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PROCEEDINGS
OF THE
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THE VEGETATION OF BERGEN SWAMP

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STRATIGRAPHY AND STRUCTURE OF THE BATAVIA QUADRANGLE

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THE PLANKTON ALGAE OF THE SOUTHEAST END OF CHAUTAUQUA LAKE

By BERNICE McKEAN GIEBNER

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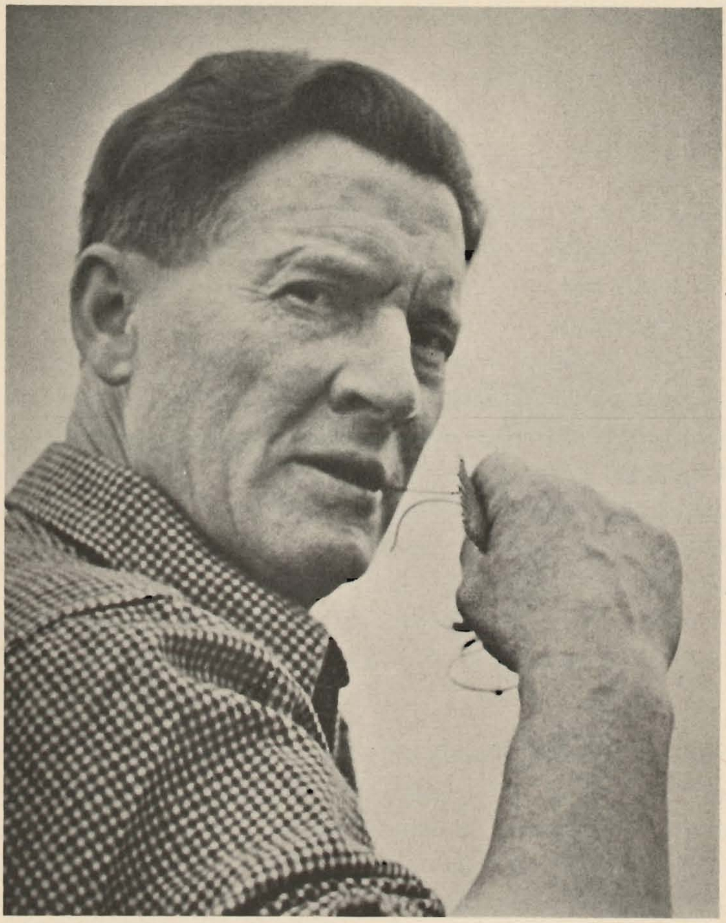

SHERMAN C. BISHOP
1887-1951

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SHERMAN BISHOP was a naturalist from childhood; and his fascinated study of the ballooning spider, the hibernating snake, the spawning fish was a bright thread in the fabric of his adult life. Out of this, perhaps, grew his abiding concern and outspoken efforts for sound policies to conserve and replenish the wild life of this state.

As a student of Wright and Crosby at Cornell and by his own later independent work, he became an eminent arachnologist and herpetologist, constantly consulted by others. His best-known work was his Handbook of Salamanders. Out of his studies also came a rich and steady harvest of 131 papers or monographs since 1911 and valuable collections, particularly of arachnids and amphibians. These specimens, now deposited in the American and Chicago Museums of Natural History, will continue to serve students and investigators. Other fruits of his work will gradually ripen as specialists at these museums and at Cornell and Florida bring into print his unpublished research notes, illustrations, bibliographies and records, and so long as some twenty-four persons who were his graduate students at the University of Rochester since 1928 remain productive biologists.

He was a wonderful man. Son of a church organist and grandson of a minister, brought up in a small town, he saw the world in terms mostly of individuals, seldom of institutions. He was sometimes refractory towards the rules and formalities of social aggregates, but the image of courtesy and considerateness to any person singly. He was a great raconteur, his stories being set in the Clyde of his youth, the top of a mountain in North Carolina, Cornell, the Okefenokee swamp, the State Museum of New York, or any place he had been and worked. His was the rare gift of winning lasting friendships wherever he went, uncourted except by his unconscious charm; his was the good fortune of the man whose work is also his play and rest.

PROCEEDINGS OF THE ROCHESTER ACADEMY OF SCIENCE
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THE VEGETATION OF BERGEN SWAMP

VIII. The Lichens

BABETTE I. BROWN[1]

Among the plants comprising the vegetation of Bergen Swamp certainly none are less familiar generally than the lichens. Small indeed are their thalli, or plant bodies; yet they cover the sides of stumps, fallen logs, occasional fence rails, drier soil in exposed, cut-over areas, and even the tree trunks in certain zones of the swamp. Thus, en masse, they can hardly be called inconspicuous. Lichens are unusual plants in that they consist of aggregations of organisms. Each lichen is a unit composed of two different species of plants living together harmoniously, intimately and so successfully that the resulting thallus may assume one of several vegetative forms:—a continuous or areolate crust—an assemblage of small leaf-like structures—a larger, spreading, irregular, more or less flattened expanse of tissue—or an erect or dependent, intricately branched, minute or extensive mass. In brief, the life form of a lichen may be crustose, squamulose, foliose or fruticose with a varying amount of the thallus within, on or free from the substratum. Thalli vary in color from white, pale or ashy gray to green, brilliant yellow, orange, olive, brown and black.

In each such thallus the hyphal, colorless threads of a fungus (which in the majority of lichens belongs to the Ascomycetes, or in a few to the Basidiomycetes or Fungi Imperfecti) constitute the bulk of the plant. Enmeshed among the fungus hyphae, which usually have a definite pattern of organization, is to be found, typically close to the top surface, a gonidial layer of algae composed of numerous cells belonging to one of the genera of Myxophyceae or Chlorophyceae. When, in 1867, Schwendener enunciated the hypothesis of the dual and composite nature of lichens, he believed the relationship between fungus and alga to be one of some sort of parasitism. Reinke, however, pointed out that in a lichen one plant is not eventually destroyed by the other, but that the lichen represents a state of interdependence and mutual growth in which a kind of organism different from either of its constituents is produced. The term consortium was suggested by him to describe the reciprocal parasitism between the alga and the fungus of a lichen. Somewhat later, DeBary, seeing in the lichen partnership a situation beneficial, though not always in equal degree, to both partners, designated it a case of symbiosis. No more successful examples of symbiotic relationship are to be found in nature than the lichens. Investigations have shown that the fungus partner absorbs and holds moisture, also obtains and supplies certain substances including compounds

[1] Department of Botany, University of Rochester, Rochester, New York.

of nitrogen and carbon and, in addition, protects the algal cells from severe desiccation. The component algae for their part synthesize carbohydrates from which the fungus certainly derives some of the energy required for its growth.

Ecologists agree that lichens are among the early colonizers of new surfaces of the earth which become available for occupancy by plants and that they are among the initiators of the cycle of plant succession known as the xerosere. In high latitudes and altitudes lichens may form climax communities. Essential factors for their development include fresh, pure air and abundant light. Water in some form, as fog, dew, clouds, rain, etc., must be available to lichens at certain periods, although they are remarkably successful in withstanding prolonged periods of desiccation, intense insolation and high winds. Rock walls, shelves and ledges, as well as isolated boulders, offer excellent situations for the growth of lichens with little competition from other organisms. Poor, sandy, leached out and thin soils are frequently well populated with certain kinds of lichens as is also the bark of living tree trunks and branches. Various lichens, seeming to prefer a more organic substratum, colonize rotting stumps and logs while others invade the moist base of living trees and the soil below trees in forests and shrubs in bogs and swamps. A few lichen genera have representatives that grow best on rocks in flowing water or in the intertidal zone along the seacoast. Such diversity of habitat has led certain workers to recognize different communities of lichens based on differences in the substratum on which they grow.

Prominent communities of lichens in Bergen Swamp have been noted. Arboreal communities include associated lichens found on leaves, on bark and on wood, epiphyllous, corticolous and lignicolous communities, respectively. Thus far no communities of the first type have been found. A conspicuous corticolous community, growing on trees in the alluvial zone of the swamp along Black Creek, includes among its dominant members *Candelaria concolor* var. *effusa, Physica tribacia, P. endochrysea, P. hispida* and *Parmelia sulcata*. These species may or may not all be present together on any given tree and invariably are accompanied by one or several of the following: *Parmelia rudecta, P. caperata, P. olivacea, Physcia stellaris* or *P. pulverulenta* and *Graphis scripta*. On *Thuja occidentalis* in the cedar swamps a limited community consisting of *Parmelia rudecta, P. sulcata* and *P. physodes* occurs while around the base of hemlocks in another zone of the swamp a *Cladonia* community embracing *Cladonia coniocraea* and its common forms, *C. cristatella* and *C. caespiticia* has been observed.

Lignicolous communities on prostrate logs and rotting stumps are dominated by *Cladoniae*. In those on stumps, *C. coniocraea, C. cristatella* and *C. chlorophaea* are most common but scattered among these are *C. macilenta, C. Grayi* f. *cyathiformis* and *C. caespiticia*. Communities on decaying logs consistently include *C. coniocraea* in several forms with varying admixtures of *C. cristatella, C. chlorophaea,* and their varieties and forms along with *C. Grayi* f. *cyathiformis, C. gracilis, C. verticillata, C. caespiticia, C. conista* and in small amounts others such as, *C. pyxidata, C. delicata* f. *quercina, C. squamosa, C. fimbriata, C. cryptochlorophaea, C. bacillaris* and *C. cylindrica.*

Terricolous communities on duff and humus in wooded areas of the swamp are fewer than the lignicolous communities and are dominated likewise by *C. coniocraea* with *C. conista, C. cristatella* and often *C. Grayi* as secondary species and a scattering of one or several others such as, *C. chlorophaea, C. macilenta* and *C. gracilis.* On certain peaty hummocks in the open marl zone of the swamp *C. glauca, C. squamosa, C. verticillata* and *C. conista* may be found in a common association, but on other hummocks where there appears to have been some disturbance pure stands of *C. rangiferina* abound. In moist, shady woodlands on soil pure stands of *C. furcata* occur.

Glacial boulders, the only available rock substrate for lichens, are of sandstone, limestone and granite principally. Intermixed on all types are communities including *Candelariella sp., Lecanora spp., Caloplaca sp.* and *Lecidea spp.,* these being less conspicuous among the saxicolous lichens of the swamp than *Parmelia conspersa* which is more prominent and more abundant than the smaller crustose lichens.

Of the approximately forty-six families of lichens recognized today, only seventeen appear to be represented in Bergen Swamp. Although the swamp provides a wide variety of habitats for higher plants, especially the Angiosperms, there is less variety in the habitats available for lichens. The shady character of many of the forested areas in the swamp offers less direct sunlight than that required by many lichens. The relatively uniform terrain provides no altitudinal variation. Glaciation has covered the underlying bedrock of the swamp with till, among which relatively few glacial boulders of granite, limestone and sandstone supply a paucity of rock surface for colonization. The most abundant habitats are those of stumps, decaying fallen trees, the trunks and branches of living trees and the swamp forest floor. Several pastures on the north and south sides of the swamp with their scattered boulders, drier soil and old cedar fences contribute a little more variety of habitat. Neither the numerous hardwater springs, which come to the surface in the hardwood and cedar swamps, nor Black Creek with its normally turbid waters appear to offer much inducement to lichens. Bergen Swamp, therefore, does not possess a rich lichen flora though its lichen vegetation may be somewhat conspicuous. This can be attributed to the lack of rock habitats available for invasion and the predominance of swamp forest conditions permitting the dominance of other plants in the successional history.

