in more than one of the types of vegetation here designated. In fact it appears probable that some of the types may represent stages in the succession of another.

A few general remarks are presented about each of the ten types of vegetation here recognized. These are followed by a list of the more striking or dominant species occurring in each.

1. *Aquatic plants.*—These are limited to restricted areas such as small spring-fed pools and the streams having their source in them, Black Creek and its laterals, and several shallow but firm-bottom, mostly intermittent ponds, chiefly along the north side and toward the east and west ends of the swamp. With the exception of *Nasturtium officinale* and *Veronica anagallis—aquatica* in spring brooks—and *Lemna minor, Ranunculus flagellaris* and *Sium suave* in ponds, none of the aquatics is abundant. Most of them are local or known only from a few stations. The submersed species are mostly limited to Black Creek. The water in this stream usually has a low transparency which probably accounts for the paucity of aquatic plants except in shallow water.

2. *Carex riparia swamp.*—This includes a very distinct association of plants. To one who finds himself in its middle, wading in water from one to two feet deep, with *Carex* leaves striking to the height of his ears, eagerly scanning the horizon just at sundown to find its margin anywhere from 200 yards to a half mile distant, its existence is very real. It lies along the north side of the swamp in wet depressions between the alluvial soil area and the alder swamp or arbor-vitae swamp. During flood periods this area may be inundated to a depth of 6 to 8 feet. This occurred on October 2 and 3, 1945, following a very heavy rainfall. On these same days the marl bogs showed no appreciable increase in water depth. The dominant species is *Carex riparia* var. *lacustris*. *Typha latifolia* encroaches the margin of the swamp. In lower areas which form stream courses during high water, *Sparganium eurycarpum, Glyceria grandis* and *Acorus Calamus* are common. The dicotyledonous species listed occur as scattered plants among the Carex.

3. *Alluvial soil plants.*—These occupy a narrow area along the banks of Black Creek which are higher than the more swampy areas farther away. Most of the characteristic species recorded for this habitat do not occur elsewhere in Bergen Swamp. A number of these species are more

common farther to the west, especially in the Ohio Basin. This alluvial soil is very rich and at flood time may be inundated under several feet of water.

4. *Open marl bogs.*—The vegetation of these areas is remarkably uniform and characterized by a restricted number of abundant species, chiefly members of the Cyperaceae, many of which do not appear elsewhere in the swamp except in the secondary marl. The open marl is usually lower and therefore covered by water for a longer part of each year than the somewhat more elevated and drier secondary marl areas. It is not continuous but forms several more or less open marl areas mostly toward the middle of the swamp and in many places the open and secondary marl gradually merge. These open marl areas are sometimes separated by arbor-vitae thickets or again may be bordered by a zone of sphagnum. Frequently they are dotted by raised hummocks covered with little sphagnum bogs.

The open marl area is not static. There are places in which marl is being formed today by *Chara* sp. and blue green algae, *Scytonema* sp., growing in small areas of open water. The boundaries of some of these areas have changed within the last 25 years, due on the one hand to the encroachment of shrubs and even small trees on open areas and on the other hand to changes in the surface contours allowing lime-rich water from spring-fed brooks to extend over areas formerly occupied by shrubs or even arbor-vitae forests.

That such changes have been going on for more than a century appears highly probable from observations. During the last few decades several observers have pointed out that the presence of marl can be demonstrated in the arbor-vitae forest or thickets where trees have been uprooted by the weight of heavy layers of snow or by wind. It is obvious that here the arbor-vitae has invaded marl areas and finally completely covered them. In open marl areas, some of them even with open water with living *Chara contraria* sp. and blue-green algae producing marl, places can be found in which occur remnants of logs, stumps and even erect snags in situ, the remains of *Thuja* trees which formerly grew where today the open marl association predominates.

In other words, it is evident that what is arbor-vitae forest now may have been open marl in the past and may become so again in the future. What is open marl today may have been an arbor-vitae forest or shrub association in the past and may again become so in the future. The changes in succession of these types of vegetation may be initiated by changes in contours which determine the position of the water level, whether above or below the soil contour.

5. *Secondary marl bogs.*—As the marl is built up or as local drainage changes so as to lower the water level, other species, many of them shrubby plants, become common. The most striking of these are *Potentilla fruticosa* and *Juniperus horizontalis.* The shrubby species are usually in scattered clumps with open areas between them which are occupied by small herbaceous species such as *Scleria verticillata, Panicum flexile, Carex* spp. and others also characteristic of the open marl.

6. *Sphagnum bog.*—The areas that are covered with Sphagnum moss are limited to small hummocks raised about one foot above the general level in the open marl bogs and to irregular strips, mostly between the arbor-vitae and secondary marl associations. *Sphagnum* spp.* make a dense carpet over the hummocks with low herbaceous species scattered among the *Sphagnum.* On these little natural "island gardens" small growths of Ericaceous shrubs and *Pyrus melanocarpa* abound. Dwarf, scraggly trees of *Larix laricina* and *Thuja occidentalis,* often only two or three feet in height, complete the setting; occasionally a few dwarf individuals of *Pinus Strobus* also appear. These "islands" appear artistic and colorful. Seldom do more than one or two species blossom at one time but many of the species show bright coloration in the foliage and fruits.

When looking across the open marl area with the hummocks of sphagnum vegetation one may be reminded of a rough sea, the open marl low and the hummocks slightly raised. All the plants, whether trees, shrubs or herbs, are low or dwarfed. The stunted nature of this vegetation has been explained as due to the greater evaporating power of the atmosphere several feet above the soil surface as compared to the more humid atmosphere near the wet soil surface.[7] Granting that the humidity in this area may be higher near the soil than at higher levels above, it does not necessarily follow that this difference is greater where the tamaracks and pines fail to grow tall than in nearby areas where they do grow to a normal height.

The explanation of the stunted growth of the plants in this area may be found in low fertility of the soil involved. Analyses of marl soil and soil from raised sphagnum hummocks from the Junius bog in Seneca County, New York, by Edgar T. Wherry showed that the former was alkaline in reaction and the latter was acid in reaction but that both types were low in nitrates. The acidity of the Sphagnum soils and the poor drainage and aeration of the marl may interfere with the production and accumulation of nitrates sufficient for optimum growth of the woody species here involved.

7. *The arbor-vitae swamp.*—The dominant species in this association is *Thuja occidentalis.* It usually makes a dense growth which in the early

* ***Sphagnum capillaceum*** (Weiss.) Schrank. is the dominant species on the hummocks. ***Sphagnum palustre*** L. occurs more commonly in lower places.

stage of development makes an almost impenetrable thicket but ultimately forms a canopied forest with a ground cover of herbaceous species. The association forms an irregular belt between the marl areas and the pine-hemlock and hardwood forests. It is mostly limited to the south side of the swamp although some more or less detached arbor-vitae areas occur on the north side toward the east end or wherever marl springs occur, even on uplands surrounding the bog. In open places in the arbor-vitae swamp the shrubs, *Lonicera oblongifolia, Rhamnus alnifolia* and *Myrica pennsylvanica* thrive. In the partial shade in some of these openings clumps of ladyslippers, *Cypripedium reginae* and *C. Calceolus* var. *pubescens* are frequently found. *Thuja occidentalis,* locally called "cedar", more than any other species is the cause of disturbances in Bergen Swamp. The "white cedar" is highly prized for fence posts and other uses requiring a durable wood. From many tracts in the swamp the "cedar" has been cut for poles and removed. Most of the trails across the bogs represent remnants or sites of former logging roads for hauling "cedar" poles. Some of this activity has been carried on as late as 1945. An examination of the growth rings of cut trees indicates that they required from 50 to 100 years to grow to a diameter of one foot.

8. *Alder swamp.*—This type of vegetation is frequently dominated by *Alnus incana* growing in clumps in soft mucky soil frequently inundated except around the bases of the shrubs. Certain herbaceous species are associated with the higher ground around the shrubs; others grow in the mucky depressions among them. In open places among the alders shrubby willows, Viburnums, *Cornus stolonifera* and *Rubus Idaeus* var. *strigosus* thrive. Around the borders of the alder swamps *Acer rubrum* and *Fraxinus nigra* may intermingle with the shrubby species.

9. *Pine-hemlock forest.*—This association is but poorly represented at the present time. It probably never was well developed in the swamp proper. However, on several so-called "islands" of upland or knolls within the swamp and a few low ridges projecting into the swamp the white pine and hemlock were well established. Unfortunately most of these areas have been cut for timber. Only a few of the more inaccessible knolls still contain relatively large pine or hemlock trees. The hardwood trees associated with the conifers and the shrubs and herbs dominant in the undergrowth and forest carpet are recorded in the list of species.

10. *Birch-maple-elm forest.*—This hardwood forest association covers the greater part of the wooded area of the swamp and the limited woodlands remaining contiguous to it. The dominant trees are yellow birch, *Betula lutea,* red maple, *Acer rubrum,* sugar maple, *Acer saccharum,* and elm, *Ulmus americana.* Beech, *Fagus grandifolia,* is absent or rare and as a component of the swamp forest has been much overrated.[4, 7] Sev-

eral smaller, less common trees occur. The forest floor abounds in numerous herbaceous species, the more characteristic of which are listed. This forest type has been designated as the beech-maple zone by Stewart and Merrill,[7] who consider it to be the climax forest developed in Bergen Swamp.

At present there is no evidence that any of the few areas about Bergen Swamp which are now occupied by the beech-maple climax forest were at any time, since the last glacial period, a part of the swamp. Judging by the recent past history of the swamp it does not seem probable that any part of the present swamp will culminate in the beech-maple climax.

The only evidence offered as "proof" by Stewart and Merrill of the invasion of the areas that were at one time open swamp is the occurrence, at "the outermost reaches of the beech-maple zone, of a minor growth of *Thuja occidentalis* and *Typha latifolia*". Their assumption that the original limits of the swamp included these localities now occupied by *Thuja* and *Typha* does not necessarily follow, in fact it appears highly improbable. Several areas along the south margin of the swamp at the present time support *Thuja* and *Typha* about springs some distance above the swamp. The spring-fed brooks often support a marl-bog vegetation much removed from the marl bog proper. The few limited areas of beech-maple in the swamp area are restricted to hard soil or uplands bordering the swamp or a few "islands" or knolls of glacial till. No beeches were found on areas underlain with marl or peat. The few small remaining woodland areas on uplands in the vicinity of Bergen Swamp show well-developed beech-maple climax forests.

1. Aquatic Plants

*Potamogeton amplifolius
*Potamogeton Berchtoldii
Sagittaria latifolia
Alisma Plantago-aquatica
*Anacharis canadensis
fLemna minor
fLemna trisulca
fSpirodela polyrhiza
Eleocharis acicularis
Glyceria grandis
*Ranunculus aquatilis
Ranunculus flagellaris
Nuphar advena
Polygonum hydropiperoides
Armoracia aquatica
Nasturtium officinale
*Ceratophyllum demersum
Callitriche palustris
Sium suave
Ludvigia palustris
*Utricularia intermedia
*Utricularia vulgaris var. americana
Veronica americana
Veronica anagallis-aquatica

* = submersed; f = floating; others emersed.

2. Carex Riparia Swamp

Carex riparia var. lacustris
Sparganium eurycarpum
Acorus Calamus
Glyceria grandis
Typha latifolia
Rumex Brittanica
Asclepias incarnata
Cicuta maculata
Cicuta bulbifera
Epilobium densum
Epilobium hirsutum
Lysimachia thyrsiflora
Mentha arvensis var. canadensis

3. Alluvial Soil Plants

Acer saccharinum
Fraxinus pennsylvanica
Ulmus americana
Carya ovata
Quercus macrocarpa
Evonymus atropurpurea
Crataegus macracantha
Ribes americanum
Salix interior
Salix nigra
Pteretis nodulosa
Allium canadense
Arisaema Dracontium
Polygonum virginianum
Laportea canadensis
Ranunculus septentrionalis
Angelica atropurpurea
Heracleum lanatum
Asclepias syriaca
Echinocystis lobata
Ambrosia trifida
Xanthium orientale

4. Open Marl Bog

Triglochin maritima
Triglochin palustris
Phragmites communis
Typha latifolia
Carex bromoides
Carex crawei
Carex flava
Carex gynocrates
Cladium mariscoides
Eleocharis rostellata
Rynchospora alba
Rynchospora capillacea
Scirpus caespitosus
Scirpus acutus
Scirpus americanus
Zygadenus chloranthus
Cypripedium candidum
Juniperus horizontalis
Sarracenia purpurea
Parnassia caroliniana
Lobelia Kalmii
Solidago uniligulata

5. Secondary Marl Bog

Juniperus horizontalis
Thuja occidentalis
Larix laricina
Potentilla fruticosa
Lonicera oblongifolia
Rhamnus alnifolia
Myrica pennsylvanica
Salix candida
Salix serissima
Carex aurea
Carex hystericina
Carex prairea
Cladium mariscoides
Scirpus caespitosus
Scirpus americanus
Scleria verticillata
Panicum flexile
Sorghastrum nutans
Sporobolus vaginiflorus
Zygadenus chloranthus
Cypripedium candidum
Commandra umbellata
Parnassia caroliniana
Aster lateriflorus var. angustifolius
Senecio pauperculus var. Balsamitae
Solidago ohioense
Solidago Houghtoni
Solidago uniligulata

6. Sphagnum Bog

Larix laricina
Gaylussacia baccata
Vaccinium Oxycoccus
Vaccinium corymbosum
Pyrus melanocarpa
Gaultheria procumbens
Ledum groenlandicum
Linnaea borealis var. americana
Chiogenes hispidula
Cornus canadensis
Arethusa bulbosa
Pogonia ophioglossoides
Tofieldia glutinosa
Drosera rotundifolia
Sarracenia purpurea

7. Arbor-Vitae Swamp

Thuja occidentalis
Lonicera oblongifolia
Myrica pennsylvanica
Rhamnus alnifolia
Cypripedium Calceolus var. pubescens
Cypripedium reginae
Rubus triflorus
Mitella nuda
Conioselinum chinense
Viola renifolia var. Brainardi
Viola blanda
Valeriana uliginosa
Trientalis borealis

8. Alder Swamp

Alnus incana
Salix cordata
Salix discolor
Cornus stolonifera
Viburnum Opulus var. americanum
Viburnum dentatum
Clematis virginiana
Rubus Idaeus var. strigosus
Fraxinus nigra
Acer rubrum
Dryopteris cristata
Dryopteris Thelypteris
Habenaria psychodes
Boehmeria cylindrica
Cardamine bulbosa
Caltha palustris
Lobelia siphilitica
Senecio aureus
Solidago patula
Rudbeckia laciniata
Eupatorium maculatum

9. Pine-Hemlock Forest

Pinus Strobus
Tsuga canadensis
Taxus canadensis
Fraxinus americana
Prunus serotina
Viburnum acerifolium
Cornus canadensis
Gaultheria procumbens
Rhododendron nudiflorum
Linnaea borealis var. americana
Chiogenes hispidula
Mitchella repens
Polygala paucifolia
Coptis trifolia var. groenlandica
Clintonia borealis
Maianthemum canadense
Medeola virginica
Aralia nudicaule
Aster macrophyllus

10. Birch—Maple—Elm Forest

Betula lutea
Acer rubrum
Acer spicatum
Acer saccharum
Ulmus americana
Fraxinus americana
Tilia americana
Fagus grandifolia
Carpinus caroliniana
Ostrya virginiana
Cornus rugosa
Adiantum pedatum
Dryopteris marginale
Dryopteris spinulosum var. intermedium
Cystopteris bulbifera
Onoclea sensibilis
Osmunda cinnamomea
Erythronium americanum
Smilacina stellata
Smilacina racemosa
Trillium grandiflorum
Arisaema triphyllum
Mitella diphylla
Tiarella cordata
Viola conspersa
Aralia nudicaulis
Circaea latifolia
Collinsonia canadensis
Eupatorium rugosum
Prenanthes alba
Solidago latifolia
Solidago graminifolia
Solidago rugosa
Solidago serotina

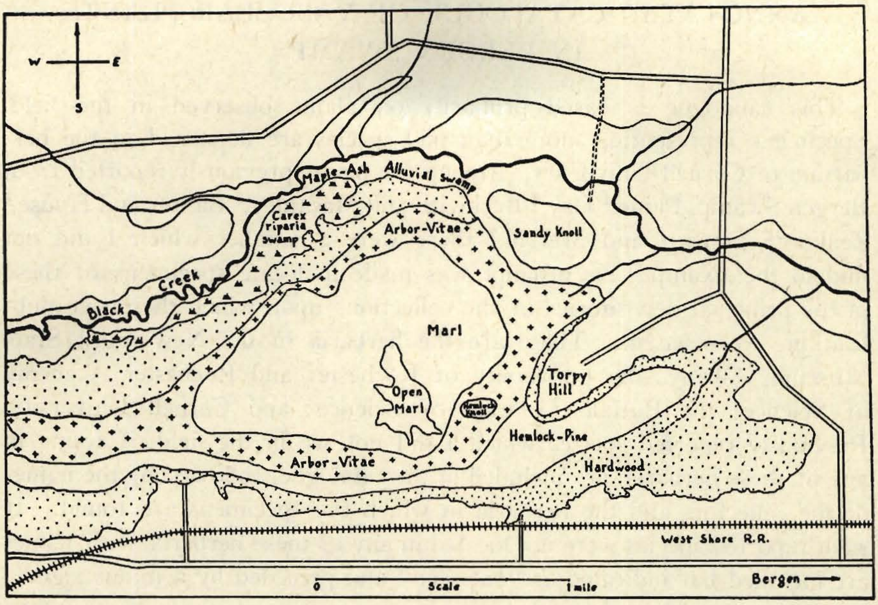

FIGURE 1
Map of Bergen Swamp

The regions indicated as hardwood, hemlock-pine, arbor-vitae and maple-ash are not all continuous but show only the approximate areas in which these types of vegetation are dominant. Some sections in each of these regions have had many of the larger trees removed. The region marked "marl" is not uniform except that it contains low vegetation on marl soil. In some parts sedges and grasses dominate; in others low shrubs are interspersed with sphagnum hummocks on which dwarf tamaracks, arbor-vitae and scattered white pines occur. Some of the arbor-vitae areas also are underlain with marl.

ANNOTATED CATALOGUE OF VASCULAR PLANTS IN BERGEN SWAMP

This catalogue is based primarily on plants observed in the field. Specimens representing more than 650 species are deposited in the herbarium of Cornell University. Among the plants previously reported from Bergen Swamp, Paine,[1] Day,[2] Beckwith and Macauley,[3] Baxter and House,[4] Zenkert,[6] Stewart and Merrill,[7] there were a number which I did not find in the swamp. An attempt was made to locate specimens of these in the principal depositories of the collections upon which the above publications were based. These are the herbaria in the New York State Museum, Albany; the University of Rochester and Rochester Academy of Science; the Buffalo Museum of Science; and Cornell University. Previously reported species which I did not see in the field, if found in any of these herbaria, are included in the catalogue, followed by the names of the collectors and the herbaria in which the specimens are found. If such reported species were not located in any of these herbaria, their names are included but indicated as "not seen" and preceded by a minus sign.

All species without citations to specimens in any of the above herbaria, except those preceded by a minus sign, are represented by herbarium specimens in the herbarium of Cornell University.

An asterisk (*) preceding a name indicates a species not included in the catalogue of Bergen Swamp plants published by Stewart and Merrill.[7]

The herbaria are cited as follows:

Albany ....New York State Herbarium
Buffalo ....Herbarium of Buffalo Museum of Science
Rochester .....Herbarium of University of Rochester
R. Acad. ......Herbarium of the Rochester Academy of Science
Cornell ....Herbarium of the Department of Botany, Cornell University

Introduced species are printed in light type.

Synonyms in italics, without authors, refer to names used in Gray's Manual, ed. 7.

1. POLYPODIACEAE

Adiantum pedatum L. MAIDENHAIR FERN. Moist hardwoods.

Athyrium acrostichoides (Sw.) Diels. SPLEENWORT. In swampy woodlands.

Athyrium felix-femina (L.) Roth., var. **Michauxii** (Spreng.) Underw. LADY FERN. In swampy woods.

Cystopteris bulbifera (L.) Bernh. BLADDER FERN. In wet woods.

Cystopteris fragilis (L.) Bernh. In swampy mixed woodlands.

Dryopteris Boottii (Tuckerm.) Underw. *(Aspidium Boottii.)* In swampy woodland. *(F. W. Johnson (16)* 1924, *Buffalo.)*

Dryopteris cristata (L.) Gray. *(Aspidium cristatum.)* On hummocks in alder swamps.

Dryopteris cristata (L.) Gray, var. **Clintoniana** (D. C. Eaton) Underw. On hummocks in hardwood swamp.

–**Dryopteris Goldiana** (Hook.) Gray. GOLDIE'S FERN. The specimen *(Stewart,* 1933)[7] reported as this species is a small sterile one belonging elsewhere. Also reported by Baxter and House.[4]

Dryopteris Linnaeana C. Chr. *(Phegopteris Dryopteris.)* OAK FERN. On hummocks in hemlock woods; rare.

Dryopteris marginalis (L.) Gray. *(Aspidium marginale.)* MARGINAL SHIELD FERN. Common in mixed woodlands.

Dryopteris noveboracensis (L.) Gray. *(Aspidium noveboracense.)* NEW YORK FERN. In moist open hardwood forest.

Dryopteris spinulosa (O. F. Müller) Ktze. *(Aspidium spinulosum.)* SPINY-TOOTHED SHIELD FERN. In hardwood swamps and forests.

Dryopteris spinulosa, var. **intermedia** (Muhl.) Underw. Mostly in swampy ground under hardwoods.

Dryopteris Thelypteris (L.) Gray. *(Aspidium Thelypteris.)* MARSH SHIELD FERN. In alder swamps and marshes.

Onoclea sensibilis L. SENSITIVE FERN. In marshes and edges of swampy woodlands.

***Pteretis nodulosa** (Michx.) Nieuwl. *(Onoclea Struthiopteris.)* OSTRICH FERN. On moist alluvial soil along streams.

Pteridium aquilinum Kuhn, var. **latiusculum** (Desv.) Underw. *(Pteris aquilina.)* BRACKEN FERN, BRAKE. In open woodland, mostly on knolls.

Polystichum acrostichoides (Michx.) Schott. CHRISTMAS FERN. In moist woodland.

***Polypodium virginianum** L. *(P. vulgare.)* POLYPODY. On hummocks and about the base of hemlock trunks.

–**Woodwardia virginica** (L.) Sm. CHAIN FERN. In sphagnum along edge of arbor-vitae swamp.

2. OSMUNDACEAE

Osmunda cinnamomea L. CINNAMON FERN. Common in swampy areas, mostly under trees.

Osmunda claytoniana L. INTERRUPTED FERN. In wet situations bordering forests.

***Osmunda regalis** L., var. **spectabilis** (Willd.) Gray. ROYAL FERN. In open swampy borders of thickets.

3. OPHIOGLOSSACEAE

Botrychium virginianum (L.) Sw. RATTLESNAKE FERN, GRAPE FERN. In moist woodlands; frequent.

Botrychium dissectum Spreng., var. **oneidense** (Gilbert) Farw. *(J. B. Fuller,* 1865, under *B. ternatum* Swartz. *R. Acad.)*

–**Botrychium multifidum** (Gmel.) Rupr. subsp. **salaifolium** (Presl.) R. T. Clausen. Reported from woods bordering swamp, by Booth and Fish.[3] under *B. ternatum* Swartz. Not seen.

4. EQUISETACEAE

Equisetum arvense L. HORSETAIL. Common in wet woodlands and open areas.

Equisetum fluviatile L. PIPES. In mucky soil along streams.

Equisetum hyemale L. SCOURING RUSH. In springy places along streams.

*__Equisetum scirpoides__ Michx. DWARF SCOURING RUSH. On mossy hummocks in hemlock swamp.

*__Equisetum variegatum__ Schleich. In wet marly ditch along railroad by Bergen Swamp. *(R. M. Schuster, 20987, Cornell.)*

5. LYCOPODIACEAE

Lycopodium clavatum L. CLUB-MOSS. In open woods on knolls.

*__Lycopodium annotinum__ L. CLUB-MOSS. On a hemlock and oak knoll.

*__Lycopodium complanatum__ L., var. **flabelliforme** Fern. CLUB-MOSS. On a sandy knoll.

Lycopodium lucidulum Michx. CLUB-MOSS. In wet depressions under hemlocks.

Lycopodium obscurum L. CLUB-MOSS. On a hemlock knoll.

6. TAXACEAE

Taxus canadensis Marsh. YEW, GROUND HEMLOCK. A frequent undershrub in swampy woodlands. Usually it does not show thrifty growth because of considerable damage by rabbits and possibly also from browsing of deer.

7. PINACEAE

Larix laricina (Du Roi) Koch. TAMARACK, LARCH. A common but dwarfed tree on hummocks in the marl bogs; of better size in the bordering spring-fed bogs.

–**Picea mariana** (Mill.) BSP. BLACK SPRUCE. Reported from the swamp.[4, 7] I have never seen a tree. No herbarium specimens have been located.

Pinus Strobus L. WHITE PINE. A common tree in the bordering forests and also on hummocks in the open marl bogs.

*PINUS SYLVESTRIS L. SCOTCH PINE. A few small trees, apparently established from seed, were found in an opening in an arbor-vitae swamp.

Tsuga canadensis (L.) Carr. HEMLOCK. A common tree in the swamp and surrounding woods.

8. CUPRESSACEAE

Juniperus horizontalis Moench. TRAILING JUNIPER. Common in the open marl bogs and also on springy slopes bordering the woodland.

***Juniperus virginiana** L. RED CEDAR. Three trees from 8 to 12 feet high, along the south edge of the bog.

***Juniperus horizontalis X J. virginiana.** Two trees, about 6 feet high, with recurved-spreading branches touching the ground, rooting, and creeping horizontally were found growing among *Juniperus horizontalis* in the marl bog. These seem intermediate and may represent hybrids between the two preceding species.

Thuja occidentalis L. ARBOR-VITAE. A common tree in the swamps, forming dense thickets between the open marl bogs and the hardwood forests.

9. TYPHACEAE

***Typha angustifolia** L. NARROW-LEAVED CATTAIL. Local in spring-fed bogs.

Typha latifolia L. COMMON CATTAIL. Common in shallow water, mostly in swales and marshes.

10. SPARGANIACEAE

***Sparganium chlorocarpum** Rydb. BUR-REED. In shallow water along streams.

Sparganium eurycarpum Engelm. GIANT BUR-REED. Along streams and in swales.