Best developed among the genera of lichens in the swamp is the genus *Cladonia* represented by some twenty–eight species and their numerous varieties and forms. This situation may be expected since, as stated by Evans (1930), the majority of the Cladoniae "require or prefer soil as a substratum". Those species of *Cladonia* which grow well on rotting tree trunks and stumps flourish in the swamp and are frequently found in mixed stands of several species, as indicated above, each species often represented by several, different, recognized forms.

The genus *Parmelia*, with seven species, follows *Cladonia* in number of species found in the swamp. The *Parmeliae* inhabit the bark of living trees except for *Parmelia conspersa*, the most conspicuous of the epilithic lichens in the swamp.

Physcia is another genus with several species accounting for its presence in the swamp. Species of *Physcia* are particularly well developed in communities on the bark of hardwoods in the alluvial area.

Most genera of lichens found in Bergen Swamp are represented by only one or a few species, and most of these do not appear to occur in very great abundance. The lichen flora of the swamp, therefore, to borrow a term from the algologists, appears to be "Baltic" in character, that is, consisting of relatively few species. Some of these, a definite minority, however, do occur in pronounced abundance.

All zones of the swamp have been visited and studied in preparing the catalogue of the lichens, but all parts of the swamp have not yet been explored thoroughly. Although it seems unlikely that any of the abundant and conspicuous lichens might have been overlooked, it is nevertheless true that further exploration in certain areas will undoubtedly yield additional species, especially of the crustose types.

The writer is indebted to Professor W. C. Muenscher of Cornell University for his interest in the lichens of the swamp and his assistance in making the collections. She is grateful to Professor A. W. Evans of Yale University and to Mr. Mason Hale for help in the determination of the *Cladoniae*, to Dr. John W. Thomson of the University of Wisconsin for checking determinations in the genus *Peltigera*, to Mr. G. G. Nearing for helpful suggestions regarding the identity of various crustose lichens, to Dr. Grace E. Howard of Wellesley College for verifying and assisting in the determination of a number of specimens in several difficult genera and to Mrs. Volney H. Jones for determining *Bacidia Schweinitzii* (Tuck.) Schneid. and *Bilimbia lignaria* (Ach.) Mass.

In the following annotated list of the lichens of Bergen Swamp data based on observation of the frequency of occurrence, habitat and in most cases zone of the swamp, numbers of the herbarium specimens and, when pertinent, other comments are supplied. Statements regarding frequency are based on the following scale:

1 – 3 stations	= Rare
4 – 9 stations	= Infrequent
10 – 20 stations	= Common
21 or more stations	= Abundant

Herbarium specimens of most of the lichen species and their varieties and forms from the same stations and the same collection so that they bear the same collection number have been deposited in the lichen collection at Cornell University, the lichen herbarium of the New York Botanical Garden and the personal herbarium of the author. Several species previously reported from Bergen Swamp (Brown, 1948) have been omitted from the series of specimens.

The annotated list follows the taxonomic arrangement and the nomenclature used in Fink's *Lichens of the United States* except for the *Cladoniae* which are arranged according to the system recently suggested by Mattick (1940). Nomenclature for varieties and forms of *Cladonia* is that found in the work of Evans (1930–1950); that for varieties and forms of *Peltigera* follows Thomson (1950).

ANNOTATED LIST OF THE LICHENS OF BERGEN SWAMP

Verrucariaceae

Verrucaria nigrescens Pers. Infrequent with other crustose lichens, on sandstone and limestone boulders particularly along the borders of the swamp, 50.

Pyrenulaceae

Pyrenula nitida (Weig.) Ach. Infrequent on the bark of hardwoods.

Graphidaceae

Graphis scripta (L.) Ach. Common on bark of hardwoods.

Diploschistaceae

Urceolaria actinostoma Pers. Rare on glacial boulders, 530.

Urceolaria scruposa (Schreb.) Ach. Rare on sandstone boulders, 151a.

Collemaceae

Leptogium tremelloides (L.) S. F. Gray. Infrequent on bark of hardwoods, 66.

Peltigeraceae

Peltigera canina (L.) Willd. Represented by the following varieties:

var. **rufescens** (Weis.) Mudd. Infrequent on decaying logs, at the bases of living and dead tree stumps and on moist hummocks in the cedar swamp, 506.

var. **spuria** (Ach.) Schaer. Rare on hummocks formed from decaying stumps, 331a.

var. **ulorrhiza** (Floerke) Schaer. Rare on duff among mosses at base of trees in hardwood swamp, 508.

Peltigera polydactyla (Neck.) Hoffm. (represented by var. **typica** f. **microphylla** Anders) or **Peltigera horizontalis** (Huds.) Baumg. (represented by var. **typica** f. **Zopfi** (Gyel.) Thomson). Rare on logs, cedar stumps and granite boulders in damp woodlands, 116. All of the material collected was sterile in which state the above-mentioned varieties and forms of the two species indicated are indistinguishable according to Dr. Thomson. One collection from a granite boulder in the damp hardwood swamp yielded fine specimens for showing regeneration along cracks. Without apothecia, however, final determination could not be made.

Lecideaceae

Bacidia Schweinitzii (Tuck.) Schneid. Rare on bark of *Fraxinus americana,* 525.

Bilimbia cupreorosella (Nyl.) Bausch. Rare on limestone boulders, 177.

Bilimbia lignaria (Ach.) Mass. Rare growing over moss on glacial boulder, 526.

Lecidea melancheima Tuck. Rare on dry, dead wood, 243.

Lecidea parasema Ach. Represented by var. **theioplaca** (Tuck.) Zahlbr. Rare on sandstone boulders, 509.

Lecidea platycarpa Ach. Rare on sandstone boulders, 337b.

Psora ostreata Hoffm. Rare on bark of conifers, 62.

Mycoblastus sanguinarius (L.) Norm. Represented by var. **alpinus** (E. Fries) Stein. Rare on bark of hardwoods.

Cladoniaceae

Cladonia bacillaris (Ach.) Nyl. Infrequent on rail fences and decaying wood. Usually found with other common members of the genus, 82.

Cladonia macilenta Hoffm. Represented by f. **styracella** (Ach.) Vainio. Infrequent, mixed with other *Cladoniae,* around and on the base of stumps, 390e.

Cladonia incrassata Floerke. Rare on stumps and hummocks in open marl bog, 398.

Cladonia cristatella Tuck. The species as such occurs rarely, but is represented by the following forms:

f. **abbreviata** Merrill. Rare on decaying wood with f. *vestita,* 90.

f. **Beauvoisii** (Del.) Vainio. Infrequent on bark and around base of *Thuja occidentalis* and on duff in cedar swamp, 405b.

f. **pleurocarpa** Robbins. Rare on hummocks in secondary marl bog with f. *vestita,* 120.

f. **ramosa** Tuck. Rare on soil in cedar zone, 343a.

f. **scyphulifera** Sandst. Rare on soil with other *Cladoniae,* 434.

f. **squamosissima** Robbins. Infrequent on fallen trees and decaying wood, 2.

f. **vestita** Tuck. Abundant on stumps, decaying trunks of both conifers and hardwoods, on base of living conifers and on soil throughout the swamp. Usually mixed with other *Cladoniae,* 19a, 510.

Cladonia pleurota (Floerke) Schaer. Represented by f. **frondescens** (Nyl.) Sandst. Rare on decaying logs with other members of the genus, 446b.

Cladonia capitata (Michx.) Spreng. Represented by f. **imbricatula** (Nyl.) Evans. Infrequent on soil and decaying logs in hardwood and cedar swamps, 80b, 100, 131d.

Cladonia gracilis (L.) Willd. Represented by var. **dilatata** (Hoffm.) Vainio. Rare among *Cladonia cristatella* f. *vestita,* 19b.

f. **anthocephala** (Floerke) Vainio. Rare on fallen, decaying tree trunks, 339, 446a.

f. **dilacerata** (Floerke) Vainio. Rare on logs in marl bogs, 219b.

Cladonia verticillata (Hoffm.) Schaer. Infrequent on decaying and damp logs with other species of the genus, 378a. Also represented by:

f. **evoluta** (Th. Fr.) Stein. Common on logs, rocks, duff and soil, often among mosses, especially in cut-over, open cedar swamps, 150, 187a, 344a, 366.

f. **aggregata** (Del.) Oliv. Infrequent mixed with other forms of the species, 150, 187a, 344a, 366.

f. **apopicta** (Ach.) Vainio. Rare mixed with other forms of the species, 320.

f. **phyllocephala** (Flot.) Oliv. Infrequent mixed with f. *evoluta,* 320, 366.

Cladonia pyxidata (L.) Hoffm. Represented by var. **neglecta** f. **simplex** (Ach.) Harm. Infrequent on rail fences, boulders, fallen logs and hummocks in the woodland, 324a, 344c. Originally this species was believed to be a common cup or goblet lichen in the swamp; as now delimited, it is rarely found in collections of cup lichens in Bergen Swamp.

Cladonia chlorophaea (Floerke) Spreng. Rare on soil and dead branches and stumps, 378c. Represented also by:

f. **pachyphyllina** (Wallr.) Sandst. Rare on glacial boulders, 6.

f. **simplex** (Hoffm.) Arn. Common on soil and duff, on dead stumps and logs of both conifers and hardwoods and on fence rails and boulders, in marl bog, cedar and hardwood swamps and in pasture, 376.

Cladonia Grayi Merrill. Represented by:

f. **carpophora** Evans. Rare on *Sphagnum* hummocks in open marl zone, 501.

f. **cyathiformis** Sandst. Abundant on decaying logs and stumps of conifers and hardwoods and on soil around the bases of trees throughout the swamp, 3, 352.

f. **peritheta** Evans. Infrequent mixed with other forms of the species, 244a.

f. **squamulosa** Sandst. Abundant throughout the swamp, 244aa.

Cladonia cryptochlorophaea Asahina. Infrequent on decaying logs and on stumps in both cedar and hardwood swamps and on open hummocks in the former, 405a. This species is one of the segregates of *Cladonia chlorophaea* based on microchemical tests.

Cladonia merochlorophaea Asahina. Rare to infrequent with other *Cladoniae* on decaying logs, on stumps and on hummocks in the open marl bog and cut-over cedar swamp, 207. This species is also a segregate from *Cladonia chlorophaea* on the basis of microchemical tests.

Cladonia fimbriata (L.) Fr. Infrequent on decaying cedars and on rotting logs in the hemlock zone, 5.

Cladonia conista (Ach.) Robbins. Represented by f. **simplex** Robbins. Infrequent on decaying logs, damp stumps, on hummocks in cedar swamp and on soil in pasture, 182.

Cladonia coniocraea (Floerke) Spreng. Represented by:

f. **ceratodes** (Floerke) Dalla Torre and Sarnth. Abundant on decaying stumps and logs, around the bases of living trees, on soil and boulders in all parts of the swamp, 340a, 343e. This appears to be the most widespread and abundant lichen in the swamp.

f. **truncata** (Floerke) Dalla Torre and Sarnth. Abundant in the same habitats as f. *ceratodes* with which it is often mixed, 345b.

f. **phyllostrata** (Floerke) Vainio. Rare on decaying wood, 425.

f. **pycnotheliza** (Nyl.) Vainio. Rare on decaying cedar logs, 340aa.

f. **robustior** (Harm.) Sandst. Rare on decaying stumps in pine-hemlock zone, 521.

Cladonia cylindrica Evans. Rare on stumps with other members of the genus, 236b.

Cladonia ochrochlora (Floerke) Sandst. Rare on boulders, 85a.

Cladonia borbonica (Del.) Nyl. Rare on rail fences and duff, 304.

Cladonia pityrea (Floerke) Fr. Rare on rail fences. Represented also by var. **Zwackhii** f. **subacuta** Vainio. Rare on decaying logs, 504.