11. POTAMOGETONACEAE

***Potamogeton amplifolius** Tuckerm. BROAD-LEAVED PONDWEED. In Black Creek.

***Potamogeton Berchtoldii** Fieber. SMALL PONDWEED. In shallow water in Black Creek and its tributaries.

*POTAMOGETON CRISPUS L. In Black Creek, rare.

12. JUNCAGINACEAE

–Scheuchzeria palustris L. Report based upon sight record by House, 1925. Not seen.

Triglochin maritima L. ARROW-GRASS. Abundant in wet depressions in the open marl.

Triglochin palustris L. SMALL ARROW-GRASS. In wet depressions, mostly along spring-fed streams in the marl bog.

13. ALISMACEAE

***Alisma plantago-aquatica** L. WATER PLANTAIN. In wet swales and along streams.

***Sagittaria latifolia** Willd. ARROW-HEAD, WAPATO. In marshy soil and shallow water along streams.

***–Sagittaria cuneata** Sheldon. ARROW-HEAD. In mucky soil along stream.

14. HYDROCHARITACEAE

***Anacharis canadensis** (Michx.) Planchon. *(Elodea canadensis.)* WATER-WEED. Common in Black Creek.

***Anacharis occidentalis** (Pursh) Marie-Vict. *(Elodea occidentalis.)* WATER-WEED. Local in Black Creek.

15. GRAMINEAE

*ANTHOXANTHUM ODORATUM L. SWEET VERNAL GRASS. Along edge of swamp.

***Agrostis stolonifera** L., var. **compacta** Hartm. REDTOP. Common in wet swales.

***Agropyron caninum** (L.) Beauv. In the marl bog.

***Agropyron repens** (L.) Beauv. QUACK GRASS. In openings in the marl bog.

–Alopecurus aequalis Sobol. FLOATING FOXTAIL. In swales. (Also reported by F. W. Johnson, 1926.)

***Asprella hystrix** (L.) Humb. (*Hystrix patula.*) BOTTLE-BRUSH GRASS. In moist woodlands.

***Bromus ciliatus** L. BROME-GRASS. In openings in the arbor-vitae swamp.

*BROMUS SECALINUS L. CHESS. Along the border of the swamp.

***Calamagrostis canadensis** (Michx.) Beauv. BLUE JOINT. In wet swales.

Cinna arundinacea L. In a wet swale.

*DACTYLIS GLOMERATA L. ORCHARD GRASS. In grassy borders of woods.

Deschampsia caespitosa (L.) Beauv., var. **glauca** (Hartm.) Lindm. In open marl bog.

–**Deschampsia flexuosa** (L.) Trin. Not seen.

***Echinochloa crus-galli** (L.) Beauv. BARNYARD GRASS. Along paths.

***Echinochloa pungens** (Poir.) Rydb. *(E. muricata.)* In swales along streams.

***Elymus virginicus** L. WILD RYE. In openings along streams.

*–FESTUCA ELATIOR L. MEADOW FESCUE. Along edges of meadows.

***Glyceria grandis** Wats. REED MEADOW GRASS. In mucky soil and in shallow streams.

***Glyceria striata** (Lam.) Hitchc. MANNA-GRASS. In openings in the bogs.

Leersia oryzoides (L.) Sw. CUT-GRASS. In swales.

***Leersia virginica** Willd. WHITE-GRASS. Along streams in wet woodland.

***Muhlenbergia foliosa** Trin. In openings in wet woods.

***Muhlenbergia mexicana** (L.) Trin. DROPSEED. In openings in woods.

***Muhlenbergia racemosa** (Michx.) BSP. On hummocks in marl bogs.

***Muhlenbergia tenuiflora** (Willd.) BSP. In wet woodlands.

***Oryzopsis asperifolia** Michx. In swampy hemlock forest.

***Panicum capillare** L. WITCH GRASS. Along paths in open bogs.

***Panicum flexile** (Gat.) Scribn. In open marl bogs.

***Panicum lanuginosum** Ell., var. **Lindheimeri** (Nash.) Fern. In wet places and along streams in marl.

*PHLEUM PRATENSE L. TIMOTHY. Introduced in openings in the woodlands.

Phragmites communis Trin. REED GRASS. Common in wet borders of marl bogs.

*POA ANNUA L. ANNUAL BLUEGRASS. Along paths in the swamp.

*POA COMPRESSA L. CANADA BLUEGRASS. In openings in the woodlands.

***Poa palustris** L. FOUL MEADOW GRASS. On dry hummocks in marl bog.

*POA PRATENSIS L. KENTUCKY BLUEGRASS. In openings bordering the swamps.

***Schizachne purpurascens** (Torr.) Swallen. *(Bromelica striata* (Michx.) Farw.) PURPLE OAT. On dry ridges. *(F. P. Metcalf (7557)* 1917. *Cornell.)*

*SETARIA LUTESCENS (Weigel) Hub. *(S. glauca.)* YELLOW FOXTAIL. Along paths.

*Setaria viridis (L.) Beauv. Green Foxtail. In open places.
Sorghastrum nutans (L.) Nash. Forming clumps in open marl bogs.
***Sporobolus vaginiflorus** (Torr.) Wood. In openings in marl bogs.

16. CYPERACEAE

***Carex albursina** Sheldon. On wooded knolls.

***Carex anceps** Muhl. On wooded knolls. Some of the earlier collections have been reported under *C. laxiflora.*

–**Carex angustior** Mack. Reported by Zenkert.[6] Not seen.

***Carex arctata** Boott. In hemlock and beech woods on a knoll.

Carex aurea Nutt. In open marl.

Carex Bebbii Olney. About edges of marshes.

***Carex blanda** Dewey. In open woods and bordering meadows. *(F. W. Johnson,* 1926; *W. A. Mathews, 4308; Albany.)*

Carex bromoides Schk. In open marl.

Carex Buxbaumii Vahl. (*C. polygama.*) In marl areas, mostly about springs.

Carex cephalantha (Bailey) Fern., var. **angustata** Carey. Edge of marl area.

–**Carex communis** Bailey. Open woods.

***Carex convoluta** Mack. In woodlands. (Also *F. W. Johnson,* 1926, *Albany.*)

Carex Crawei Dewey. In open marl.

Carex cristatella Britton. *(C. cristata.)* About marl springs.

***Carex cryptolepis** Mack. Edge of marl bogs.

***Carex diandra** Schrank. Edge of marl bogs.

***Carex disperma** Dewey. *(C. tenella.)* In mucky soil under trees.

Carex eburnea Boott. On grassy hummocks in arbor-vitae swamp.

Carex flava L. Common along streams in open marl bog. Specimens from drier marl areas have been referred to *C. laxior* (Kueken) Mack. These appear to be but forms of *C. flava* with shorter spikes. *(W. A. Mathews, 4317, 3555, Albany.)*

Carex gracillima Schwein. Border of swamp.

***Carex granularis** Muhl., var. **Haleana** (Olney) Porter. About the edges of the swamp.

***Carex grisea** Wahl. Edge of open woods.

Carex gynocrates Wormsk. In marl bogs.

***Carex Howei** Mack. On hummocks, edge of sphagnum bogs. *(M. S. Baxter, 5097, Albany.)*

Carex hystericina Muhl. Along spring-fed brook in marl bog.

***Carex incomperta** Bickn. *(G. W. Clinton,* under *C. sterilis* Willd., det. by K. Mackenzie, *Albany.)*

***Carex interior** Bailey. In wet sphagnum bog near edge of marl. (Also *W. A. Mathews, 4320; M. S. Baxter, 5020; Albany.*)

***Carex lasiocarpa** Ehrh. *(C. filiformis.)* In wet mucky area bordering marl bog. (Also *M. S. Baxter, 219a,* 1913, *Albany.*)

***Carex laxiflora** Lam. Bergen Swamp. *(M. S. Baxter,* 1917, det. by F. J. Hermann. *R. Acad.)* Most specimens from here reported under this species belong to *C. anceps.*

***Carex leptalea** Muhl. *(H. D. House,* 1917, *Albany; M. S. Baxter,* 1917, *Rochester.)*

Carex lupulina Muhl. In shallow water and marshes along streams.

–**Carex lurida** Wahl. In wet swales. (Reported by Day[2] as *C. tentaculata.*) Not seen.

***Carex pallescens** L. In open marsh. *(M. S. Baxter (185),* 1895; *F. W. Johnson,* 1926; *Albany.)*

Carex pauciflora Lightf. On sphagnum hummocks.

***Carex paupercula** Michx. About edge of marl bog.

Carex pedunculata Muhl. On hummocks about arbor-vitae swamp. *(F. P. Metcalf, 7740, Cornell.)*

***Carex plantaginea** Lam. In moist woodlands.

***Carex prairea** Dewey. In marl bog.

Carex pseudo-cyperus L. In shallow water, edge of swamp.

***Carex riparia** Curtis, var. **lacustris** (Willd.) Kueken. Covering extensive areas in swales along the north side of the swamp.

Carex rosea Schk. In wet woodland. (Also *H. D. House,* 1917, *Albany.*)

–**Carex rostrata** Stokes. Reported from Bergen Swamp.[7] Not seen.

–**Carex scabrata** Schwein. Reported.[7] Not seen.

–**Carex siccata** Dewey. Reported by *Clinton* (Day).[3, 6] Not seen. Since this species is usually associated with a dry, sandy habitat, its occurrence here is doubtful.

Carex sterilis Willd. In open marl bog.

***Carex stipata** Muhl. In mucky soil along trails.

***Carex stricta** Lam. In swales along streams.

***Carex tenera** Dewey. In wet fields and along edge of swamp.

Carex trisperma Dewey. Among sphagnum and in arbor-vitae swamp.

Carex vaginata Tausch. In arbor-vitae swamp. *(Booth; M. S. Baxter; F. P. Metcalf, Cornell.) C. saltuensis* Bailey, the type of which is stated to be Bergen Swamp, appears to belong here. (N. A. Flora 18:241. 1935.)

Carex viridula Michx. *(C. Oederi,* var. *viridula.)* In openings in the swamp. (Also H. D. *House,* 1917, *Albany.*)

Carex vulpinoidea Michx. In swales and along streams.

Cladium mariscoides (Muhl.) Torr. *(Mariscus mariscoides.)* In wet marl bogs; common.

–**Cyperus diandrus** Torr. In wet places along ponds and streams.

***Cyperus rivularis** Kunth. In mud along banks of streams.

*–**Dulichium arundinaceum** (L.) Britt. In wet sphagnum areas.

***Eleocharis acicularis** (L.) R. & S. In shallow water and on marshy stream banks.

–**Eleocharis acuminata** (Muhl.) Ness. Reported.[7] Not seen.

***Eleocharis calva** Torr. SPIKE RUSH. In shallow water and in marshy places.

***Eleocharis elliptica** Kunth. (*E. tenuis.*) In wet marly areas.

***Eleocharis intermedia** (Muhl.) Schultes. *(J. B. Fuller* under *Scirpus pauciflorus* Lightf. *(R. Acad.))*

***Eleocharis obtusa** (Willd.) Schultes. On muddy areas about margins of shallow pools and streams.

Eleocharis rostellata Torr. In wet open marl bogs; abundant.

–**Eriophorum virginicum** L. Reported.[7] Not seen.

Eriophorum viridi-carinatum (Engelm.) Fern. COTTON GRASS. On sphagnum hummocks in marl bogs; frequent.

Rynchospora alba (L.) Vahl. BEAK RUSH. In sphagnum bogs and also in marl bogs.

Rynchospora capillacea Torr. BEAK RUSH. Common among larger plants in open marl.

Rynchospora capillacea, var. **leviseta** Hill. In open marl.

***Scirpus acutus** Muhl. TULE, HARD-STEM BULRUSH. In shallow water and wet marshes.

Scirpus americanus Pers. THREE-SQUARE, SHORE RUSH. In marl bogs and along streams.

Scirpus atrovirens Muhl. In wet open places.

–**Scirpus atrocinctus** Fern. In wet swales; common.

Scirpus caespitosus L. In wet marl bogs; common.

Scirpus cyperinus (L.) Kunth. In wet swales.

***Scirpus lineatus** Michx. In wet open places and along trails.

***Scirpus pedicellatus** Fern. In swales.

–**Scirpus Torreyi** Olney. Reported by Paine,[2] Day.[3] Apparently not seen since then.

Scirpus validus Vahl. GREAT BULRUSH. Local about springy places, usually in shallow water.

Scleria verticillata Muhl. Among larger plants in open marl; mostly in drier areas.

17. ARACEAE

*__Acorus Calamus__ L. Sweet Flag. In shallow water along streams and in swales.

Arisaema triphyllum (L.) Schott. Jack-in-the-Pulpit. In swamps and moist woods.

*__Arisaema Dracontium__ (L.) Schott. Green Dragon. On alluvial soil along streams, usually among *Pteretis nodulosa.*

Calla palustris L. Wild Calla. In shallow water along streams and in swamps.

Symplocarpus foetidus (L.) Nutt. Skunk Cabbage. In wet woodlands and in swamps.

18. LEMNACEAE

*__Lemna minor__ L. Floating on the surface of sluggish streams and temporary pools and spring-holes.

*__Lemna trisulca__ L. In spring-fed brooks.

*__Spirodela polyrhiza__ (L.) Schleid. In spring-fed pools.

*__Wolffia columbiana__ Karst. With *Lemna minor* L., floating in quiet water in a slough.

*__Wolffia punctata__ Griseb. With the preceding.

19. JUNCACEAE

–**Juncus acuminatus** Michx. Rush. Reported by Paine,[1] and others.[7] Not seen

Juncus alpinus Vill., var. **fuscescens** Fern. In muddy borders of ponds and in swales.

Juncus alpinus Vill., var. **insignis** Fries. In marl openings.

*–**Juncus articulatus** L. In marl bogs.

Juncus balticus Willd., var. **littoralis** Engelm. Rush. In wet depressions in open marl bog.

Juncus brachycephalus (Engelm.) Buch. Along streams and in swales.

Juncus brevicaudatus (Engelm.) Fern. In swales.

Juncus bufonius L. Toad Rush. Along paths and on muddy stream banks.

–**Juncus canadensis** J. Gay. Reported by M. S. Baxter.[3] Not seen.

Juncus Dudleyi. Wieg. In spring-fed bog; rare.

*__Juncus effusus__ L., var. **solutus** Fern. and Wieg. Bulrush. In swales.

*__Juncus macer__ S. F. Gray. Along paths in the bogs.

*__Juncus marginatus__ Rostk. Along streams in marl bog.

*__Juncus nodosus__ L. Rush. In swales and along small streams.

*__Juncus Torreyi__ Coville. In a dried-up pool.

*__Luzula saltuensis__ Fern. Wood Rush. In rich woodlands.

20. LILIACEAE

*__Allium canadense__ L. WILD ONION. In open woods, mostly on alluvial soil.

Allium tricoccum Ait. WILD LEEK. In open woods; rare.

*ALLIUM VINEALE L. WILD GARLIC. Introduced, edge of field.

*__Clintonia borealis__ (Ait.) Raf. WOOD LILY. In swampy woodlands.

*__Erythronium americanum__ Ker. YELLOW ADDER'S TONGUE. In upland hardwoods.

HEMEROCALLIS FULVA L. DAY LILY. Introduced, edge of swamp.

*__Lilium canadense__ L. CANADA LILY. In wet meadows.

*__Lilium philadelphicum__ L. WOOD LILY. In openings in arbor-vitae swamp.

Maianthemum canadense Desf. WILD LILY-OF-THE-VALLEY. On hummocks in swampy forests.

Medeola virginiana L. INDIAN CUCUMBER ROOT. In rich woodlands.

Polygonatum pubescens (Willd.) Pursh. SMALL SOLOMON'S SEAL. In rich woodlands.

Smilacina racemosa (L.) Desf. FALSE SOLOMON'S SEAL. In openings in upland forests.

Smilacina stellata (L.) Desf. In swampy woods and arbor-vitae thickets.

Smilacina trifolia (L.) Desf. On sphagnum hummocks in arbor-vitae thickets.

*__Smilax hispida__ Muhl. GREEN BRIER. In thickets bordering the bogs.

*–__Smilax herbacea__ L. CARRION-FLOWER. Edge of woodland.

*__Streptopus roseus__ Michx. TWISTED-STALK. Among hemlocks in open woods.

Tofieldia glutinosa (Michx.) Pers. Mostly on hummocks in marl bogs.

Trillium erectum L. WAKE ROBIN, RED TRILLIUM. In rich woodlands; rare.

Trillium grandiflorum (Michx.) Salisb. WHITE TRILLIUM. In rich woodlands; common.

Uvularia grandiflora Sm. BELLWORT. In hardwood forests.

–**Uvularia perfoliata** L. Reported.[7] Not seen.

*__Veratrum viride__ Ait. AMERICAN HELLEBORE. On alluvial soil along Black Creek; infrequent.

Zygadenus chloranthus Richards. In open marl bogs. This is the most extensive of the few stations in New York for this species.

21. IRIDACEAE

*__Iris versicolor__ L. BLUE FLAG, WILD IRIS. In swales and sloughs.

*–__Sisyrinchium angustifolium__ Mill. BLUE-EYED-GRASS. In grassy border along stream.

22. ORCHIDACEAE

Arethusa bulbosa L. On sphagnum hummocks in marl bogs.

Calopogon pulchellus (Sw.) R. Br. GRASS-PINK ORCHID. In wet places in marl bog.

Calypso bulbosa (L.) Oakes. CALYPSO. The habitat of this species is usually in moss in deep coniferous woods. According to C. M. Booth, who discovered Calypso in Bergen Swamp in 1863, about forty plants were growing in hemlock woods bordering the swamp when the station was last visited by Booth and Fuller.[3] Paine[1] reported a single plant noticed by C. M. Booth. It was also reported by G. T. Fish, 1866, and another plant was reported by W. H. Lennon (no date) but probably before 1900.[6] Apparently this species has not been seen in Bergen Swamp since 1900. In the herbarium of the Rochester Academy of Science is the only Bergen material that I have seen, a single sheet containing one plant, labelled "border, Bergen Swamp," 1866, (no collector). It is questionable whether this species still grows in Bergen Swamp.

Corallorhiza maculata Raf. CORAL ROOT. In moist woods. *(Stewart,* 1933, *Rochester.)*

Corallorhiza trifida Chat. CORAL ROOT. The only specimens seen are those collected by *W. H. Lennon,* 1893 *(Albany).*

Cypripedium acaule Ait. STEMLESS LADYSLIPPER, MOCCASIN FLOWER. On hemlock knolls and borders of swamps; infrequent.

Cypripedium Calceolus L., var. **pubescens** (Willd.) Correll. *(C. parviflorum,* var. *pubescens.)* LARGE-FLOWERED YELLOW LADYSLIPPER. Local in openings in the arbor-vitae swamps; infrequent in the open marl.

Cypripedium Calceolus L., var. **parviflorum** (Salisb.) Fern. *(C. parviflorum.)* SMALL-FLOWERED YELLOW LADYSLIPPER. In marl bogs; infrequent. (Cf. Fernald, M. L., Rhodora 48: 4, 1946.)

Cypripedium candidum Muhl. SMALL WHITE LADYSLIPPER. Local in open marl bogs. Most of the specimens occur on the raised drier parts of the marl area. This species is rare in New York State. It is known from only a few other stations in the western part of the state. The New York State Conservation law makes it illegal to disturb the white ladyslipper in Bergen Swamp.

Cypripedium reginae Walt. *(C. spectabile, C. hirsutum.)* SHOWY LADYSLIPPER. Local in wet openings in the arbor-vitae swamp.

*EPIPACTIS LATIFOLIA (L.) All. *(Serapius Helleborine.)* Common in moist woodlands. This orchid is believed to have been introduced from Europe.

–**Goodyera pubescens** (Willd.) R. Br. *(Epipactis pubescens.)* RATTLESNAKE PLANTAIN. Reported.[7] Not seen.

–**Goodyera repens** (L.) R. Br. var. **ophioides** Fern. *(Epipactis repens.)* RATTLESNAKE PLANTAIN. Reported.[7] Not seen.

–**Habenaria blephariglottis** (Willd.) Torr. WHITE FRINGED ORCHIS. Reported by *F. W. Johnson,* Zenkert.[7] I have seen no specimens from Bergen Swamp.

–**Habenaria bracteata** (Willd.) R. Br. Reported.[6, 7] Not seen.

Habenaria dilitata (Pursh) Gray. In open marl bogs.

Habenaria fimbriata (Ait.) R. Br. PURPLE FRINGED ORCHIS. In openings in wet swamps.

Habenaria Hookeri Torr. In rich hardwood forests; rare. (*W. H. Lennon,* 1885, *Albany; E. P. Killip,* 1913, *R. Acad.*)

Habenaria hyperborea (L.) R. Br. In springy marl bogs; infrequent. *H. D. House, 6539,* 1919, *Albany.* Also collected by *Lennon, Peck* and *F. W. Johnson.*

*****Habenaria lacera** (Michx.) R. Br. RAGGED ORCHIS. In open grassy places; rare.

–**Habenaria orbiculata** (Pursh) Torr. *W. H. Lennon,* 1892, according to Beckwith and Macauley.[7] Not seen.

Habenaria psychodes (L.) Sw. PURPLE FRINGED ORCHIS. In wet alder swamps; infrequent.

Liparis Loeselii (L.) Rich. In marly areas about springs. First reported by *C. M. Booth.*[3] *(H. D. House, 6522,* 1919, *Albany. F. W. Johnson, 310,* 1923, *Buffalo.* Without name of collector, 1867, *R. Acad.)*

Listera cordata (L.) R. Br. On mossy hummocks in arbor-vitae swamp; infrequent.

Microstylis monophyllos (L.) Lindl. ADDER'S MOUTH. Reported by several authors.[1, 2, 6, 7] Not seen.

Orchis spectabilis L. SHOWY ORCHIS. In moist woodlands; infrequent.

Pogonia ophioglossoides (L.) Ker. On sphagnum hummocks in marl bog; common.

*****Spiranthes Romanzoffiana** Cham. In open marl bogs. (Also *W. H. Lennon,* 1891, *R. Acad.; H. D. House,* 1916, *Albany.*)

*****Spiranthes cernua** (L.) Rich. AUTUMN LADY'S TRESSES. In grassy openings bordering the swamp.

*****Spiranthes lucida** (H. H. Eaton) Ames. LADY'S TRESSES. On hummocks in swales.

23. PIPERACEAE

Saururus cernuus L. LIZARD'S TAIL. In shallow water and in mucky, over-flow soil along streams.

24. SALICACEAE

Populus balsamifera L. *(P. deltoides.)* COTTONWOOD. In wet woodlands and along streams.

*POPULUS CANDICANS Ait. BALM OF GILEAD. Edge of spring-fed bog; rare.

***Populus grandidentata** Michx. LARGE-TOOTHED ASPEN. In open upland woods.

***Populus tacamahacca** Mill. TACAMAHAC. A clump of small trees on the edge of the swamp.

Populus tremuloides Michx. QUAKING ASPEN. In openings about the bogs.

*SALIX ALBA L. var. VITELLINA (L.) Koch. WHITE WILLOW. Along streams.

***Salix amygdaloides** Anders. PEACH-LEAVED WILLOW. Along streams and in swales.

Salix Bebbiana Sarg. BEBB'S WILLOW. In openings in the woodlands and bogs.

Salix candida Flügge. HOARY WILLOW. In openings in the marl.

***Salix cordata** Muhl. Along streams and in marshes.

Salix discolor Muhl. PUSSY WILLOW. Along streams.

–**Salix humilis** Marsh. A fragmentary specimen so determined *(F. W. Johnson,* barren marl, *(336)* 1923, *Buffalo.)* is *Salix petiolaris* Smith.

***Salix interior** Rowlee. *(S. longifolia.)* SAND-BAR WILLOW. Mostly on alluvial soil along Black Creek.

Salix lucida Muhl. SHINING WILLOW. In springy openings.

***Salix nigra** Marsh. BLACK WILLOW. In sloughs and along streams.

***Salix petiolaris** Smith. In openings in the bogs.

***Salix pedicellaris** Pursh. Along small streams in the bog.

*SALIX PURPUREA L. BASKET WILLOW. Established in swales and along streams.

***Salix sericea** Marsh. In openings in the swamp.

***Salix serissima** (Bailey) Fern. AUTUMN WILLOW. In the marl bog, mostly about springs.

25. MYRICACEAE

Myrica pennsylvanica Lois. *(M. carolinensis.)* BAYBERRY. On hummocks in the marl and common in openings in the Thuja swamps.

26. JUGLANDACEAE

***Carya cordiformis** (Wang.) K. Koch. BITTERNUT. A few scattered trees in the hardwood forest.

***Carya glabra** (Mill.) Sweet. PIGNUT. Rare, near west end of swamp.

*__Carya ovata__ (Mill.) K. Koch. SHAGBARK HICKORY. A number of large trees mostly on alluvial soil near Black Creek.

*__Juglans cinerea__ L. BUTTERNUT. Scattered along streams in the hardwood forest.

27. BETULACEAE

Alnus incana (L.) Moench. SPECKLED ALDER. Common in wet thickets and alder swamps.

Betula lutea Michx. YELLOW BIRCH. In the bordering swamp forests; common.

*__Betula pendula__ Roth. EUROPEAN WHITE BIRCH. A few small trees in openings in the arbor-vitae swamp; probably introduced.

*__Betula pumila__ L. DWARF BIRCH. Rare in the open marl bog, 1944. Otherwise apparently not recorded in western New York outside of Tonawanda Swamp in Erie County, Booth.

Carpinus caroliniana Walt. BLUE BEECH. In woods bordering the swamp.

*__Corylus cornuta__ Marsh. BEAKED HAZELNUT. In thickets and under hardwoods.

Ostrya virginiana (Mill.) K. Koch. HOP HORNBEAM. In hardwood forests bordering the swamp.

28. FAGACEAE

Fagus grandifolia Ehrh. BEECH. Infrequent in upland forests.

Quercus alba L. WHITE OAK. On ridges; infrequent.

Quercus bicolor Willd. SWAMP WHITE OAK. In swales and swampy woodlands.

Quercus borealis Michx. f., var. **maxima** (Marsh.) Sarg. RED OAK. On ridges with Tsuga; infrequent.

*__Quercus macrocarpa__ Michx. BUR OAK. In wet depressions and on alluvial soil along Black Creek.

29. URTICACEAE

*__Boehmeria cylindrica__ (L.) Sw. FALSE NETTLE. In rich mucky soils.

*__Humulus lupulus__ L. HOP. Established in thickets and along streams; rare.

Laportea canadensis (L.) Gaud. WOOD NETTLE. Common in rich woodlands.

Pilea pumila (L.) Gray. CLEARWEED. In mucky soil under trees.

Urtica procera Muhl. *(U. gracilis.)* STINGING NETTLE. Along streams.

30. MORACEAE

Ulmus americana L. AMERICAN ELM. A common tree in wet woodlands.