Cladonia caespiticia (Pers.) Floerke. Infrequent to common on rail fences, decaying stumps and on fallen trunks in hardwood swamp, 326a, 332a.

Cladonia delicata (Ehrh.) Floerke. Rare in a sterile state on rail fence in hardwood swamp. Represented also by f. **quercina** (Pers.) Floerke. Rare on fallen cedars, 330.

Cladonia glauca Floerke. Rare on hummocks. Represented also by f. **capreolata** (Floerke) Sandst. Infrequent on duff in cedar swamp and on hummocks in open marl bog, 8.

Cladonia squamosa (Scop.) Hoffm. Common on cedar stumps and logs, on rail fences in hardwood swamp and with other *Cladoniae* on hummocks in open marl bog, 240, 442. Represented also by f. **levicorticata** Sandst. Rare on stumps of *Thuja occidentalis,* 170a.

Cladonia multiformis Merrill. Represented by f. **Finkii** (Vainio) Evans. Rare under and on *Juniperus horizontalis* in secondary marl zone, 344b.

Cladonia caroliniana (Schweinitz) Tuck. Rare on *Sphagnum* hummocks in marl bogs, 502.

Cladonia furcata (Huds.) Schrad. Represented by:

var. **pinnata** f. **foliolosa** (Del.) Vainio. Common on boulders, decaying logs, organic soil in moist hardwood swamp and on cedar logs and around bases of living cedar trees, 137.

var. **racemosa** f. **squamulifera** Sandst. Infrequent on soil among mosses and on boulders and logs in hardwood swamp, 234.

Cladonia rangiferina (L.) Web. Common on denuded *Sphagnum* hummocks in open marl bog, 9. Represented also by:

f. **incrassata** Schaer. Rare on hummocks in open marl zone, 142.

f. **patula** Flot. Infrequent on hummocks in open marl zone, 246.

f. **setigera** Oxner. Infrequent on hummocks in open marl zone, 92, 342.

Acarosporaceae

Acarospora fuscata (Schrad.) Arn. Rare on sandstone boulders, 59.

Pertusariaceae

Pertusaria multipuncta (Turn.) Nyl. Rare on bark of dying hardwoods, 153a.

Lecanoraceae

Candelariella vitellina (Ehrh.) Müll. Arg. Abundant on sandstone, limestone and granite boulders and on rail fences with other crustose forms on all borders of the swamp, 512a, 201.

Lecanora Hageni Ach. Infrequent on sandstone and limestone boulders with other crustose lichens in the open areas along the margins of the swamp and on bark, 50, 51a.

Lecanora muralis (Schreb.) Rabh. Infrequent to common on sandstone boulders in open places around the borders of the swamp, 58, 382.

Lecanora pallida (Schreb.) Rabh. Rare on bark of hardwoods in the alluvial zone, 194b.

Lecanora polytropa (Ehrh.) Rabh. Rare on sandstone boulders on borders of the swamp, 406.

Parmeliaceae

Candelaria concolor (Dicks.) Arn. Represented by var. **effusa** (Tuck.) Merrill and Burnh. Infrequent on bark of hardwoods both living and dead especially in the alluvial area along Black Creek, 193a, 221.

Parmeliopsis aleurites (Ach.) Nyl. Infrequent on dead branches of *Larix laricina* on *Sphagnum* hummocks in marl bogs as well as on decorticated trunks and branches of *Thuja occidentalis* in the same area, 63.

Parmelia caperata (L.) Ach. Common on hardwoods as well as *Tsuga canadensis* and *Thuja occidentalis* throughout the swamp.

Parmelia conspersa (Ehrh.) Ach. Common on sandstone boulders on the open margins of the swamp, usually with other rock lichens, 41. Represented also by f. **isidiata** Anzi. Rare on boulders, 148.

Parmelia olivacea (L.) Ach. Common on bark of hardwoods throughout the swamp.

Parmelia pertusa (Schrank) Schaer. Rare on bark of conifers on hummocks in the marl bog.

Parmelia physodes (L.) Ach. Common on bark of conifers and hardwoods in cedar and hardwood swamps and in marl bogs, 190.

Parmelia rudecta Ach. Common on bark of living conifers and hardwoods throughout the swamp, 236c.

Parmelia sulcata Tayl. Rare on dead branches as well as on the bark of living hardwoods in the alluvial zone along Black Creek and on hardwoods and cedars in the respective swamps, 184.

Cetraria ciliaris Ach. Rare on *Larix laricina* growing on *Sphagnum* hummocks in marl bogs.

Usneaceae

Evernia prunastri (L.) Ach. Rare on *Larix laricina* and *Thuja occidentalis* in marl bog, 154.

Alectoria chalybeiformis (L.) Röhling. Rare on *Larix laricina* growing on *Sphagnum* hummocks in marl bog.

Ramalina calicaris (L.) Röhling. Rare on isolated hardwoods in hardwood swamp.

Usnea baorbata (L.) Wigg. Rare on *Larix laricina* growing on *Sphagnum* hummocks in marl bogs, 500.

Caloplacaceae

Caloplaca cerina (Ehrh.) T. Fries. Common on sandstone and limestone boulders with other crustose lichens on the north and south borders of the swamp, 386a, 406.

Buelliaceae

Buellia punctata (Hoffm.) Mass. Rare on bark of *Ulmus americana* in alluvial zone along Black Creek, 193bb, 245b.

Rinodina ocellata (Hoffm.) Arn. Rare on sandstone boulders, 386.

Physciaceae

Physcia astroidea (Clem.) Nyl.. Common on bark of *Pinus strobus* and hardwoods in alluvial area and hardwood swamp.

Physcia endochrysea (Hampe) Nyl. Common on bark of hardwoods throughout the swamp, 191.

Physcia hispida (Schreb.) Frege. Infrequent on trunks and branches of hardwoods in the alluvial area and on *Pinus strobus,* 193a, 194.

Physcia pulverulenta (Schreb.) Nyl. Infrequent on bark of hardwoods in the alluvial area along Black Creek, 175a.

Physcia stellaris (L.) Nyl. Rare on bark of *Pinus strobus* and hardwoods, 189, 193c.

Physcia tribacia (Ach.) Nyl. Infrequent on bark of hardwoods and *Pinus strobus,* especially along Black Creek, 193b, 195, 245a.

Lepr ariaceae

Amphiloma lanuginosum (Hoffm.) Nyl. Infrequent on some hardwoods and conifers throughout the swamp, 139, 153b.

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THE BERGEN SWAMP PRESERVATION SOCIETY, INC. has contributed most generously toward the publication of the series of papers on the vegetation of Bergen Swamp of which this is the last. The authors and the Rochester Academy of Science are grateful to the Society for this assistance which has helped to further one of the primary aims of the Academy—the dissemination of knowledge of the natural history of the Rochester area.

THE VEGETATION OF BERGEN SWAMP

IX. Supplement

WALTER C. MUENSCHER [1]

It is axiomatic that a field botanist takes advantage of abundance of materials and makes the best of exceptional plant associations and habitats. An exceptional opportunity to study the vegetation of Bergen Swamp presented itself a third of a century ago. Then, in 1945 the late Dr. Sherman C. Bishop, a charter member and until his death an ardent supporter and trustee of the Bergen Swamp Preservation Society Inc., suggested that I prepare a paper on The Vegetation of Bergen Swamp. Part I. Vascular Plants, was published under the above title (Muenscher, 1946) with the full realization that additional explorations required to cover other groups of plants known to be represented in the swamp surely would amplify the known list of vascular plants. With the collaboration of several former graduate students seven additional papers have been published between 1948 and 1951. (Cf. references to the various groups covered at the end of this paper.)

The present paper, Part IX. Supplement, concludes this series. In its preparation I have received substantial aid from Dr. Clark T. Rogerson in providing the supplement to the fungi and from Dr. Robert F. Thorne whose field work expanded our knowledge of the species of Carex growing in Bergen Swamp.

[1] Department of Botany, Cornell University, Ithaca, New York.

SUPPLEMENT TO ANNOTATED LIST OF VASCULAR PLANTS

Polypodiaceae

Dryopteris Goldiana (Hook.) Gray. Goldie's Fern. Local in moist rich woodland along southwest border of swamp.

Ophioglossaceae

Botrychium dissectum Sprengel ssp. *typicum* Clausen. In open woods.

Botrychium dissectum Sprengel var. *obliquum* (Muhl.) Clausen. In open woods.

Botrychium simplex Hitchc. In hardwood forest.

Potamogetonaceae

Potamogeton Friesii Rupr. In pond near west end of swamp.

Gramineae

Andropogon furcatus Muhl. Beard Grass. In dry open places near south edge of swamp.

Bromus commutatus Schrad. Brome Grass. In open places near south side.

Bromus japonicus Thunb. On dry grassy knoll.

Bromus purgans L. In opening in cutover cedar swamp.

Bromus tectorum L. Along path, entrance to swamp.

Danthonia spicata (L.) Beauv. Open places, south side of swamp.

Digitaria sanguinalus (L.) Scop. Along trail.

Eragrostis poaeoides Beauv. Along trails.

Glyceria borealis (Nash) Batch. In swale along north edge near Black Creek.

Panicum virgatum L. Switch Grass. On gravelly ridge, near southwest edge of swamp.

Cyperaceae

Carex alopecoidea Tuckerman. In woods on alluvial soil.

Carex Careyana Torr. In rich woods.

Carex cephalophora Muhl. In rich hardwoods.

Carex comosa Boott. In alluvial woods near Black Creek.

Carex crinita Lam. In woods on alluvial soil.

Carex Deweyana Schwein. In moist woods.

Carex hirtifolia Mack. In rich woods.

Carex Hitchcockiana Dewey. Rich woods near southwest entrance.

Carex Jamesii Schwein. In rich hardwoods.

Carex laevivaginata (Kuken) Mack. In mucky woods.

Carex molesta Mack. Along border of swamp, near Black Creek.

Carex normalis Mack. Along woodland borders near Black Creek.
Carex laxiculmis Schwein. On sandy wooded slope.
Carex leptonervia Fern. In rich woods.
Carex lurida Wahl. On alluvial soil.
Carex oligocarpa Schk. In rich woods.
Carex scabrata Schwein. In mucky woodland.
Carex sparganioides Muhl. In rich hardwoods.
Carex Woodii Dewey. In rich woodland.

Araceae

Peltandra virginica (L.) Kunth. Arrow Arum. In opening in cattail swamp.

Liliaceae

Trillium undulatum Willd. Painted Trillium. On gravelly hemlock-beech ridge.

Iridaceae

Iris Pseudacorus L. Yellow Iris. Along Black Creek.

Juglandaceae

Juglans nigra L. Black Walnut. Two large trees and several saplings along stream, west end; saplings in cut-over Thuja swamp.

Betulaceae

Corylus americana Walt. Hazelnut. Along north edge of swamp.

Chenopodiaceae

Chenopodium polyspermum L. Goosefoot. Along Black Creek.

Portulacaceae

Portulaca oleracea L. Purslane. Edge of field.

Ranunculaceae

Aquilegia vulgaris L. Garden Columbine. Along path by hemlock knoll.
Ranunculus repens L. Creeping Buttercup. In pasture along edge of swamp.
Ranunculus bulbosus L. Bulbous Crowfoot. In open pasture, near west end.

Magnoliaceae

Liriodendron tulipifera L. Tulip Tree. A large tree and several saplings in rich woods.

Cruciferae

Alyssum Alyssoides L. On grassy slopes near southwest border. Previously reported from along railroad track.

Brassica nigra (L.) Koch. Black Mustard. In disturbed open places along Black Creek.