***Ulmus rubra** Michx. (*U. fulva* Michx.) SLIPPERY ELM. Infrequent in openings in the forest.

–**Morus rubra** L. A record based upon a seedling with a single lobed leaf (Zenkert,[7] 1932. Among arbor-vitae, *Buffalo*) appears to belong to *Morus alba* L.

31. SANTALACEAE

Comandra umbellata (L.) Nutt. BASTARD TOADFLAX. In openings in the marl bogs.

32. ARISTOLOCHIACEAE

Asarum canadense L. WILD GINGER. In rich humus under hardwoods.

33. POLYGONACEAE

***Polygonum amphibium** L. WATER SMARTWEED. In shallow water.

*POLYGONUM AVICULARE L. KNOTWEED. Along paths and in open areas.

***Polygonum coccineum** Muhl. In larger streams, temporary pools and marshes.

*POLYGONUM CONVOLVULUS L. BLACK BINDWEED. In openings along paths.

***Polygonum Hydropiper** L. SMARTWEED. In mucky openings.

***Polygonum hydropiperoides** Michx. WATER PEPPER. In streams and swales.

***Polygonum lapathifolium** L. Along stream banks.

***Polygonum pennsylvanicum** L. PENNSYLVANIA SMARTWEED. In openings along streams.

POLYGONUM PERSICARIA L. LADY'S THUMB. In paths and open grassy places.

***Polygonum punctatum** Ell. In a swale.

***Polygonum punctatum** Ell., var. **leptostachyum** (Meisn.) Small. On borders of pools and ditches.

Polygonum robustius (Small) Fernald. In mucky soil in swales.

Polygonum sagittatum L. On boggy banks of streams.

***Polygonum scandens** L. On alluvial soil and in marshes.

***Polygonum virginianum** L. In wet open woodlands.

*RUMEX ACETOSELLA L. SHEEP SORREL. Infrequent on grassy hummocks in open areas.

Rumex Brittanica L. GREAT WATER DOCK. In swales and marshes.

*RUMEX CRISPUS L. CURLY DOCK. In openings along trails.

*RUMEX OBTUSIFOLIUS L. BROAD-LEAVED DOCK. In open grassy places.

Rumex verticillatus L. SWAMP DOCK. In swales and temporary pools.

34. CHENOPODIACEAE

*__Atriplex patula__ L., var. __hastata__ (L.) Gray. In openings along paths; probably introduced.

*CHENOPODIUM ALBUM L. LAMB'S QUARTERS. Openings along trail.

*CHENOPODIUM GLAUCUM L. OAK-LEAVED GOOSEFOOT. On muddy banks of Black Creek.

*__Chenopodium hybridum__ L. MAPLE-LEAVED GOOSEFOOT. Along woodland road.

*__Chenopodium paganum__ Reich. PIGWEED. Along bank of Black Creek.

35. AMARANTHACEAE

*AMARANTHUS GRAECIZANS L. TUMBLEWEED. On island in Black Creek.

*AMARANTHUS HYBRIDUS L. GREEN AMARANTH. Along Black Creek.

*AMARANTHUS RETROFLEXUS L. AMARANTH PIGWEED. Along trails.

36. PHYTOLACCACEAE

*__Phytolacca americana__ L. POKEWEED. On rich moist soil in openings in the forests.

37. ILLEBRACACEAE

*SCLERANTHUS ANNUUS L. KNAWEL. In open sandy places.

38. CARYOPHYLLACEAE

*AGROSTEMMA GITHAGO L. PURPLE COCKLE. Edge of field bordering the swamp.

*ARENARIA SERPYLLIFOLIA L. SANDWORT. In open places.

*CERASTIUM VULGATUM L. MOUSE-EAR CHICKWEED. In open grassy places.

*DIANTHUS ARMERIA L. DEPTFORD PINK. In grassy openings.

*LYCHNIS ALBA Mill. WHITE COCKLE. Along road; edge of swamp.

*SILENE NOCTIFLORA L. NIGHT-FLOWERING CATCHFLY. Along woods road.

STELLARIA GRAMINEA L. STITCHWORT. In grassy openings.

Stellaria longifolia Muhl. STITCHWORT. On hummocks in the arborvitae swamp; also *J. Laird*, 1898 *(R. Acad.)*

STELLARIA MEDIA (L.) Cyrill. CHICKWEED. In open places along paths.

39. PORTULACCACEAE

Claytonia virginica L. SPRING BEAUTY. In moist hardwood forests.

*__Claytonia caroliniana__ Michx. In hardwood forest.

40. CERATOPHYLLACEAE

*__Ceratophyllum demersum__ L. HORNWORT. Submersed in Black Creek.

41. NYMPHAEACEAE

*__Nuphar advena__ Ait. SPATTERDOCK, YELLOW POND-LILY. In a small stream entering Black Creek.

42. RANUNCULACEAE

Actaea alba (L.) Mill. WHITE BANEBERRY. In rich woodlands.

*__Actaea rubra__ (Ait.) Willd. RED BANEBERRY. In rich woodlands.

*__Anemone canadensis__ L. ANEMONE. In open areas in the swamp.

Anemone virginiana L. In open woodlands and along streams.

*__Anemonella thalictrioides__ (L.) Spach. Open upland woods; rare.

Aquilegia canadensis L. COLUMBINE. In secondary marl bogs and in openings in woods.

Caltha palustris L. COWSLIP, MARSH MARIGOLD. In marshes along brooks.

Clematis virginiana L. VIRGIN'S BOWER. In thickets in the bogs and on uplands.

Coptis trifolia (L.) Salisb. subsp. **groenlandica** (Oeder) Hulten. GOLDTHREAD. In rich humus in woods bordering the bogs.

Hepatica americana (DC.) Ker. HEPATICA. In rich woodlands.

Hepatica acutiloba DC. HEPATICA. In upland woodlands.

–**Hydrastis canadensis** L. GOLDEN SEAL. Reported from Bergen by *W. H. Lennon.*[3] No specimens have been seen in the field or herbaria.

Ranunculus abortivus L. SMALL-FLOWERED BUTTERCUP. Open woodlands.

RANUNCULUS ACRIS L. TALL FIELD BUTTERCUP. In openings in the swamp.

*__Ranunculus aquatilis__ L. WHITE WATER-CROWFOOT. In streams and ponds.

Ranunculus flagellaris Raf. YELLOW WATER-BUTTERCUP. Temporary ponds and swales.

*__Ranunculus recurvatus__ Poir. HOOKED BUTTERCUP. In wet woodlands.

*__Ranunculus sceleratus__ L. CURSED CROWFOOT. In shallow water and mucky stream banks.

*__Ranunculus septentrionalis__ Poir. SWAMP BUTTERCUP. Marshy thickets and sloughs.

*__Thalictrum dioicum__ L. MEADOW RUE. In open woodlands.

*__Thalictrum polygamum__ Muhl. MEADOW RUE. Swamps and along streams.

43. MAGNOLIACEAE

*Magnolia acuminata** L. CUCUMBER TREE. A few small trees near the border.

44. MENISPERMACEAE

***Menispermum canadense** L. MOONSEED. Borders of woodlands and thickets.

45. BERBERIDACEAE

*BERBERIS THUNBERGII DC. JAPANESE BARBERRY. Established in the open marl and edge of the swamp.

*BERBERIS VULGARIS L. COMMON BARBERRY. Established in openings in the marl.

***Caulophyllum thalictroides** (L.) Michx. BLUE COHOSH. In moist rich woodlands.

Podophyllum peltatum L. MAY APPLE. In openings and borders of woodland.

46. LAURACEAE

Lindera Benzoin (L.) Bl. (*Benzoin aeativale* L.) SPICEBUSH. In wet woodlands.

47. PAPAVERACEAE

Sanguinaria canadensis L. BLOODROOT. In open woods and thickets.

*CHELIDONIUM MAJUS L. CELANDINE. Under trees along the south border of the swamp.

48. FUMARIACEAE

Dicentra canadensis (Goldie) Walp. SQUIRREL CORN. In rich woodlands.

Dicentra Cucullaria (L.) Bernh. DUTCHMAN'S BREECHES. In rich woodlands.

49. CRUCIFERAE

–**Arabis hirsuta** (L.) Scop. The specimen so reported[7] is a depauperate plant of *Cardamine bulbosa (Stewart,* 1933, *Rochester).*

***Armoracia aquatica** (Eaton) Wieg. LAKE CRESS. In streams. Along margin of Black Creek.

*ARMORACIA RUSTICANA Gaertn. HORSE RADISH. In swales and along streams.

*BARBAREA VULGARIS R. Br. WINTER CRESS. In openings in the bogs and elsewhere.

*CAPSELLA BURSA-PASTORIS (L.) Medic. SHEPHERD'S PURSE. Along path. Rare.

*CAMELINA MICROCARPA Andrz. FALSE FLAX. Along paths.

–CAMELINA SATIVA Grantz. Specimens so reported are *C. microcarpa.* (E. P. Killipp, R. Acad.)

Cardamine bulbosa (Schreb.) BSP. SPRING CRESS. In rich mucky soil.

***Cardamine pennsylvanica** Muhl. In mucky swales and in shallow brooks.

***Cardamine pratensis** L., var. **palustris** Wimm. and Grab. CUCKOO FLOWER. In wet alder swamps.

Dentaria diphylla Michx. TOOTHWORT. In hardwood forests.

Dentaria laciniata Muhl. TOOTHWORT. In moist hardwoods; rare.

*ERYSIMUM CHEIRANTHOIDES L. WORMSEED MUSTARD. In openings, mostly on mucky soil.

*HESPERIS MATRONALIS L. ROCKET. In open woods bordering the swamp.

*LEPIDIUM CAMPESTRE (L.) R. Br. DOWNY PEPPERGRASS. In openings and along trails.

*NASTURTIUM OFFICINALE R. Br. WATER CRESS. In small spring-fed pools and their outlets.

***Roripa islandica** (Oeder ex. Murr.) Borbás var. **hispida** Butters and Abbe. *(R. palustris,* var. *hispida.)* MARSH CRESS. In swales and marshes.

***Roripa islandica** (Oeder ex. Murr.) Borbás var. **microcarpa** (Regal.) Fern. *(R. hispida,* var. *glabrata.)* In marshy places.

*SISYMBRIUM ALTISSIMUM L. TUMBLE MUSTARD. In openings along trails.

SISYMBRIUM OFFICINALE (L.) Scop. HEDGE MUSTARD. Along trails and in openings.

50. SARRACENIACEAE

Sarracenia purpurea L. PITCHER PLANT. In sphagnum bogs and on hummocks in the marl bogs; sometimes in wet depressions in the open marl.

51. DROSERACEAE

Drosera rotundifolia L. SUNDEW. On sphagnum hummocks in arborvitae swamps and open marl bogs.

52. CRASSULACEAE

***Penthorum sedoides** L. DITCH STONECROP. In swales and along streams.

SEDUM PURPUREUM Tausch. LIVE-FOR-EVER. Established along edge of swamp.

53. SAXIFRAGACEAE

Chrysosplenium americanum Schw. GOLDEN SAXIFRAGE. In mucky soil along streams.

Mitella diphylla L. Miterwort. In rich woodlands.

Mitella nuda L. In mucky soil, usually under evergreen trees.

Parnassia caroliniana Michx. Grass-of-Parnassus. In marl bog, and about marl springs.

***Ribes americanum** Mill. Wild Black Currant. In swampy places.

Ribes Cynosbati L. Prickly Gooseberry. In open woodlands.

***Ribes hirtellum** Michx. Swamp Gooseberry. In marl bogs and in openings in arbor-vitae swamp.

***Ribes triste** Pall., var. **albinervium** (Michx.) Fern. Wild Red Currant. In wet marshy woodlands.

Saxifraga pennsylvanica L. Swamp Saxifrage. In mucky soil in swamps.

***Saxifraga virginensis** Michx. Early Saxifrage. Upland woods; rare.

Tiarella cordifolia L. False Miterwort. In rich woodlands.

54. HAMAMELIDACEAE

***Hamamelis virginiana** L. Witch-Hazel. In open woodlands.

55. PLATANACEAE

***Platanus occidentalis** L. Sycamore. Several large trees occur among the hardwoods within the swamp.

56. ROSACEAE

Agrimonia gryposepala Wallr. Agrimony. In open grassy places.

Amelanchier arborea (Michx.) Fern. (*A. canadensis.*) Shadbush. In open woods, mostly on upland.

***Amelanchier intermedia** Spach. Serviceberry. In openings in the bogs.

***Amelanchier laevis** Wieg. Juneberry. On uplands bordering the bogs.

***Crataegus brainerdi** Sarg. Thornapple. In open places; infrequent.

***Crataegus macracantha** Lodd. Long-spurred Thorn. On alluvial soil along streams; frequent.

***Crataegus punctata** Jacq. Thornapple. In thickets, edge of swamp; frequent.

Dalibarda repens L. On rotten logs and stumps; rare. (also *G. T. Fish,* 1865 *(708) R. Acad.*)

Fragaria vesca L. Wild Strawberry. In openings in woods; rare.

Fragaria virginiana Duch. Field Strawberry. Common in grassy places and cut-over woodlands.

***Geum canadense** Jacq. White Avens. In openings in woods.

***Geum rivale** L. Purple Avens. In mucky soil mostly in alder swamps.

Geum aleppicum Jacq., var. **strictum** (Ait.) Fern. (*G. strictum.*) YELLOW AVENS. In grassy openings.

–MALUS GLAUCESCENS Rehder. Report based upon a specimen collected by *C. H. Peck* in 1904, *(Albany)* is labelled Bergen. This undoubtedly refers to the village and not the swamp.

***Potentilla argentea** L. SILVERY CINQUEFOIL. Along trails and in cut-over areas.

*POTENTILLA ARGUTA Pursh. In grassy opening bordering the swamp.

Potentilla fruticosa L. SHRUBBY CINQUEFOIL. In marl bogs; abundant.

***Potentilla norvegica** L., var. **hirsuta** (Michx.) Lehm. ROUGH CINQUEFOIL. In openings in and about the swamp.

–**Potentilla palustris** (L.) Scop. MARSH CINQUEFOIL. Reported by Day.[2] Not seen.

*POTENTILLA RECTA L. SULFUR CINQUEFOIL. In cut-over woodland areas and along trails; infrequent.

*PRUNUS AVIUM L. SWEET CHERRY. Scattered trees established in thickets.

*PRUNUS MAHALEB L. MAHALEB CHERRY. A clump of shrubby specimens established along a fence row.

***Prunus pennsylvanica** L. f. PIN- or FIRE-CHERRY. A common tree in new growth on cut-over areas.

***Prunus serotina** Ehrh. WILD BLACK CHERRY. In openings in the bog and in the surrounding forest.

Prunus virginiana L. CHOKE CHERRY. In thickets in and about the swamp.

*PYRUS AUCUPARIA L. (*Sorbus aucuparis* L.) EUROPEAN MOUNTAIN ASH. A few small specimens established in openings in arbor-vitae swamp.

Pyrus arbutifolia (L.) lf., var. **atropurpurea** (Britt.) Robins. (*Aronia arbutifolia,* var. *atropurpurea* [Britt.] Schneid.) RED CHOKEBERRY. On hummocks in marl bogs; infrequent.

*PYRUS COMMUNIS L. PEAR. A few trees are established, one even in the marl bog.

*PYRUS MALUS L. (*Malus pumila* Mill.) APPLE. Scattered trees occur in thickets about the swamp.

***Pyrus melanocarpa** (Michx.) Willd. (*Aronia melanocarpa* [Michx.] Britt.) In marl bogs and swamp; common.

***Rosa acicularis** Lindl., var. **sayana** Erlanson. *(F. W. Johnson,* 1923, *Albany.)*

–**Rosa carolina** L. DWARF ROSE. Reported,[7] but not seen.

***Rosa palustris** Marsh. SWAMP ROSE. In marshes, frequent.

***Rosa Housei** Erlandon. *(F. W. Dorst,* 1931, (Det. E. W. Erlanson.) *30785.* Marl bog. *Buffalo.)*

***Rosa setigera** Michx. PRAIRIE ROSE. Forming a thicket along a spring-fed brook.

Rubus allegheniensis Porter. BLACKBERRY. In cut-over woods.

***Rubus flagellaris** Willd. DEWBERRY. In openings in the woodlands and borders of bog.

–**Rubus hispidus** L. BLACKBERRY. In open woods.

*–RUBUS IDAEUS L. RED RASPBERRY. In cut-over swampland.

***Rubus idaeus** L., var. **strigosus** (Michx.) Maxim. RED RASPBERRY. In openings and along stream banks.

***Rubus occidentalis** L. BLACK RASPBERRY. In thickets bordering the swamp.

Rubus odoratus L. FLOWERING RASPBERRY. In rich soil bordering woodlands.

Rubus pubescens Raf. *(R. triflorus.)* DWARF DEWBERRY. In wet mossy woodlands.

***Waldsteinia fragarioides** (Michx.) Tratt. BARREN STRAWBERRY. In open woods on uplands.

57. LEGUMINOSAE

***Amphicarpa bracteata** (L.) Fern. *(A. monoica.)* HOG PEANUT. In rich moist woods.

Apios americana Medic. *(A. tuberosa.)* GROUNDNUT. On alluvial soil along streams.

–**Desmodium bracteosum** (Michx.) DC. Reported.[7] Not seen.

–**Desmodium canescens** (L.) DC. Reported.[7] Not seen.

Desmodium glutinosum (Muhl. ex. Willd.) Wood. *(D. grandiflorum.)* TICK TREFOIL. In openings in upland woods.

*GLEDITSIA TRIACANTHOS L. HONEY LOCUST. Several trees along a fence row of an abandoned roadway; introduced.

*MEDICAGO LUPULINA L. BLACK MEDIC. In open places and along trails.

*MELILOTUS ALBA Desv. WHITE SWEET CLOVER. Established in cut-over areas.

*MELILOTUS ALTISSIMA Thuill. YELLOW SWEET CLOVER. Established along trails.

*MELILOTUS OFFICINALIS (L.) Lam. YELLOW SWEET CLOVER. In open grassy places along bank of Black Creek.

*TRIFOLIUM AGRARIUM L. YELLOW CLOVER. In cut-over areas.

–TRIFOLIUM ARVENSE L. RABBIT CLOVER. Reported growing along a logging road. *(F. W. Johnson.)* Not seen.

*TRIFOLIUM HYBRIDUM L. ALSIKE CLOVER. Established in openings along trails.

*–TRIFOLIUM REPENS L. WHITE CLOVER. Established in openings.

*TRIFOLIUM PRATENSE L. RED CLOVER. Established along trails and in openings.

58. OXALIDACEAE

***Oxalis europaea** Jord. *(O. corniculata.)* Yellow Wood Sorrel. In openings along trails.

***Oxalis stricta** L. Yellow Wood Sorrel. In grassy openings.

59. GERANIACEAE

Geranium maculatum L. Cranesbill. In open woodlands.

Geranium Robertianum L. Herb Robert. In cut-over woodlands and in thickets.

60. RUTACEAE

***Zanthoxylum americanum** Mill. Prickly Ash. Forming thickets, mostly where the swamp joins the upland.

61. POLYGALACEAE

Polygala paucifolia Willd. Fringed Polygala. In open woodlands on ridges and in the arbor-vitae swamps; common. An extensive colony with pure white corollas was found in an opening in a wet arbor-vitae swamp.

62. EUPHORBIACEAE

***Acalypha rhomboidea** Raf. *(A. virginica.)* Three-seeded Mercury. In grassy openings.

*EUPHORBIA ESULA L. Leafy Spurge. Along an old roadway leading into the swamp. A common introduced weed along roadsides and in grasslands between the village of Bergen and the swamp.

***Euphorbia nutans** Lag. Spurge. In open places along trails.

63. CALLITRICHACEAE

***Callitriche palustris** L. Water Starwort. In shallow pools and streams with mucky bottom; local among *Cephalanthus* in swamps.

64. LIMNANTHACEAE

Floerkea proserpinacoides Willd. False Mermaid. In moist woods bordering a stream, rare.

65. ANACARDIACEAE

Rhus Toxicodendron L. Poison Ivy. In thickets and in cut-over arbor-vitae swamps where it may form a luxurious growth.

Rhus typhina L. Staghorn Sumach. In openings in the bogs and surrounding forests.

Rhus vernix L. Poison Sumach. In a cut-over arbor-vitae swamp; rare elsewhere.

66. AQUIFOLIACEAE

Ilex verticillata (L.) Gray. Winterberry, Black Alder. In openings in and about the marl bogs; infrequent.

*__Nemopanthus mucronata__ (L.) Trel. Mountain Holly. In thickets, mostly between the open marl and arbor-vitae swamps.

67. CELASTRACEAE

*__Celastrus scandens__ L. Bittersweet. In upland thickets.

*__Euonymus atropurpureus__ Jacq. Burning Bush, Wahoo. Several extensive areas on alluvial soil near Black Creek.

68. ACERACEAE

*__Acer nigrum__ Michx. f. Black Maple. In moist hardwood forest; infrequent.

Acer pennsylvanicum L. Striped Maple. In rich woods on ridge; rare.

Acer rubrum L. Red Maple. In the swamp and also in marl bogs; common.

Acer saccharinum L. Silver Maple. In wet woodlands; common; mostly along the north side of swamp.

Acer saccharum Marsh. Sugar Maple. A common tree in the hardwood forest.

Acer spicatum Lam. Mountain Maple. In openings between arborvitae and in upland forests.

69. BALSAMINACEAE

Impatiens biflora Walt. Touch-me-not. In moist woodlands and along streams.

*__Impatiens pallida__ Nutt. Pale Touch-me-not. In moist woodlands.

70. RHAMNACEAE

Rhamnus alnifolia L'Her. Swamp Buckthorn. In openings in marl bogs and along streams in arbor-vitae swamps; common.

*Rhamnus cathartica L. Common Buckthorn. A few clumps established in the drier marl openings.

71. VITACEAE

*__Vitis vulpina__ L. Frost Grape. In thickets and woodlands; common.

Parthenocissus quinquefolia (L.) Planch. Virginia Creeper. In open woodlands; common.

*__Parthenocissus vitaceae__ (Knerr.) Hitchc. In thickets and woodlands, infrequent.

72. TILIACEAE

Tilia americana L. Basswood. Common in hardwood forest.

73. MALVACEAE

–**Hibiscus moscheutos** L. Swamp Mallow. Reported.[7] Not seen.

*Malva moschata L. Musk Mallow. In grassy cut-over area; rare.

*Malva neglecta Wallr. (*M. rotundifolia.*) Round-leaved Mallow. Established along a trail; rare.

74. HYPERICACEAE

–**Hypericum boreale** (Britt.) Bickn. In wet openings bordering arbor-vitae swamp.

*Hypericum perforatum L. St. John's-wort. Established in numerous places in openings in the woods and dry border of marl bog.

Hypericum punctatum Lam. In spring-fed boggy areas.

Hypericum virginicum L. In sphagnum hummocks along edge of arbor-vitae swamp.

75. VIOLACEAE

***Viola affinis** LeConte. In wet woods, chiefly on alluvial soil; infrequent. (Also *E. P. Killipp,* 1916, *R. Acad.*)

Viola blanda Willd. Stemless White Violet. In wet arbor-vitae swamp.

*Viola arvensis Murr. Field Pansy. In field bordering Bergen swamp. *(F. W. Johnson,* 1924, *Rochester.)*

Viola canadensis L. Canada Violet. In open upland woods; infrequent.

Viola conspersa Reichenb. Dog Violet. In open woodlands; frequent.

***Viola cucullata** Ait. Marsh Blue Violet. In marshy woodlands; infrequent.

Viola eriocarpa Schwein., var. **leiocarpa** Fern. & Wieg. *(V. scabriuscula.)* Stemmed Yellow Violet. In moist woods.

***Viola incognita** Brainerd. Stemless White Violet. In wet woods and boggy areas. *(K. M. Wiegand,* 1918, *Cornell.)*

Viola nephrophylla Greene. Northern Bog Violet. In marl bogs.

Viola pallens (Banks) Brainerd. Stemless White Violet. In bogs and wet woodlands.

***Viola pubescens** Ait. Stemmed Yellow Violet. In rich woodlands.

Viola renifolia Gray, var. **Brainerdii** Fern. Stemless White Violet. In mossy carpets in arbor-vitae swamp; common.

Viola rostrata Pursh. Long-spurred Violet. In open woods; common.

–**Viola rotundifolia** Michx. Stemless Yellow Violet. In rich moist woods; rare.

–**Viola septentrionalis** Greene. NORTHERN BLUE VIOLET. In open woodlands; infrequent.

Viola sororia Willd. (*V. cucullata* in part.) MEADOW BLUE VIOLET. On alluvial soils, chiefly in moist open woodlands.

76. ONAGRACEAE

Circaea alpina L. ENCHANTER'S NIGHTSHADE. In arbor-vitae swamp; frequent.

Circaea latifolia L. ENCHANTER'S NIGHTSHADE. In moist open woodlands.

Epilobium angustifolium L. FIREWEED. In openings in the bogs and woodlands.

***Epilobium densum** Raf. MARSH WILLOW HERB. Among sedges in open marshes.

***Epilobium coloratum** Muhl. WILLOW HERB. In cut-over arbor-vitae swamps and along streams.

***Epilobium glandulosum** Lehm., var. **perplexans** (Trel.) Fern. Along small streams and about springy places.

*EPILOBIUM HIRSUTUM L. WILLOW HERB. In mucky soil along spring-fed streams and ditches.

***Ludvigia palustris** (L.) Ell. WATER PURSLANE. In small streams and shallow ponds.

OENOTHERA BIENNIS L., var. NUTANS (Atkins. and Bart.) Wieg. EVENING PRIMROSE. In openings in arbor-vitae swamp.

OENOTHERA BIENNIS L., var. PYCNOCARPA (Atkins. and Bart.) Wieg. Along trails and in openings and swampy areas.

***Oenothera perennis** L. SUNDROPS. In grassy areas bordering the swamp.

77. ARALIACEAE

Aralia hispida Vent. BRISTLY SARSAPARILLA. On a gravelly ridge; infrequent.

Aralia nudicaulis L. WILD SARSAPARILLA. Common in swampy woodlands.

***Aralia racemosa** L. SPIKENARD. In moist rich woodlands bordering the swamp; infrequent.

78. UMBELLIFERAE

***Angelica atropurpurea** L. ANGELICA. On alluvial and swampy areas; infrequent.

*CARUM CARVI L. CARAWAY. Established along a trail; frequent in grasslands about the swamp.

***Cicuta bulbifera** L. In shallow temporary pools in the swamp; sometimes growing on floating mats.

Cicuta maculata L. WATER HEMLOCK. Along streams and in open swampy areas.