Rosaceae

Agrimonia parviflora Ait. Agrimony. In grassy opening.
Rosa Eglanteria L. Along edge of thicket, border of swamp.
Potentilla canadensis L. On open grassy hummocks.

Leguminosae

Vicia villosa Roth. Hairy Vetch. In open place along west edge of swamp.

Euphorbiaceae

Euphorbia vermiculata Raf. (*E. hirsuta* (Torr.) Wieg.). Near Black Creek.

Hypericaceae

Hypericum majus (Gray) Britton. In wet depressions on sandy knoll.

Haloragidaceae

Myriophyllum exalbescens Fernald. Water Milfoil. In pond near west end of swamp.

Ericaceae

Moneses uniflora (L.) Gray. One-flowered Pyrola. Forming small patches scattered over about an acre of moist cedar-pine woods. Reported many years ago by Macauley but not seen by the writers before 1948.

Gentianaceae

Gentiana Andrewsii Griseb. Edge of Thuja thicket, east end of swamp.

Boraginaceae

Lithospermum arvense L. Along paths, edge of Torpy Hill.

Labiatae

Melissa officinalis L. Established, probably from discarded trash, along base of Torpy Hill.
Pycnanthemum flexuosum (Walt.) BSP. Mountain Mint. In marly swale, south part of swamp.
Pycnanthemum Torrei Benth. In marly swale, south side of swamp.
Pycnanthemum virginianum (L.) Dur. & Jackson. South edge of swamp.

Caprifoliaceae

Lonicera Morrowi Gray. Honeysuckle. In cut-over Thuja swamp.
Symphoricarpus albus (L.) Blake. Snowberry. Along south border of swamp.

Viburnum alnifolium Marsh. Hobble-bush. On hemlock-beech knoll.
Viburnum Opulus L. European Cranberry Bush. Several specimens about four meters high were observed in marl bog, among *Thuja occidentalis*.

Campanulaceae

Campanula rapunculoides L. Bellflower. Edge of swamp.

Compositae

Helianthus grosse-serratus Martens. In open swale, probably naturalized.
Petasites palmata (Ait.) Gray. In open hardwood forest.
Picris hieracioides L. Along paths in openings in woods.
Silphium laciniatum L. Rosin Weed. Apparently introduced; near railroad right-of-way along south edge of swamp.

SUPPLEMENT TO THE FUNGI OF BERGEN SWAMP[1]

Since the publication of a list of the fungi of Bergen Swamp (Rogerson and Muenscher, 1950) additional visits to the swamp have been made with the inevitable finding of new records of fungi.

As a result thirty additional species of fungi including representatives of eight additional genera have been collected in the swamp. Specimens of three species not recorded heretofore were found in the herbarium of Charles Peck at the New York State Museum and a specimen of one species was found in the Durand herbarium at Cornell University. Of these thirty-four additional records of species, thirteen are Ascomycetes, nine are Basidiomycetes and twelve are Fungi Imperfecti. Four additional genera of Ascomycetes, two of Basidiomycetes and two of Fungi Imperfecti are recorded.

A total of 634 species and sixteen varieties representing 256 genera of fungi are now known to occur in Bergen Swamp.

In the following list ** represents a new genus and species record, * represents a new species record, and † represents a new host record for the swamp.

ASCOMYCETES

Pezizaceae

***Scutellinia albospadicea** (Grev.) Kuntze. On rotten stump, 38055 (Det. R. P. Korf).
***Scutellinia** sp. (*Lachnea hemisphaerioides* Mouton). On burned hemlock duff, K2131. (Det. R.P. Korf).

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[1] Rogerson, Clark T. and Walter C. Muenscher. 1950. The Vegetation of Bergen Swamp. VI. The Fungi. Proc. Roch. Acad. Sci. 9: 277–314.

Dermateaceae

**Fabraea maculata (Lev.) Atk. On Amelanchier arborea, R3469. (conidial stage).

Orbiliaceae

*Orbilia curvatispora Boud. On rotten log, R3054.

Hyaloscyphaceae

*Arachnopeziza delicatula Fckl. On wood, Durand Herb., Cornell Univ. No. 83–125. (Det. R. P. Korf).

*Hyaloscypha hyalina (Pers. ex. Fr.) Boud. On rotten log, R3042.

*Lachnum Caricis (Desm.) Hoehn. On dead stems of Scirpus caespitosus, R989.

*Lachnum inquilinum (Karst.) Schroet. On overwintered stems of Equisetum arvense, K2130. (Det. R. P. Korf).

Helotiaceae

**Phialea sp. On rotten stem, K2136.

**Stamnaria Persoonii (Fr.) Fckl. On overwintered stems of Equisetum arvense, K2133. (Det. R. P. Korf).

**Trichoscyphella calycina (Schum. ex. Fr.) Nannf. On dead twigs of Larix laricina, R2151.

Pseudosphaeriaceae

*Pleospora herbarum (Pers. ex Fr.) Rabenh. On dead stems of Triglochin palustris, Herb., N. Y. State Museum. (Det. by H. H. House).

Erysiphaceae

Uncinula Salicis (DC.) Wint. On †Populus tremuloides, 38050.

Nectriaceae

Hypomyces aurantius (Pers. ex Fr.) Tul. On pore surface of †Polyporus versicolor, R 3455.

*Hypomyces polyporinus Peck. On pore surface of Polyporus versicolor, 38052.

*Hypomyces rosellus (Fr.) Tul. On small deformed agaric, R3317. (conidial stage).

Nectria episphaeria Tode ex Fr. On †Hypoxylon multiforme, R3323.

Nectria Pezizae Tode ex Fr. On dead †Betula lutea, R3456.

BASIDIOMYCETES

Ustilaginaceae

*Ustilago striaeformis (Westend.) Niessl. On leaves of Dactylis glomerata, R3458.

Melampsoraceae

*Melampsora Abieti-canadensis C. A. Ludwig. On cones of Tsuga canadensis, R3454.

Pucciniaceae

Puccinia Caricis (Schum.) Schroet. On leaves of †Carex blanda, R3326.

*Puccinia tumidipes Pk. On leaves of Lycium halimifolia, 38049.

Auriculariaceae

Herpobasidium deformans Gould. On leaves of Lonicera oblongifolia, R3457. (basidial stage).

Clavariaceae

**Pistillaria capitata (Pat.) Sacc. On dead leaves of Carex sp., R2852.

Hydnaceae

**Caldesiella ferruginosa (Fr.) Sacc. On log of Betula lutea, 38053.

*Odontia crustosa (Fr.) Quel. On rotten log, 38054.

Agaricaceae

*Clitopilus novaboracensis Pk. In woods, Herb. N. Y. State Museum. (Det. C. Peck).

*Hygrophorus flavescens (Kauff.) Smith & Hesler. On the ground, mixed woods, R3473.

FUNGI IMPERFECTI

Sphaerioidaceae

*Cytospora ambiens Sacc. On dead branches of Ulmus americana, R2915.

*Phomopsis oblonga (Desm.) Hoehn. On dead twigs of Ulmus americana, R2915.

*Septoria increscens Pk. On leaves of Trientalis borealis, R3470.

Melanconiaceae

**Colletotrichum liliacearum (Desm.) Hoehn. On leaves of Polygonatum pubescens, R3460.

*Cylindrosporium Cicutae Ell. & Ev. On leaves of Cicuta maculata, R3467.

*Cylindrosporium lutescens Higgins. On leaves of Prunus virginiana, R3468.

*Cylindrosporium Steironematis Atk. On leaves of Steironema ciliata, R3471.

Moniliaceae

*__Botrytis geniculata__ Corda. On Hypoxylon sp., R3475.
**__Monilia angustior__ (Sacc.) Reade. On fruits of Prunus virginiana, R3459.

Stilbaceae

*__Isaria flabelliformis__ (Schw.) Lloyd. On rotten log. R3476, 3477. (Det. J. A. Stevenson).

Dematiaceae

*__Cladosporium aphidis__ Thum. On aphids on Phragmites communis. Herb., N. Y. State Museum. (Det. C. Peck).

Additions to the Host Index

Amelanchier arborea (Michx.) Fernald; Fabraea maculata.
Betula lutea Michx.; Caldesiella ferruginosa, Nectria Pezizae.
Carex blanda Dewey; Puccinia Caricis.
Cicuta maculata L.; Cylindrosporium Cicutae.
Dactylus glomerata L.; Ustilago striaeformis.
Equisetum arvense L.; Lachnum inquilinum, Stamnaria Persoonii.
Larix laricina (DuRoi) Koch.; Trichoscyphella calycina.
Lycium halimifolium Mill.; Puccinia tumidipes.
Polygonatum pubescens (Willd.) Pursh; Colletotrichum liliacearum.
Populus tremuloides Michx.; Uncinula Salicis.
Prunus virginiana L.; Cylindrosporium lutescens, Monilia angustior.
Scirpus caespitosus L.; Lachnum Caricis.
Steironema ciliatum (L.) Raf.; Cylindrosporium Steironematis.
Trientalis borealis Raf.; Septoria increscens.
Triglochin palustris L.; Pleospora herbarum.
Tsuga canadensis (L.) Carr.; Melamspora Abieti-canadensis.
Ulmus americana L.; Cytospora ambiens, Phomopsis oblonga.

SUPPLEMENT TO THE ALGAE

One novelty, a large diatom, has been collected from slightly brackish water by the west end of Bergen Swamp on October 24, 1948. This has been described and named *Navicula bergeni* sp. nov. It will be published by Dr. Matthew H. Hohn in an early issue of the Transactions of the Microscopical Society of America, 1952. The type slide (No. 161) is deposited in the Wiegand Herbarium of Cornell University.

SUMMARY

In summarizing this supplement it can now be stated that the list of plants known from Bergen Swamp, an area covering approximately 3000 acres, includes 2392 species of plants. These consist of:

Vascular plants	860
Myxomycetes	73
Algae	586
Fungi	634
Mosses and Liverworts	164
Lichens	75
Total	2392

REFERENCES TO THE VEGETATION OF BERGEN SWAMP

WALTER C. MUENSCHER—I. The Vascular Plants. 1946. Proc. Roch. Acad. Sci., 9: 64–117.

BABETTE I. BROWN—II. The Epiphytic Plants. 1948. Ibid., 9: 119–129.

WALTER C. MUENSCHER—III. The Myxomycetes. 1948. Ibid., 9: 131–137.

ARLAND T. HOTCHKISS—IV. The Algae. 1950. Ibid., 9: 237–264.

MATTHEW H. HOHN—V. The Diatoms. 1950. Ibid., 9: 265–276.

CLARK ROGERSON and WALTER C. MUENSCHER—VI. The Fungi. 1950. Ibid., 9: 277–314.

WILLIAM T. WINNE—VII. The Bryophytes. 1950. Ibid., 9: 315–326.

BABETTE I. BROWN—VIII. The Lichens. 1951. Ibid., 9: 327–338.

WALTER C. MUENSCHER—IX. Supplement. 1951. Ibid., 9: 339–347.

STRATIGRAPHY AND STRUCTURE OF THE BATAVIA QUADRANGLE

by

Robert G. Sutton [1]

Abstract

A geologic map has been prepared and a survey made of the structural aspects in the Batavia Quadrangle of western New York State. Southward dipping formations of Lower(?), Middle and Upper Devonian age crop out in this Quadrangle. The Clarendon-Linden monocline trends approximately north-south through the central portion of the area and locally deflects the dip to the west.

Twenty-four formations or members were identified and traced across the area. The Ledyard and Wanakah shale members of the Ludlowville formation were not separated as defined by Cooper (1930).

The trends of the jointing and broken anticlines were also measured and an attempt has been made to correlate this data with adjacent areas as well as major structural features in the Quadrangle.

Table of Contents

[1] Department of Geology, Alfred University, Alfred, New York.

Illustrations

ACKNOWLEDGMENTS

The writer wishes to express his sincere thanks to Dr. William Evitt for his guidance in the stratigraphic and paleontologic problems; to Dr. William F. Jenks for his help in structural aspects and in preparation of the map and to Dr. Harold L. Alling without whose knowledge of western New York Geology many of the problems could not be visualized in their true aspect. Gratitude is also extended to John Van Ostrand who aided the author in the field and in the preparation of the maps and to my wife, Betty, without whose aid and encouragement this work would not have been completed.

INTRODUCTION

The Batavia Quadrangle is situated in western New York, approximately twenty-eight miles east of Buffalo and twenty-five miles southwest of Rochester. The city of Batavia is located at the northern boundary and Warsaw is at the southern edge of the sheet. The quadrangle is over seventeen miles long and thirteen miles wide with an area of 225 square miles. More precisely, the United States Geological Survey topographic map is bounded by the latitudes, 42° 45′ N and 43° 00′ N and by the longitudes, 78° 00′ W and 78° 15′ W.

The geology of western New York has been under intense scrutiny since the time of James Hall (1843) when an excellent groundwork was laid. Later revisions and refinements were carried out by John M. Clarke and D. Dana Luther. Their energetic program included the mapping of most of the 15′ quadrangles in western New York. Unfortunately the Batavia Quadrangle manuscript was never published. The Caledonia Quadrangle to the east has suffered the same fate. A report on it prepared by William Grossman (1938) has not yet been published.

In recent years, the regional stratigraphy has received much attention from such men as G. Arthur Cooper (1929) who has produced the most complete and up-to-date work on the Middle Devonian, and George H. Chadwick (1933) who has made outstanding revisions of the Upper Devonian. Dr. Chadwick is responsible for the discovery of the Clarendon-Linden monocline, a portion of which occurs in this quadrangle.

It is upon this groundwork that more detailed studies must be made. Even this paper on the Batavia Quadrangle represents only a reconnaissance study of the area. Problems concerned with the Ledyard-Wanakah members still exist. Their solution may be found by careful examination and measurement of the Ludlowville sections from Lake Erie to the Genesee Valley.

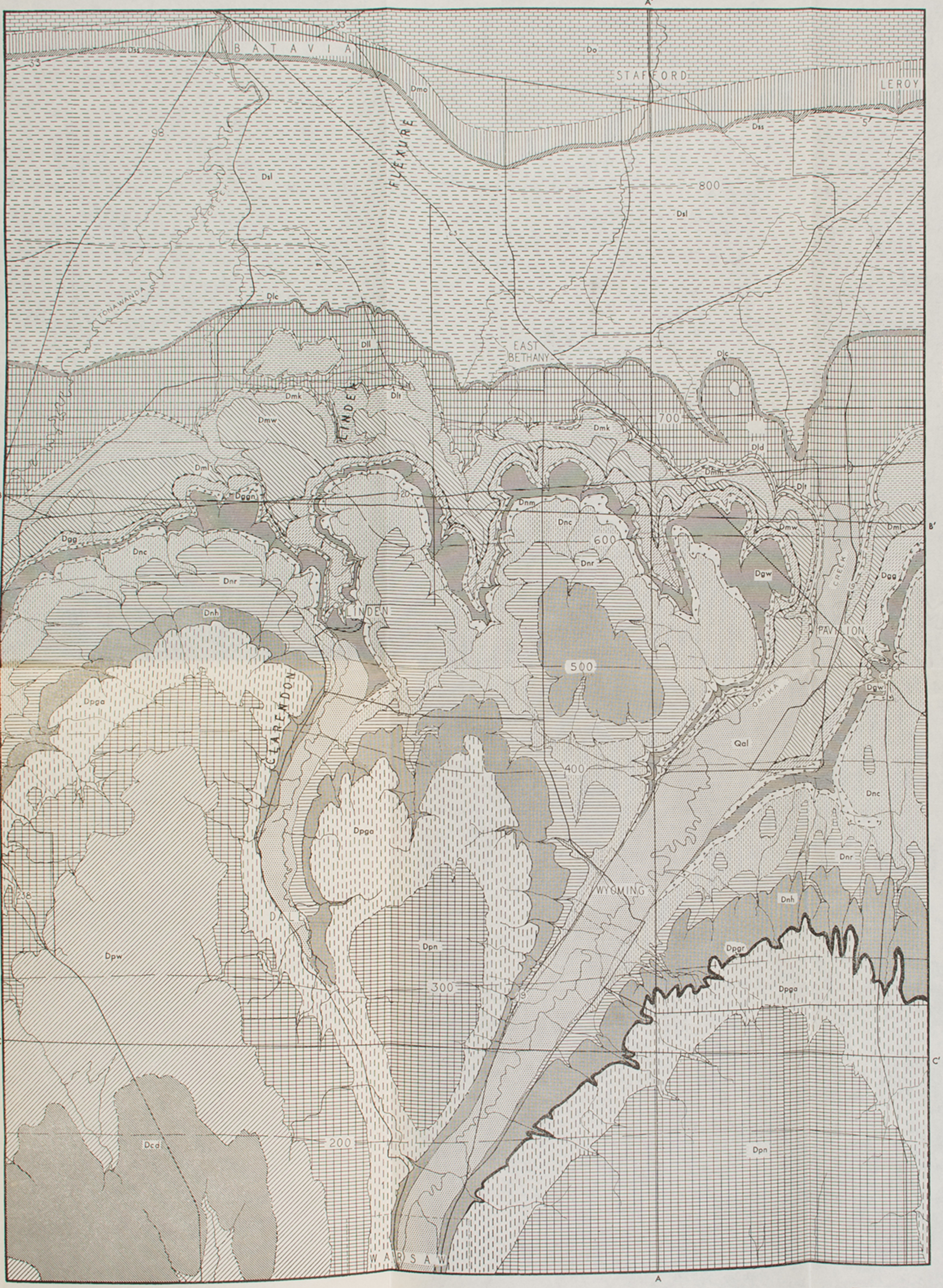
The author has included some data on structure. It will be necessary for others to add information from each quadrangle so that when all the data is compared and critically analyzed, we may have a more accurate picture of what has happened to the bed rock since deposition.

Many paleontological problems still remain. Among these are ones of a paleo-ecological aspect. The Hamilton formations should prove most useful for studies of this type because of their extremely fossiliferous character and excellent exposure.

The study began with a few weeks of field work in the summer of 1948 and was completed in the summer of the following year. Over 120 geologic

GEOLOGIC MAP

PLATE I



BATAVIA QUADRANGLE, NEW YORK

SCALE 1/63,360

1 0 1 2 3 4 MILES

MAGNETIC

DECL. 6° NO ANNUAL MAGNETIC CHANGE-1943

400 STRUCTURE CONTOURS ON THE ONONDAGA LS.

EXPLANATION

QUATERNARY

Qal (most glacial deposits omitted)
ALLUVIUM

UPPER DEVONIAN

CANADAWAY GROUP

Dcd (black shale and sandstones)
DUNKIRK FM.

Dpw (black and gray calcareous shales)
WISCOY SHALE

Dpn (sandstone, shale and flags)
NUNDA FM.

Dpga (heavy flags and shales)
GARDEAU FM.

Dpgr
GRIMES SS.

NAPLES GROUP

Dnh (flags and shales)
HATCH FM.

Dnr (black and gray shales)
RHINESTREET SH.

Dnc (gray shales)
CASHAQUA SH.

Dnm (black and dark gray shales)
MIDDLESEX BL. SH.

GENESEE GROUP

Dgw
WEST RIVER SH.

Dggn GENUNDEWA LS. MEM.
Dgg (black shales and limestone)
GENESEO FM.

? UNCONFORMITY ?

MIDDLE DEVONIAN

HAMILTON GROUP

MOSCOW FM.

Dml (marcasite and pyrite)
LEICESTER MARCASITE MEM.

Dmw
WINDOM SH. MEM.

Dmk
KASHONG SH. MEM.

Dmm
MENTETH LS. MEM.

LUDLOWVILLE FM.

Dld
DEEP RUN SH. MEM.

Dlt (limestone, calcareous shale and shale)
TICHENOR LS. MEM.

Dll (dark to light gray shale facies, limestone)
LEDYARD-WANAKAH SH. MEMS.

Dlc
CENTERFIELD LS. MEM.

SKANEATELES FM.

Dsl (dark gray to black shale)
LEVANNA SH. MEM.

Dss
STAFFORD LS. MEM.

MARCELLUS FM.

Dmo (black shale)
OATKA CREEK SH. MEM.

Do (limestone and chert)
ONONDAGA LS.

sections were measured with the aid of a Jacobs staff and Brunton compass. The base map consisted of the four 7½ minute quadrangle maps on the scale of 1:31,680. The final product was reduced to the scale of 1:63,360.

Jointing and structure were recorded by means of the Brunton compass. The broader structural relationships were discernable only by comparison of stratigraphic sections but minor structures could be measured directly.

PHYSIOGRAPHY

Two distinct physiographic provinces are found in this area. One is the Central or Interior Lowlands and the other is the Appalachian Plateau Province. The entire quadrangle has been well glaciated but a discussion of this aspect has been omitted from the report.

Central Lowland Province—In western New York State the southern shore line of Lake Ontario is characterized by relatively low, flat terrain broken here and there by glacial deposits. The land surface dips north toward the lake but is interrupted by northward facing cuestas. These cuestas are formed by resistant rock formations, usually limestone, that dip to the south at less than one degree. One of these cuestas occurs just north of Batavia so that the northern portion of the area is on the gentle south-slope of such a physiographic feature. The resistant rock is the Onondaga limestone which is over 140 feet thick and forms an east-west cuesta across the state.

The Appalachian Plateau Province—The plateau area in the southern portion of the quadrangle represents the type of topography found in southern New York and Pennsylvania. Fenneman (1938) terms this the "Glaciated Allegheny Plateau" and states that if it were not for the glaciation, the area would be very similar to the unglaciated portions of the Plateau farther south.

The province is characterized by rather uniformly high relief, with summit surfaces of approximately the same elevation into which deep valleys have been incised. The northern boundary is marked in western New York (and this area) by a northward facing cuesta which is formed by the resistant Upper Devonian strata. The area south of Pavilion and Linden is considered to be in this province. The Upper Devonian formations crop out in a belt which defines this cuesta. The area to the south has rather deep valleys cut into these resistant rocks.

The plateau surface, while not well defined, may be represented by the higher flat-topped hills in the southern portion. These hills are underlain by resistant beds of sandstone. Although glacial deposits are abundant, the outcrops of resistant formations can often be traced.

STRATIGRAPHY

Introduction

Formations of Lower or Middle, Middle and Upper Devonian age crop out in this area. The oldest formations appear in the northern part and successively younger ones occur to the south. This is due to a slight southward dip and the higher topography in the south.

Only the Onondaga limestone may be of Lower Devonian age. Its classification in this report is Lower or Middle Devonian. The Hamilton Group overlies the Onondaga limestone and is definitely Middle Devonian. Above this is the Genesee Group which elsewhere is Middle or Upper Devonian but here is placed in the Upper Devonian because of reasons outlined later. The overlying Naples Group and formations above are of Upper Devonian age.

The lithologic units are discussed in ascending order. A history of the nomenclature, followed by the extent, type locality, and thicknesses, is included. Important outcrops in the area are located and lithology and fauna are treated in detail wherever possible. The faunas are those collected and identified from exposures in this area. No attempt was made to produce detailed faunal lists but only representative specimens were collected.