*CONIUM MACULATUM L. POISON HEMLOCK. Along Black Creek; rare.

Conioselinum chinense (L.) BSP. In rich mucky soil in arbor-vitae swamp.

Cryptotaenia canadensis (L.) DC. In open upland woods.

DAUCUS CAROTA L. WILD CARROT. Established in numerous openings and cut-over areas.

***Heracleum lanatum** Michx. COW PARSNIP. On alluvial soil along streams; rare.

*–**Hydrocotyle americana** L. In mucky soil along small streams.

Osmorhiza Claytoni (Michx.) Clarke. SWEET CICELY. In open upland woods; infrequent.

*PASTINACA SATIVA L. PARSNIP. Established in openings.

Sanicula marilandica L. SANICLE. In open upland woods.

***Sium suave** Walt. WATER PARSNIP. In temporary pools and along streams; frequent.

79. CORNACEAE

***Cornus alternifolia** L. f. In open woods and openings in the arbor-vitae swamps.

***Cornus amomum** Mill. In thickets about streams and edges of swamps.

Cornus canadensis L. BUNCHBERRY, DWARF CORNEL. In rich humus in the arbor-vitae swamp; also on sphagnum hummocks in the marl bogs.

***Cornus racemosa** Lam. *(C. paniculata.)* GRAY DOGWOOD. Forming thickets about borders of swamp and forests.

Cornus rugosa Lam. (*C. circinata.*) ROUND-LEAVED DOGWOOD. In openings in the hardwood forests and arbor-vitae swamps.

Cornus stolonifera Michx. RED OSIER DOGWOOD. In wet places about springy areas and in marshes.

80. ERICACEAE

–**Chamaedaphne calyculata** (L.) Moench. LEATHER-LEAF. Recorded as one of the "sub-dominant species in the secondary marl association".[7] Although diligently searched for, no specimens were seen in the swamp. No specimens could be found in herbaria.

Chiogenes hispidula (L.) T. and G. CREEPING SNOWBERRY, SQUAWBERRY. On mossy forest floor, especially on decayed logs and stumps; frequent.

Gaultheria procumbens L. WINTERGREEN. On sphagnum hummocks in the marl bogs; also on upland ridges and in openings in the arbor-vitae swamps.

Gaylussacia baccata (Wang.) K. Koch. BLACK HUCKLEBERRY. Common on hummocks in marl bogs; in openings in the arbor-vitae swamps.

***Chimaphila umbellata** (L.) Bart. PIPSISSEWA. On pine-hemlock ridge. *(J. Laird,* 1894, *R. Acad.)*

Ledum groenlandicum Oeder. LABRADOR TEA. Between marl bogs and arbor-vitae swamps.

–**Moneses uniflora** (L.) Gray. Reported by *M. E. Macauley,*[3] and others.[7] No specimens from Bergen Swamp were seen.

Monotropa uniflora L. INDIAN PIPE. In rich moist woodlands; infrequent.

Pyrola americana Sweet. SHINLEAF. In woodlands; infrequent.

Pyrola asarifolia Michx., var. **incarnata** (Fisch.) Fern. About borders of arbor-vitae swamps.

Pyrola chlorantha Sw. SHINLEAF. On hummocks in wooded swamp.

Pyrola elliptica Nutt. SHINLEAF. *(W. H. Lennon,* 1893, *Albany.)*

Pyrola secunda L. SHINLEAF. In upland woods; rare. *(E. P. Killipp,* 1913, *R. Acad.)*

Rhododendron nudiflorum (L.) Torr., var. **roseum** (Lois.) Wieg. PINK AZALEA. On hummocks about margin of marl bogs and in openings in the forests.

***Vaccinium canadense** Kalm. CANADA BLUEBERRY. In openings in marl bogs and arbor-vitae swamps; infrequent.

Vaccinium corymbosum L. HIGHBUSH BLUEBERRY. In swamps; frequent.

–**Vaccinium macrocarpon** Ait. LARGE CRANBERRY. Recorded from Bergen Swamp.[3, 7] A careful search in many sphagnum areas failed to locate it. No herbarium specimens could be found.

Vaccinium Oxycoccus L. SMALL CRANBERRY. On sphagnum hummocks, mostly in marl bogs.

Vaccinium angustifolium Ait. *(V. pennsylvanicum.)* EARLY UPLAND BLUEBERRY. On upland ridges and knolls; infrequent.

–**Vaccinium stamineum** L. DEERBERRY. On gravelly ridge, rare.

81. PRIMULACEAE

LYSIMACHIA NUMMULARIA L. MONEYWORT. In swales or along streams; common.

Lysimachia terrestris (L.) BSP. YELLOW LOOSESTRIFE. In open places bordering swamp; infrequent.

***Lysimachia thyrsiflora** L. TUFTED LOOSESTRIFE. In swales and temporary pools; frequent.

Samolus floribundus HBK. WATER PIMPERNEL. In mucky soil along trails and streams.

Steironema ciliatum (L.) Raf. FRINGED LOOSESTRIFE. In swampy thickets and along streams.

Trientalis borealis Raf. STARFLOWER. In rich humus mostly in the arbor-vitae swamp; common.

82. OLEACEAE

Fraxinus americana L. WHITE ASH. A common tree in the hardwood forest.

Fraxinus nigra Marsh. BLACK ASH. In bogs and marshes; common.

***Fraxinus pennsylvanica** Marsh. RED ASH. In swamps and alluvial soil; common.

83. GENTIANACEAE

***Gentiana crinita** Froel. FRINGED GENTIAN. No date, Bergen. W. H. Lennon. (Under *G. Andrewsii, Albany.*)

84. MENYANTHACEAE

–**Menyanthes trifoliata** L. BUCKBEAN. Reported from swamp by Day,[3] and Baxter and House.[5] Not seen.

85. APOCYNACEAE

***Apocynum androsaemifolium** L. SPREADING DOGBANE. In openings along trails and in openings on ridge.

Apocynum cannabinum L. INDIAN HEMP. In openings and along border of swamp.

***Apocynum cannabinum** L. var. **pubescens** (R. Br.) DC. In dry open areas in marl bogs.

86. ASCLEPIADACEAE

***Asclepias incarnata** L. SWAMP MILKWEED. In swales and openings in swamps; common.

Asclepias quadrifolia Jacq. On low sandy ridge; rare.

***Asclepias syriaca** L. MILKWEED. In openings, especially on alluvial soil; common.

87. CONVOLVULACEAE

***Convolvulus sepium** L. HEDGE BINDWEED. In openings in the swamp and along streams.

***Cuscuta Gronovii** Willd. DODDER. On numerous hosts in several areas in the swamp.

88. POLEMONIACEAE

Phlox divaricata L. BLUE PHLOX. In open upland forest. Several clumps were found in which the corollas were pure white.

89. HYDROPHYLLACEAE

***Hydrophyllum virginianum** L. WATERLEAF. Among trees and in thickets bordering the swamp.

90. BORAGINACEAE

*CYNOGLOSSUM OFFICINALE L. HOUND'S-TONGUE. In open grassy places; infrequent.

***Hackelia virginiana** (L.) Johnston. BEGGAR'S LICE. In rich open woodlands.

–**Myosotis laxa** Lehm. FORGET-ME-NOT. In spring-fed brook; rare.

91. VERBENACEAE

***Verbena hastata** L. BLUE VERVAIN. In open swampy areas.

***Verbena urticaefolia** L. WHITE VERVAIN. Along streams, mostly on alluvial soil.

92. LABIATAE

***Collinsonia canadensis** L. HORSE BALM. In wet woodlands; common.

***Hedeoma pulegioides** (L.) Pers. AMERICAN PENNYROYAL. In grassy places along trail.

*LEONURUS CARDIACA L. MOTHERWORT. Established in open places; common.

Lycopus americanus Muhl. WATER HOREHOUND. In swales and along streams.

***Lycopus uniflorus** Michx. BUGLE WEED. In bogs and marshes, especially near streams.

***Lycopus lucidus** Turcz., var. **americanus** Gray. *(H. D. House,* 1916. *Albany.)* In marl bogs, apparently rare.

***Mentha arvensis** L., var. **canadensis** (L.) Briq. WILD MINT. In openings in swampy places and along streams.

*MENTHA PIPERITA L. PEPPERMINT. Established along spring-fed brooks; frequent.

*MENTHA SPICATA L. SPEARMINT. Established in open places along streams; frequent.

*NEPETA CATARIA L. CATNIP. Common along edge of woods.

*NEPETA HEDERACEA (L.) Trev. GROUND IVY. In open woods bordering the swamp.

PRUNELLA VULGARIS L. HEAL-ALL. In open grassy places.

***Satureja vulgaris** (L.) Fritsch. WILD BASIL. In open grassy places on uplands.

Scutellaria lateriflora L. SKULLCAP. In bogs and along streams.

***Scutellaria epilobiifolia** Hamil. SKULLCAP. Along streams and in sloughs.

***Stachys tenuifolia** Willd., var. **aspera** (Michx.) Fern. HEDGE NETTLE. In swales.

Teucrium canadense L. GERMANDER. In grassy places along streams.

***Teucrium occidentale** Gray, var. **boreale** (Bickn.) Fern. In marshy openings.

93. SOLANACEAE

***Physalis heterophylla** Nees., var. **ambigua** (Gray) Rydb. GROUND CHERRY. In sandy soil, near base of ridge.

***Physalis subglabrata** Mack. and Bush. GROUND CHERRY. In openings bordering the swamp.

SOLANUM DULCAMARA L. EUROPEAN BITTERSWEET. In thickets along streams and in swamps. A clump with pure white corollas was found near the margin of the swamp.

***Solanum nigrum** L. NIGHTSHADE. Along edge of woods; rare.

94. SCROPHULARIACEAE

Chelone glabra L. TURTLEHEAD. In mucky soil along streams.

***Gerardia paupercula** (Gray) Britt. In open marl bogs; rare. Determined as subsp. *borealis* (Penn.) Penn. by Pennell.

–**Gerardia purpurea** L. Specimens reported as this species upon examination proved to belong to the preceding species.

***Gratiola neglecta** Torr. In swales.

*LINARIA VULGARIS L. BUTTER-AND-EGGS. In open grassy places.

Mimulus ringens L. MONKEY FLOWER. In marshes and along streams.

***Pedicularis canadensis** L. LOUSEWORT. In open woodlands.

*PENTSTEMON LAEVIGATUS Ait. var. DIGITALIS (Sweet) Gray. BEARD-TONGUE. In grassy openings in the swamp.

***Scrophularia lanceolata** Pursh. FIGWORT. Along the forest margin.

*VERBASCUM BLATTARIA L. MOTH MULLEIN. Along trails and in openings.

*VERBASCUM THAPSUS L. MULLEIN. On a cut-over ridge.

Veronica americana Schwein. AMERICAN BROOKLIME. In spring-fed brooks.

***Veronica anagallis-aquatica** L. BROOKLIME. In spring-fed brooks and swales.

*VERONICA ARVENSIS L. CORN SPEEDWELL. In grassy openings along trails.

*VERONICA PEREGRINA L. PURSLANE SPEEDWELL. In open places along trails.

***Veronica catenata** Penn., var. **glandulosa** (Farw.) Penn. SPEEDWELL. In spring-fed streams and along Black Creek.

***Veronica officinalis** L. COMMON SPEEDWELL. In open woodlands.

Veronica scutellata L. MARSH SPEEDWELL. In streams and temporary pools.

***Veronica serpyllifolia** L. THYME-LEAVED SPEEDWELL. In grassy openings along trails.

*VERONICA SPICATA L. SPEEDWELL. Established on a grassy knoll.

95. OROBANCHACEAE

***Epifagus virginiana** (L.) Bart. BEECHDROPS. In rich hardwood forests.

–**Orobanche uniflora** L. CANCER-ROOT. Not seen.

96. LENTIBULARIACEAE

***Utricularia intermedia** Hayne. BLADDERWORT. In shallow water in open marl bogs.

***Utricularia vulgaris** L., var. **americana** Gray. GREAT BLADDERWORT. In Black Creek.

97. PHRYMACEAE

Phryma leptostachya L. LOPSEED. In rich woodlands.

98. PLANTAGINACEAE

*PLANTAGO LANCEOLATA L. NARROW-LEAVED PLANTAIN, BUCKHORN. In grassy places.

*PLANTAGO MAJOR L. BROAD-LEAVED PLANTAIN. Along trails.

*PLANTAGO RUGELII Dcne. RUGEL'S PLANTAIN. Along trails.

99. RUBIACEAE

***Cephalanthus occidentalis** L. BUTTONBUSH. Along streams and in wet swales.

***Galium Aparine** L. CLEAVERS. In open woods.

***Galium asprellum** Michx. ROUGH BEDSTRAW. In marshes and thickets.

Galium boreale L. NORTHERN BEDSTRAW. On hummocks in marl bogs and about springs.

*Galium circaezans Michx. WILD LICORICE. In rich woodlands.

*Galium lanceolatum Torr. WILD LICORICE. In upland woods.

Galium triflorum Michx. BEDSTRAW. In marshes.

*Galium trifidum L. In marshes.

Mitchella repens L. PARTRIDGE BERRY. On ridges, under coniferous trees.

100. CAPRIFOLIACEAE

*Diervilla Lonicera Mill. BUSH HONEYSUCKLE. In openings on the knolls.

Linnaea borealis L., var. americana (Forbes) Rehder. TWIN-FLOWER. Forming mats over humus floor of rich woodlands.

*Lonicera canadensis Marsh. FLY HONEYSUCKLE. In openings about the arbor-vitae swamp.