"Lexicon of Geologic Names of United States" by M. Grace Wilmarth (1938) was used as a general reference for the history of the nomenclature, supplemented by the writings of the particular workers. The works of G. Arthur Cooper (1930) were consulted for the stratigraphy of the Hamilton Group while material on the Upper Devonian was obtained from the writings of George H. Chadwick, John Clarke and D. Dana Luther. References to these and other writers will be made in the appropriate places.

Source of the sediments in this area was to the east. The Onondaga limestone represents a long period of quiescence. It was not terminated abruptly but the first Hamilton clastic sedimentation began in the eastern part of New York State. The border of this clastic sedimentation moved westward so that the limestone was progressively covered from east to west.

Black shales and interbedded limestones were deposited in the lower Hamilton. This type of sedimentation grades into the gray shale and limestone of the middle and upper. Hamilton deposition ended abruptly with an influx of black shales of the Genesee Group, followed by black and gray shales of the Naples and finally the clastics of the overlying formations.

Deposition was rather continuous throughout the Middle and Upper Devonian in this part of New York State. It is possible that disconformities exist at the top of the Onondaga limestone, at the top of the Hamilton Group and in the Genesee Group.

All of these sediments represent outpourings of clastics from the east.

Figure 1 ←

Figure 2 →

Figure 3 ←

Figure 4 →

PLATE III. *Fig. 1*—Onondaga ls. quarry 1 mile west of Stafford, N. Y. *Fig. 2*—Closer view of chert bed in quarry wall. *Fig. 3*—"Strophalosia" bed of westward dipping Ledyard-Wanakah shales at East Bethany section. *Fig. 4*—Septaria in Cashaqua shale 2 miles S.W. of West Bethany.

The deposits have been described as a large delta (Chadwick, 1933). When stratigraphic units are traced eastward, they are found to grade into or interfinger with coarser deposits. Marine shales of the Hamilton Group grade into coarser clastics and finally red continental shales in the Catskill Mountain area. Moreover, the facies changes have in many instances brought about a change in the faunal content of contemporaneous beds so that the problems of correlation have been extremely difficult. Many problems of this type still exist.

As sedimentation continued, the facies migrated. Red beds came to lie over marine sandstones, while the sandstones were deposited over areas which had previously received silts and muds. This is especially true of the Upper Devonian when the migration to the west was rather rapid. Nor was this change in facies of a uniform nature. In the Upper Devonian, oscillations occurred which changed the lithology rather rapidly and produced an intertonguing of these facies. It is however, still possible to divide the clastics into formational units based upon dominant types of sediments and characteristic fauna.

Formations generally thin to the west. Thin limestone beds of the Hamilton that are separated by shale, are collectively treated as a member. Thicknesses of the members usually reflect the westward thinning of the shales and not the limestone beds. Exceptions are the Onondaga limestone and some of the black shales. The Upper Devonian black shales increase in thickness westward until they constitute the dominant type of sediment in Ohio. Devonian sedimentation in New York State may be described as a wedge of clastics with time lines converging westward.

LOWER OR MIDDLE DEVONIAN

The Onondaga limestone represents the only formation of possible Lower Devonian age. The problem concerning its stratigraphic position is most interesting. The Onondaga has two faunas, according to Cooper et al. (1942). The lower one is called the *Amphigenia* fauna (a brachiopod) which is correlated with the Schoharie of eastern New York and the Camden of western Tennessee. Above this is found a *Paraspirifer* fauna. The Genus *Paraspirifer* ranges from the Onondaga well up into the Marcellus (Lower Hamilton).

In Germany, Paraspirifer characterizes Upper Coblenzian (Lower Devonian) and Eifelian (Middle Devonian). The Onondaga seems to correlate with the Coblenzian while the Marcellus correlates with the Eifelian.

Onondaga Limestone

History of the Nomenclature—The term was first used by Hall in 1839. At that time it was defined as the limestone which underlies the Seneca limestone and succeeds Oriskany sandstone. The name, "Gray Sparry limestone", had previously been applied to it in earlier New York reports. The name Onondaga was used for the salt group beneath and subsequently abandoned by Dana in 1863. Later, Hall (1843) defined it as overlying the Schoharie grit and underlying the Corniferous limestone.

Finally, Emmons (1846) revised it to include the limestone between the Marcellus slate (shale) and the Schoharie grit. This is the use today. Hall, for many years, followed his definition of 1843. Clarke and Luther applied the term as used by Emmons.

In this area the Onondaga is found between the Oriskany sandstone (or its horizon) and the Marcellus shales of the Hamilton Group.

The type section is in Onondaga County, New York. This is 90 miles to the east of the Batavia Quadrangle. It extends from the Catskill area, westward across New York State, to Ohio. There is a general thickening of the formation toward the west. The following table demonstrates this change in the western part of the State:

75 feet at Seneca Lake
125 feet at Canandaigua Lake
135 feet at the Livonia Salt Shaft
140 feet in the Caledonia Quadrangle
168 feet at Lake Erie

Only the upper portion of the Onondaga is found in this area. The best exposure is at a quarry west of Stafford, just south of Route 5. The limestone quarried here is being used for road metal. A total of 61 feet is exposed. This is believed to be the uppermost part of the formation, although the upper contact was not located. The total thickness in this area is approximately 150 feet.

Lithology and Fauna—It appears as a massive, fine-grained limestone with layers and lenses of chert between the more massive beds (see Plate III, Figs. 1 and 2). There are also irregular masses of chert in the limestone beds. The layers of chert range up to eight inches in thickness and the masses average two inches in diameter. The surface, when weathered, has a light gray, powdery appearance, but is dark gray on fresh fracture. There is very little recrystallization.

Most of the fossils are grouped in separated beds, two or three inches thick. Others are found in the thicker limestone beds. The base of the quarry has massive beds up to three feet thick, but higher, these become thinner and the chert increases in proportion.

The following list of fossils represent the most common forms in the quarry. For a more complete faunal list, refer to J. M. Clarke, and D. D. Luther (1904).

Heliophyllum halli
Favosites argus
Favosites sp.
Stareolasma rectum
Atrypa reticularis
A. spinosa
Brevispirifer gregarius
Camarotoechia billingsi
Leptaena rhomboidalis
Megastrophia hemisphaerica
Stropheodonta demissa
Crinoid columnals
Clathrodictyon sp.

MIDDLE DEVONIAN

The Hamilton Group overlies the Onondaga and is Middle Devonian in age. As previously stated, the genus *Paraspirifer* ranges well up into the Hamilton and correlates the lower part with the Eifelian of Europe (Cooper et al., 1942). The lowermost formation, Marcellus, had been correlated with the Givetian (Middle Devonian) because the Onondaga had been considered the "reefy" equivalent of the Eifelian (lower Middle Devonian). More recently it was discovered that the "reefy" facies in North America is represented by limestones on top of the Marcellus equivalent and not by the Onondaga. Therefore, the Marcellus is moved down to correlate with the Eifelian (lower Middle Devonian). The Onondaga thus moves down to become Coblenzian (Lower or Middle Devonian) in age.

A possible disconformity may mark the Onondaga-Marcellus contact. The contact is abrupt but whether this is caused by a time break or rapid facies change is not certain.

HAMILTON GROUP

The name was first applied by Lardner Vanuxem (1840) to the sequence of shales which were above the Skaneateles shale and beneath the Moscow shale. This sequence later become known as the Ludlowville shale. He then extended the term to include all the rock from the base of the Skaneateles shale to the base of the Tully limestone.

Hall expanded the term in 1851 to include the Chemung Group, the Portage Group and the Marcellus shale. Many changes had occurred in its usage from 1851 to 1890, when Prosser (1890) and others placed the base of the Hamilton at the top of the Marcellus and the top at the base of the Tully limestone, just as Vanuxem had done some fifty years before.

J. M. Clarke and nearly all other geologists followed this established definition until Cooper (1930) included the Marcellus in the Hamilton. This last definition includes all the strata from the Onondaga limestone to the "Tully pyrite". In 1935, Cooper and Williams included the "Tully pyrite" in the Hamilton Group. Now the Group includes four formations, the Marcellus, Skaneateles, Ludlowville, and Moscow. In this paper the "Tully pyrite" will henceforth be called the Leicester marcasite.

All of the formations of the Hamilton Group outcrop in this quadrangle. The Marcellus is represented by the Oatka Creek member which is between the Onondaga limestone and the Stafford limestone. The Skaneateles formation is composed of two members. They are the Stafford limestone and the Levanna shale.

Following this is the Ludlowville formation with the Centerfield, Ledyard-Wanakah, Tichenor and Deep Run members. The Ledyard and Wanakah are separated by Cooper but their division is not feasible in this area. The youngest formation is the Moscow which consists of the

Menteth, Kashong, and Windom, according to Cooper. The Leicester marcasite is added as the top member of the Moscow.

The Leicester marcasite represents the top of the Middle Devonian in western New York. Above it and possibly unconformable with it are the beds of the Genesee Group with a strikingly different sedimentation and fauna. The stratigraphic terminology for the Hamilton Group is that of Cooper with the following exceptions:

1. The Ledyard and Wanakah members of the Ludlowville formation are included as one unit.
2. The contact of the Kashong and Windom is defined upon a limestone zone instead of one of the many *Ambocoelia-Chonetes* zones.
3. The Leicester marcasite (formerly called the "Tully pyrite") is included as the top member of the Moscow formation.

The type locality is at West Hamilton, in Madison County. The formations of the Hamilton outcrop from the Hudson River to Lake Erie and, in general, the thicknesses increase from west to east. The following is a table of thicknesses of the Hamilton, in part from Cooper (1930).

1465 feet at Chenango Valley
670 feet at Cayuga Lake
625 feet at Canandaigua Lake
560 feet in the Livonia Salt shaft
525 feet in the Caledonia Quadrangle
230 feet at Lake Erie

The Hamilton is well exposed in the Batavia Quadrangle. The total thickness of the group is approximately 482 feet. Outcrops are numerous but most of them are small. Therefore a composite section must be made with minor parts of the column not exposed.

LITHOLOGY AND FAUNA—The beds of the Hamilton consist, for the most part, of shales with a few interbedded limestones. The lower part is characterized by dark gray and bituminous shales, grading into progressively lighter beds until the upper ones appear as bluish shales. The limestones form a small percentage of the rock section but are valuable horizon markers. Their persistence across the State served as the basis for Cooper's reclassification.

The lower black shales have a characteristic *Leiorhynchus* fauna (Chadwick, 1933) which reappears above in the black and dark gray shales. The Hamilton limestones also may carry a characteristic fauna so that a repetition of thin limestones serves as a source of confusion in the solution of problems in Hamilton stratigraphy.

MARCELLUS FORMATION

The name was first proposed by Hall (1839) to include the shale at Marcellus (Onondaga County) between the Onondaga limestone and the horizon marking the first appearance of the Hamilton fauna.

In 1840, Lardner Vanuxem (1840) further subdivided it. He described the upper Marcellus shales as being less highly colored than the lower shales and showing peculiar concretionary characters. Hall (1843) then admitted the division and stated that the lower part is very black, slaty, and bituminous, containing iron pyrite and concretions. This division is terminated upward by a thin band of limestone, above which the shale is more fissile and gradually passes from black to olive or dark slate color.

Clarke and Luther (1904) subdivided the Marcellus into the Marcellus (lower) and the Cardiff (upper) but their correlations to the west were confused according to Cooper (1930, p. 129), who says:

> "But they fell into confusion because farther west (of the Canandaigua Lake region) the shale below the Stafford is jet-black and the shale above the Stafford is lithologically like the Cardiff. They therefore defined the Cardiff as lying above the Stafford when actually it lies on the Marcellus and is overlain by the Mottville, which is the eastern equivalent of the Stafford, as clearly defined by Smith. Since the Stafford is actually the equivalent of the basal bed of the Skaneateles, it is necessary to exclude this member from the Marcellus."

Therefore, the only representative of the formation in this area is the Oatka Creek member.

Oatka Creek Shale Member

This shale was named by Cooper (1930) as the upper member of the Marcellus from Cayuga Lake westward to Seneca Lake, being overlain by the Mottville member of the Skaneateles shale, and underlain by the Cherry Valley limestone member of the Marcellus. To the west of Seneca Lake it comprises all of the Marcellus.

The type section is below the Main Street bridge over Oatka Creek at LeRoy where the whole section of thirty feet is exposed. In all localities studied by Cooper, it is overlain by the thin Stafford limestone. It thickens to the east and west of the type section.

The upper part of the shale is displayed in an outcrop just to the north of the Fargo and Adams road junction, two and one-half miles southwest of Stafford. Here the Oatka Creek shale and the Stafford limestone occur in the road ditch on the west side of the road and in the northwestward flowing stream, just east of the road. Only the top part of the member is exposed.

Since good exposures of the shale are lacking in the area, the writer studied the outcrop at the type locality which is less than one-half mile east of the quadrangle.

Lithology and Fauna—The lower ten feet consists of a black, bituminous, resistant, blocky, shale and its exposure reveals excellent joint patterns in the resistant beds. The upper twenty feet are less resistant with a few concretionary layers and black, fissile shales which contain pyrite crystals. It is in these fissile beds that most of the fossils are found. The top ten feet have zones so fossiliferous that when the shale is split the fossils cover the entire surface. Here the fauna is represented for the most part by the brachiopods, *Leiorhynchus limitare, L. laura* and in even greater numbers, the pteropod, *Styliolina fissurella.* The following fossils are most abundant and easily collected:

Chonetes lepidus	Liopteria laevis
Leiorhynchus laura	Nuculites triqueter
L. limitare	Panenka linklaeni
Orbiculoidea minuta	Platystoma euomphaloides
Productella truncata	Styliolina fissurella
Cornullites flabella	Orthoceras subulatum

The type of deposition and the presence of pyrite seems to indicate the environment in which these forms lived. Most of the fossils are characterized by thin shells and seem to be adapted to foul bottom conditions.

Skaneateles Formation

This is the name that Vanuxem (1840) applied to the poorly exposed shales that occur between the upper Marcellus and his Hamilton Group at Skaneateles Lake. He justifies the retention of the name by a much clearer report on the Skaneateles shale at Cayuga Lake. This is the second *Leiorhynchus* zone of Cleland (1903). The Centerfield limestone was included by Luther (1914) as the top member of the formation. It was not until Cooper (1930) correlated the Hamilton sections, that the Stafford limestone was included at the base and the Centerfield placed in the overlying Ludlowville formation.

The Skaneateles formation is found to outcrop from east-central New York to the extreme western limits of the State. The following table not only indicates the general westward thinning but the irregular nature of the thickness:

200 feet	at Cayuga Lake
225 feet	at Canandaigua Lake
216 feet	at the Livonia salt shaft
234 feet	in the Caledonia quadrangle
83–98 feet	in Darien and vicinity
60 feet	at Lake Erie

In this quadrangle the thickness is estimated to be 215 feet, which is represented by the Stafford limestone member and the overlying Levanna shale member.

Stafford Limestone Member

Although first mentioned by Clarke (1894) in his description of the Livonia salt shaft section, the type locality referred to was Stafford, New York. The limestone was considered to be contained in the Marcellus, as discussed before, until Cooper (1930) correlated it with the Mottville limestone member to the east. The Mottville is the basal member of the Skaneateles. Therefore, the Stafford is now considered the basal Skaneateles to the west.

The Stafford limestone is exposed just north of the Fargo and Adams road junction, two and one-half miles southwest of Stafford. The outcrops are in a road ditch on the west side of the road and in a stream just a few yards to the east. In the stream bank, large pieces of it have weathered sufficiently to display the fauna. At LeRoy, where the limestone makes the cap rock of the falls under the Main Street bridge, a faunal collection can be made only with difficulty.

No outcrop of the limestone could be found southeast of Stafford where the type locality has been described. It is suggested that the outcrop southwest of the town be used as the standard of reference because of its nearness to Stafford.

In general, the limestone zone increases in thickness from a few inches at Seneca Lake to fifteen feet at Lake Erie. Near Stafford it is two feet thick. The following measurements indicate this general change:

6 inches at Seneca Lake
2 feet at the Livonia salt shaft
8.5 feet at Lancaster
15 feet at Lake Erie

Lithology and Fauna—The limestone is massive, fossiliferous, and dark gray, and weathers to a brownish or buff color. The crystals of calcite are barely visible to the unaided eye. It is composed of two massive beds with a shale parting, making a total thickness of slightly more than two feet.

The Stafford contains fewer species than the younger Hamilton limestones. The most abundant forms found were:

Ambocoelia umbonata
Camarotoechia sappho
Chonetes coronatus
C. mucronatus
Leiorhynchus mysia
L. limitare
Meristella barrisi
Productella spinulicosta
Crinoid columnals
Euryzone itys
Mourlonia itys (?)
Styliolina fissurella
Orthoceras sp.
Greenops boothi
Phacops rana

Many Cephalopods of the orthoconic type are found in the limestone but time did not permit a detailed study of them.

Levanna Shale Member

This name was proposed by Cooper (1930) for the shale between the Stafford or Mottville member of the Skaneateles formation and the Centerfield member of the Ludlowville formation, where it is essentially the "Marcellus or *Leiorhynchus* facies" of the Skaneateles formation and cannot be differentiated into members.

Previously, Clarke (1903) had proposed the name, Shaffer shale, for the Skaneateles equivalent on Shaffer Creek (Ontario County), but it is poorly exposed there.

The Levanna shale extends from Cayuga Lake to the shore of Lake Erie and the type locality is near the town of Levanna on Cayuga Lake, 100 miles east of this quadrangle. Although the thickness decreases toward the west, the thinning is not uniform. The following measurements indicate this:

200 feet at Cayuga Lake
225 feet at Canandaigua Lake
214 feet in the Livonia salt shaft
75–90 feet at Darien and vicinity
43 feet at Lake Erie

Grossman (1938) reports a thickness of 128 feet for the Batavia quadrangle. Although the thickness of the member is not known in the western part of the quadrangle, the thickness in the eastern part is estimated to be 213 feet from well number nine (Genesee County) of the Bradley and Pepper report (1938).

The most complete section of the Levanna occurs along Oatka Creek from the Main Street bridge in LeRoy, southwest along the stream and then along White Creek to a point just east of East Bethany where the Centerfield limestone crops out in the stream bank. Smaller exposures occur at Canada, in the streams just west of School No. 5 on the Center (Bethany) road and again just north of the junction of route 63 and the Town Line road.

Lithology and Fauna—The basal part of the member is composed of black, bituminous shale, similar to the Oatka Creek shale below, and carries the *Leiorhynchus* fauna so prevalent in the dark gray shales of the member. The brachiopod, *Orbiculoidea minuta,* is present in great numbers.

Twenty-three feet from the base is a limestone, one and three tenths of a foot thick, which is brownish gray, crystalline, and rather fossiliferous. Wood (1901) recognized eight different limestone beds of the Stafford in the Lancaster region (forty miles to the west). It is possible that a lentil similar to the ones described by Wood, extends eastward and correlates with this limestone. If this were true, the twenty-three feet of shales beneath would then be included in the Stafford member.

Above the limestone, the shales are fissile and dark to medium gray. This represents the dark gray or *Leiorhynchus* facies interfingering from the west. Upper portions are characterized by calcareous shales which are dark gray to black, irregularly bedded and rather fossiliferous. The *Leiorhynchus* fauna still dominates as in the underlying strata. Most of the fauna listed was collected from the upper part of the member.

Ambocoelia umbonata	Nuculites oblongus
Chonetes mucronatus	N. triqueter
C. lepidus	Pleurotomaria sp.
Leiorhynchus laura	Styliolina fissurella
L. limitare	Orthoceras sp.
Orbiculoidea minuta	Bairdia sp.
Productella truncata	Plant remains
Crinoid columnals	

Ludlowville Formation

The name Ludlowville was first used by Hall (1839) for the sequence on Cayuga Lake from the base of the Centerfield member to his "Encrinal limestone", (now the Tichenor). Cooper (1930) points out that this Cayuga Lake section does not have a complete exposure of the formation but, since the name of Ludlowville is so well entrenched in the literature, the sequence on Paines Creek at Aurora should be the type section. This is 70 miles east of the Batavia Quadrangle.

The formation crops out from Schoharie Valley to Lake Erie. In the eastern part of the State, subdivisions are lacking because of the uniform lithology and fauna. Toward the west, however, the formation can be separated into members. The lower part is composed of a dark shale having the *Leiorhynchus* fauna but the upper part, according to Cooper, consists of soft gray shales and carries "the typical Hamilton fauna".

As in the case of the other Hamilton formations, the Ludlowville generally thins toward the west. This is demonstrated by the following thicknesses:

535 feet at the Chenango Valley
181 feet at Canandaigua Lake
130 feet at Jaycox Run (Caledonia Quadrangle)
88 feet at Darien
100 feet at Lake Erie

It is interesting to note the thickening of the formation in the Lake Erie area. In the Batavia Quadrangle the thickness is approximately 113 feet.

Cooper (1930) has divided the Ludlowville formation into five members. They are, from the base, the Centerfield, Ledyard, Wanakah, Tichenor and Deep Run. This classification is followed with the exception that the Ledyard and Wanakah are treated as one unit. Reasons for this change will be discussed later.

Centerfield Limestone Member

This is the name proposed by Clarke (1903) for a group of limestones exposed on Shaffer Creek, one mile north of Centerfield. By 1909 Luther included the Centerfield in the Ludlowville shale but later (1914) treated it as the top member of the Skaneateles. Cooper again placed the Centerfield limestone in the Ludlowville formation as its basal member.

This member extends from Cayuga County to Blossom, Erie County. West of this the typical Centerfield is not present but is thought to be represented by a one and one-half foot limestone. This westward extension was called the "Pteropod bed" by Grabau (1898) from its exposure in the cliff at Bayview, Lake Erie.

East of Blossom it thickens from four and one-half feet to nineteen feet in the Livonia Salt Shaft and consists of thin limestones and shale bands. Still farther east of the type section, it becomes more homogeneous, being a bluish, arenaceous limestone with an increase in the percentage of sand toward the east. The thicknesses are tabulated as follows:

50 feet at Skaneateles Lake
35 feet at Cayuga Lake
19 feet in the Livonia Salt Shaft
11 feet in the Caledonia Quadrangle
4.5 feet at Blossom

In the Batavia Quadrangle, the thickness is not definitely known, since outcrops are usually on small streams or in open fields where glacial drift and soil mantle obscure the complete section. The Centerfield is at least two feet thick. It is known to be composed of a massive crinoidal limestone bed over one foot thick and calcareous shales at least one foot thick.

Several excellent exposures may be found in this quadrangle. They are, from east to west:

1. One and one-half miles east of East Bethany along Transit Road, one-fourth mile south of the Delaware, Lackawanna and Western Railroad.
2. Three-fourths of a mile east of East Bethany on White Creek.
3. North of Bethany, along the Delaware, Lackawanna and Western Railroad, on either side of the Center Road overpass.
4. Three miles west of East Bethany, east of the Francis Road along the D. L. and W. R. R. and in a westward flowing stream just north of the railroad.
5. One mile north of outcrop 4, on either side of Francis Road where it crosses a southern branch of a westward flowing stream.