*Lonicera dioica L. HONEYSUCKLE. In open woodlands.

Lonicera oblongifolia (Goldie) Hook. SWAMP FLY HONEYSUCKLE. In open marl bogs and about marl springs.

LONICERA TATARICA L. TARTARIAN HONEYSUCKLE. A few bushes scattered in open woods.

Sambucus pubens Michx. (S. racemosa) RED-BERRIED ELDER. In rich woodlands.

*Sambucus canadensis L. COMMON ELDER. In the swamp border and along small streams.

Triosteum perfoliatum L., var. aurantiacum (Bickn.) Wieg. HORSE GENTIAN. Along bank of Black Creek; rare.

Viburnum acerifolium L. MAPLE-LEAVED ARROW-WOOD. On the knolls and ridges.

–Viburnum cassinoides L. WITHE-ROD. Reported.[7] Not seen.

*Viburnum recognitum Fern. *(V. dentatum.)* ARROW-WOOD. In open marshy places.

*Viburnum lentago L. NANNYBERRY. In woodlands and about swamp border.

*Viburnum Opulus L., var. americanum Ait. *(V. trilobum.)* HIGHBUSH CRANBERRY. In open places in marshes, forming clumps.

101. VALERIANACEAE

Valeriana uliginosa (T. and G.) Rydb. SWAMP VALERIAN. In marl bogs, especially about springs and streams.

102. DIPSACACEAE

*DIPSACUS SYLVESTRIS Huds. TEASEL. Established in open places.

103. CUCURBITACEAE

***Echinocystis lobata** (Michx.) T. and G. Wild Cucumber. In thickets on alluvial soil.

104. CAMPANULACEAE

*–**Campanula uliginosa** Rydb. Marsh Bellflower. Edge of marl bogs.

*Specularia perfoliata (L.) A. DC. Venus' Looking-glass. In grassy openings.

105. LOBELIACEAE

***Lobelia cardinalis** L. Cardinal-flower. In mucky soil along streams; rare.

***Lobelia inflata** L. Indian Tobacco. In openings in the swamp.

Lobelia Kalmii L. Kalm's Lobelia. In marl bogs; common.

Lobelia siphilitica L. Great Lobelia. Along streams and in swales.

106. COMPOSITAE

Achillea Millefolium L. Yarrow, Milfoil. In openings along trails.

***Ambrosia artemisiifolia** L. Ragweed. In openings in woods and swamps.

***Ambrosia trifida** L. Giant Ragweed. Along Black Creek.

Anaphalis margaritacea (L.) B. and H. Pearly Everlasting. In cut-over areas and borders of woodlands.

***Antennaria canadensis** Greene. Lady's Tobacco, Pussy's Toes. On grassy knolls.

***Antennaria fallax** Greene. In dry grassy places.

***Antennaria neglecta** Greene. In open places bordering the swamp.

***Antennaria neodioica** Greene. Pussy's Toes. In open grassy places.

***Antennaria petaloidea** Fernald. On knolls in grassy places; infrequent.

***Antennaria plantaginifolia** (L.) Richards. Borders of thickets; rare.

*Anthemis arvensis L., var. agrestis (Wallr.) DC. Mayweed. Established along trails.

*Anthemis Cotula L. Dog Fennel. Established along a wood road; rare.

*Apargia autumnale (L.) Hoffm. Fall Dandelion. On grassy banks along trail.

*Arctium minus (Hill) Bernh. Burdock. In cut-over places; infrequent.

***Aster acuminatus** Michx. Wild Aster. In open woodlands.

***Aster ericoides** L. In a wet swale; rare.

*__Aster cordifolius__ L. In upland woods.

*__Aster divaricatus__ L. In moist woodlands.

*__Aster lateriflorus__ (L.) Britt. In openings in the woodland.

*__Aster lateriflorus__ (L.) Britt., var. __angustifolius__ Wieg. Common in open marl bogs and along small spring-fed streams. Earlier collections of this species were recorded as *A. Junceus* Ait.

*__Aster lucidulus__ (Gray) Wieg. In swales and about spring holes.

Aster macrophyllus L. In open woodlands.

Aster novae-angliae L. New England Aster. In open areas and along streams.

Aster paniculatus Lam. Edge of swamp.

*__Aster paniculatus__ Lam., var. __simplex__ (Willd.) Burg. Along small streams.

*__Aster pilosus__ Willd. Edge of woods; rare.

*__Aster prenanthoides__ Muhl. In swales and open marshy woods.

Aster puniceus L. In swampy places along streams and spring holes.

Aster umbellatus Mill. In open places in marshes and moist woods.

Bidens cernua L. In mucky soil along streams.

*__Bidens comosa__ (Gray) Wieg. In mucky soil.

*__Bidens connata__ Muhl. In wet boggy places along trails and streams.

Bidens frondosa L. Beggar's Ticks. Along wet trails.

*__Bidens vulgata__ Greene. Beggar's Ticks. Along streams and trails.

Chrysanthemum Leucanthemum L., var. pinnatifidum Lecoq. and Lam. Ox-eye Daisy. On grassy knolls; infrequent.

*Cichorium Intybus L. Chicory. Along the edge of the swamp.

*Centaurea Jacea L. Knapweed. On the margin of a field bordering the swamp.

*__Centaurea vochinensis__ Bernh. Star Thistle. In a cut-over area in the hardwood forest.

*Cirsium arvense (L.) Scop. Canada Thistle. Occasional in openings in the swamp and cut-over areas.

*Cirsium lanceolatum (L.) Hill. Bull Thistle. On alluvial soil along Black Creek.

*__Cirsium muticum__ Michx. Swamp Thistle. Mostly in wet alder thickets.

Erechtites hieracifolia (L.) Raf. Fireweed. Common in cut-over arbor-vitae swamps.

*__Erigeron annuus__ (L.) Pers. Daisy Fleabane. Along trails.

*__Erigeron canadensis__ L. Horseweed. In cut-over areas.

Erigeron philadelphicus L. Fleabane. In moist open woodlands.

*-__Erigeron pulchellus__ Michx. Robin's Plantain. Along trails and borders of open woods.

*Erigeron strigosus Muhl. *(E. ramosus.)* DAISY FLEABANE. Along trails on uplands.

Eupatorium perfoliatum L. BONESET. Along streams and in swales.

–Eupatorium falcatum Michx. JOE-PYE WEED. In swales, usually in partial shade.

*Eupatorium maculatum L. JOE-PYE WEED. In marshy places.

Eupatorium rugosum Houtt. *(E. urticaefolium.)* WHITE SNAKEROOT. Common in moist, rich, hardwood forests.

*Gnaphalium obtusifolium L. In cut-over upland.

*Gnaphalium Macounii Greene. *(G. decurrens.)* On a sandy knoll; rare.

*Gnaphalium uliginosum L. CUDWEED. In dried-up swales and along stream banks.

Helenium autumnale L. SNEEZEWEED. In marshes, swales and along streams.

*Helianthus strumosus L. WILD SUNFLOWER. In moist places.

*Helianthus divaricatus L. WILD SUNFLOWER. In open upland woods.

*Heliopsis helianthoides (L.) Sweet. On alluvial soil along stream bank.

HIERACIUM AURANTIACUM L. ORANGE HAWKWEED. On knolls in open grassy places.

HIERACIUM PRATENSE Tausch. YELLOW PAINTBRUSH. In meadows bordering the bogs.

*INULA HELENIUM L. ELECAMPANE. On alluvial soils.

*LACTUCA SCARIOLA L. PRICKLY LETTUCE. Along a trail; infrequent.

*Lactuca spicata (Lam.) Hitchc. BLUE LETTUCE. In moist open woodlands.

-ONOPORDUM ACANTHIUM L. SCOTCH THISTLE. Reported from Bergen.[2, 3, 6, 7] This record is probably based upon specimens observed in the village of Bergen. Not seen.

–Petasites palmatus (Ait.) Gray. SWEET COLTSFOOT. Reported from marly soil by *F. W. Johnson.*[6] Some specimens so labelled appeared to be basal leaves of *Prenanthes sp.*

Polymnia canadensis L. LEAFCUP. Moist overflow land in hardwoods.

–Polymnia uvedalia L. LEAFCUP. Reported.[7] Not seen.

Prenanthes alba L. RATTLESNAKE ROOT. In rich mucky soil in woods.

RUDBECKIA HIRTA L. BLACK-EYED SUSAN. In grass, edge of swamp.

Rudbeckia laciniata L. CONE-FLOWER. In wet mucky swamps.

Senecio aureus L. RAGWORT. In mucky soil along spring-fed brooks.

Senecio pauperculus Michx., var. balsamitae (Muhl.) Fern. In open marl.

*Solidago altissima L. GOLDENROD. Edge of swamp.

Solidago arguta Ait. In arbor-vitae swamp. (Also *M. S. Baxter,* 1913, *R. Acad.*)

Solidago bicolor L. SILVERROD. On a sandy knoll.

Solidago canadensis L. In open places, chiefly on alluvial soil.

Solidago graminifolia (L.) Salisb. FLAT-TOPPED GOLDENROD. In openings and along stream banks.

Solidago Houghtonii T. and G. HOUGHTON'S GOLDENROD. Local in open marl bogs. This is the only known station for this species in New York State.

*__Solidago juncea__ Ait. EARLY GOLDENROD. In open places on uplands.

Solidago latifolia L. In rich woodlands; common.

*__Solidago nemoralis__ Ait. On a dry grassy knoll.

Solidago ohioensis Riddell. Common in open marl bogs; also abundant in abandoned fields and about springs.

Solidago patula Muhl. In swampy places and openings in woodlands.

Solidago rugosa Mill. In rich woodlands, along streams and in disturbed areas.

*__Solidago serotina__ Ait. In open woods and by borders of swamp.

*__Solidago serotina__ Ait., var. **gigantea** (Ait.) Gray. In borders of woods and open places along trails.

Solidago ulmifolia Muhl. In open woods.

Solidago uniligulata (DC.) Porter. *(S. neglecta,* var. *linoides.)* This is the common, rather small, narrow-leaved goldenrod in the open marl. About the edge of the open marl bogs and in cut-over arbor-vitae swamps it becomes larger and develops wider leaves and larger and often less secund panicles approaching the following variety.

Solidago uniligulata (DC.) Porter, var. **neglecta** (T. and G.) Fern. *(S. neglecta.)* In wet springy places and in cut-over arbor-vitae swamps. In Bergen swamp specimens intermediate between this variety and the preceding species are not uncommon. The species seems smaller and narrow-leaved when growing in the open marl but in other places it appears to gradually merge with the larger broader-leaved variety. Some specimens have a narrow thyrsoid inflorescence approaching *S. humilis* in general appearance except for the larger heads.

*SONCHUS ARVENSIS L. PERENNIAL SOW THISTLE. In cut-over areas and openings in the bogs.

*SONCHUS ASPER (L.) Hill. SPINY SOW THISTLE. Along paths.

*SONCHUS OLERACEUS L. ANNUAL SOW THISTLE. In disturbed areas.

*TANACETUM VULGARE L. TANSY. Several clumps along the border of the swamp.

*TARAXACUM OFFICINALE Weber. DANDELION. In open grassy places.

*TRAGOPOGON PRATENSIS L. GOAT'S BEARD. In cut-over areas.

*–TRAGOPOGON PORRIFOLIUS L. SALSIFY. Along trails.

TUSSILAGO FARFARA L. COLTSFOOT. In wet open areas.

***Xanthium orientale** L. COCKLEBUR. On alluvial soil along Black Creek.

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APPENDIX

Among the plants that one would expect to see growing in Bergen Swamp several notable absences may be mentioned. *Trollius laxus, Spiraea alba, Anemone quinquefolia, Panax trifolia, Andromeda glaucophylla, Monarda didyma, Staphylea trifolia, Hippuris vulgaris* and *Peltandra virginica,* species found in similar habitats nearby, as far as I know, have not been found in Bergen Swamp. Perhaps future explorations may yet reveal at least some of these. *Scirpus Torreyi, Picea rubra, Chamaedaphne calyculata, Vaccinium macrocarpon, Gentiana crinita* and *Calypso borealis,* all strikingly distinct species, were reported by early botanists but have not been observed by me. Herbarium specimens of the latter two have been seen but of the other species none could be located.

ADDENDA

After the type for the foregoing paper had been set I discovered several additional species in Bergen Swamp. Since it is too late to insert them in their proper sequence in the catalogue they are appended here. This expands the list of species to 800.

Potamogeton pectinatus L. SAGO PONDWEED. In Black Creek.

Potamogeton zosteriformis Fernald. PONDWEED. In Black Creek.

ARRHENATHERUM ELATIUS (L.) Mert. and Koch. OAT GRASS. On raised places along border of swamp.

Milium effusum L. In wet woodland.

Phalaris arundinacea L. REED CANARY GRASS. In sloughs bordering streams.

Poa alsodes Gray. In wet woodlands.

ASPARAGUS OFFICINALIS L. ASPARAGUS. Escaped in an open place in the swamp.

BRASSICA KABER Wheeler. (*B. arvensis* Ktze.) FIELD MUSTARD. In open overflow areas along streams.

RIBES SATIVUM Syme. RED CURRANT. In mucky woodland near the border of the swamp.

VIOLA ARVENSIS Murr. WILD PANSY. In open grassy area.

LAMIUM AMPLEXICAULE L. DEAD NETTLE. Along path through cut-over area.

Utricularia minor L. BLADDERWORT. In shallow water in open marl areas.

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