Lithology and Fauna—The member may best be described as a massive limestone, one foot thick, underlain by calcareous shales. This limestone is a hard, compact, crystalline, fossiliferous, steel gray bed while the underlying shale is calcareous, bluish gray, fossiliferous and irregularly bedded. Upon weathering, the limestone has a brownish appearance due to the oxidation of its iron content.

At the White Creek exposure, a piece of the limestone reveals a very interesting replacement phenomenon. A thin section of it shows the fossils to be partially replaced with what is now iron oxide. The matrix still retains the appearance of a recrystallized limestone but the fossils were irregularly replaced. The iron is found in zones radiating from some point on the surface of the fossil with the rest of the shell composed of calcite.

There are thin beds of marcasite in the Ludlowville and Moscow formations. The origin of the iron and its relation to the faunal content of these beds is unknown.

This limestone reveals one of the greatest faunal developments in the Hamilton, and records an environment in which hundreds of different species thrived in great numbers. Clarke and Luther (1904) listed fourteen crustaceans, eleven gastropods, eleven pelecypods, twenty-nine brachiopods and twenty corals from the Centerfield in the Canandaigua Lake area. Specimens found by the author in this area are listed below. For a more complete list refer to Slocum (1906).

Aulopora tubaeformis (?)
Amplexus hamiltoniae
A. intermittens (?)
Ceratopora dichotoma
C. jacksoni
Craspedophyllum archiaci
Cyathophyllum sp.
Favosites arbuscula
F. argus
F. clausus
F. hamiltoniae
F. placenta
Heliophyllum halli
H. halli var. confluens
Streptelasma ungula
Syringopora sp.
Trachypora limbata
Athyris spiriferoides
Atrypa reticularis
Brachyspirifer audaculus
Cryptonella rectirostra
Cyrtinia hamiltonensis
Elytha fimbriata
Fimbrispirifer divaricatus
Meristella haskinsi
Mucrospirifer mucronatus
Parazyga hirsuta
Pentamerella pavilionensis
Rhipidomella penelope
R. vanuxemi
Spirifer sculptilis
Strophodonta demissa
S. inequistriata
Tropidoleptus carinatus
Cladopora sp.
Fenestrellina emaciata
Pleurotomaria lucina (?)
Rhombopora lineata (?)
Crinoid fragments
Grammysia arcuata
Platyceras sp.
Orthoceras sp.
Phacops rana
Aechmina sp.
Amphissites sp.
Bairdia sp.
Bollia sp.
Bufina sp.
Ctenobolbina papillosa
Ctenoloculina sp.
Euglyphella sp.
Healdia sp.
Hollina sp.
Janetina sp.
Jenningsina sp.
Jonesina sp.
Kirkbyella sp.
Ponderodictya bispinulata
Quasillites sp.
Richina sp.
Ropolonellus sp.
Strepulites sp.

The member is characterized by *Favosites hamiltoniae* in this area but Cooper points out that *Fimbrispirifer divaricatus* (= *Spirifer divaricatus* Hall), *Pustulina pustulosa* (= *Vitulina pustulosa* Hall), and *Pentamerella pavilionensis* are the important forms. The notable abundance of *Heliophyllum halli* must not be overlooked but its presence in the Tichenor limestone prevents it from being diagnostic.

Ledyard-Wanakah Member

The name Ledyard was applied by Cooper (1930) to 100 feet of black shale succeeding the Centerfield limestone on Paines Creek, Ledyard township, in the Cayuga Lake area. This is approximately 75 miles to the east of the Batavia quadrangle. It had been called the "third Leiorhynchus zone" by Cleland (1903) and designated the Canandaigua shale by Clarke (1903–4).

Extending from Lake Erie to the east, the Ledyard changes from a Marcellus fauna and black shale to a Hamilton fauna (i. e., the fauna of the higher gray shale and limestone facies) and a blue-gray arenaceous shale, so that the name Ledyard eventually loses its significance. It rests on the Centerfield limestone or its westward extension and its upper limits are defined, according to Cooper, by a thin limestone, the "Strophalosia" bed. This bed contains *Productella truncata* (formerly *Strophalosia truncata*) in great numbers hence the name of the limestone. Cooper believes this bed overlies the Ledyard from Lake Erie to the Genesee Valley. Farther east, the "Strophalosia" bed being absent, Cooper defined the top of the Ledyard as being at the Pleurodictyum (= Michelinia) zone.

Grabau (1917) applied the name of Wanakah to the Hamilton shales underlying the "Encrinal limestone" (now Tichenor) at Eighteenmile Creek but did not define it further. This is 50 miles to the west of the Batavia Quadrangle. Later, the "Strophalosia" bed and *Pleurodictyum* bed, as discussed above, were designated at the base of the Wanakah by Cooper. He then traced the Wanakah from the type section as far east as Seneca Lake. According to him, its lithology varies in that it consists of a number of light and dark blue-gray shales and also contains a number of thin bands of limestone which persist for nearly 100 miles.

These thin limestones are named for their characteristic fauna and listed below:

1. *Pleurodictyum* bed—from Lake Erie to Cayuga Lake.
2. Trilobite beds—Lake Erie to Canandaigua Lake.
3. *Stropheodonta demissa zone*—Cazenovia Creek to Darien.

These represented some of the units upon which the two shale members of the Ludlowville were correlated from type sections 120 miles apart.

It is now necessary to study the thickness of these two members and the relation of these thicknesses to the section in the Batavia Quadrangle. The Ledyard has the following measurements:

60 feet at Cayuga Lake
50 feet at the Livonia Salt Shaft
52 feet at Jaycox Run (Caledonia Quad.)
? 46.5 feet at East Bethany ?
53–75 feet at Darien and vicinity
30 feet at Lake Erie

The Wanakah in turn thins from the Seneca Lake area to Lake Erie in following manner:

60 feet at Seneca Lake
74 feet at Canandaigua Lake
55 feet at the Livonia Salt Shaft
? 40 feet at Murder Creek and East Bethany ?
48 feet at Darien and vicinity
46 feet at Lake Erie

The question marks in the tables above are my own.

These sections for the Batavia Quadrangle not only represent unusual thicknesses in relation to those of the adjacent areas, but the Ledyard shale was remeasured and found to be approximately 90 feet to the "Strophalosia" bed. The section in question is three miles west of East Bethany, along the Delaware, Lackawanna and Western Railroad and in the streams just to the north and south of the railroad. These small streams eventually flow into the Little Tonawanda Creek. This general area now will be referred to as the East Bethany Section (see figs. 3 and 9).

LITHOLOGY AND FAUNA—The great difference in the thickness of the Ledyard at the East Bethany Section, as measured by Cooper and myself, is not due to a stratigraphic error. His measurements would be very accurate if the beds in the outcrops were horizontal. But they are not. A structural feature, unique in western New York geology, occurs in the area of this outcrop. This is the Clarendon-Linden monocline. In general it strikes a little east of north and dips to the west. (This structure is discussed in greater detail in the portion of this paper dealing with structure.) The dip ranges up to three and one-half degrees at the outcrop of the "Strophalosia" bed and since the section here is a composite one, error resulting because of the dip was not accounted for.

Below is the section as measured by Cooper:

Cooper, (Ph.D. Thesis)
pages 194–95
Section three and one-half miles west of East Bethany

The section presented below is located along the Lackawanna railroad tracks three and one-half miles west of the village of East Bethany.

Ludlowville shale Fm.

Shale .... 15 ft.

Spring Brook shale member (See note below)

Impure ls. .... 0′.6 in.

This ls. contains *Modimorpha sublata, Bucanopsis leda, Euryzone itys.* It is the concret. bed below the upper Trilobite bed. The bed "M" of Grabau was not observed, therefore the upper limit of the Spring Brook is not here precisely defined.

Shale, middle Trilobite bed .... 1′8 in.

Impure ls. containing *Streptelasma rectum.* (This bed is the lower Trilobite bed) .... 10 ft.

Shale, soft gray .... 7 ft.

Streptelasma rectum	Sprifer pennatus
Adolfia audacula	Athyris spiriferoides
Nucleospira concinna	Rhipidomella penelope

Ledyard sh. member

Impure ls. .... 6 in.

Strophalosia truncata	Styliolina fissurella
Modiella pygmaea	Geisonoceras subalatum
Nuculites oblongatus	Primitoipsis punctilifera

This bed is the Strophalosia bed

Soft shale .... 30 ft.

This bed is not completely exposed along the tracks. Its most important fossil is *Leiorhynchus laura.*

A small tributary to Little Tonawanda Creek rises on the north side of the Lackawanna RR. tracks two and one-half miles west of East Bethany. From the point where this brook passes under the tracks to its head, there are a few outcrops as follows:

Covered .... 16 ft.

The soil which covers the rock and forms this interval contains enormous numbers of fossils that have weathered free of the matrix. It is very probable that this material represents disintegrated rock thrown out during the excavation of the railroad cut and dumped along the brook. This covered interval must include a large part of the Ledyard shale

Centerfield member

Hard ls. abounding in corals .... 8 in.

Shale, very fossiliferous .... 1'5 in

This shale and limestone represent a part of the Centerfield member. The fossil species at this place have been listed by Slocum 1906 and Monroe 1902.

NOTE: The Spring Brook Shale member and the shale above (Eighteenmile Creek member) were the stratigraphic divisions of the Ludlowville shale formation made by Cooper in the Lake Erie sections. These names were used by him in his unpublished thesis but he has since modified the stratigraphy by combining the Spring Brook Shale and the Eighteenmile Creek to form the Wanakah shale member.

The Centerfield is well exposed for over one mile along the railroad east of this section. At a point two and one-half miles west of East Bethany, it dips to the west and is again found exposed in the stream just north of the railroad.

The East Bethany Section (condensed)
as measured by Sutton, 1949

The section begins at the outcrop of Centerfield in the stream bed just to the north of the railroad.

Bed 8. Shale, brownish gray. Contains—*Chonetes lepidus, Ambocoelia umbonata, Nuculites oblongus, Phacops rana* 2 ft. plus

Bed 7.	Limestone, shaly, gray weathering brown, not recry. Contains—*Orthoceras sp.*, *Stereolasma rectum, Modiomorpha subalata, Buchanopsis leda, Styliolina fissurella*	.4 ft.
Bed 6.	Shale, gray, fossil, medium bedded. Contains—*Streptelasma rectum, Pleurodictym stylopora, Ambocoelia umbonata, Athyris spiriferoides, Chonetes lepidus, C. scitulus, Rhipidomella penelope, Mucrospirifer mucronatus*	9.6 ft.
Bed 5.	Limestone, shaly, not too massive, "Strophalosia" bed. Contains—*Productella truncata, Mucrospirifer mucronatus, Euryzone itys, Buchiola retrostriata, Platyceras symmetricum, Nuculites oblongus, Phacops rana, Dalmanites boothi*	.6 ft.
Bed 4.	Shale, dark brownish gray, unfossiliferous in lower part grading to light gray fossil. shale in upper part. Covered from four ft. to fourteen ft.—*Leiorhynchus limitare, Chonetes setigarus, C. lepidus, Phacops rana, Tentaculites bellulus*	33 ft.
Bed 3.	Shale, brownish gray, fissile.—*Leiorhynchus laura, Chonetes lepidus*	9 ft.
Bed 2.	Limestone, concretionary in places, very fossil. also a calcareous shale. Contains—*Leiorhynchus limitare, Nuculites triquiter, Chonetes viscinus, C. lepidus, Ambocoelia umbonata, Styliolina fissurella*	.5 ft.
Bed 1.	Begins at railroad track, first four feet covered. Shale, brownish gray drying to light bluish gray, not too fossiliferous. Contains—*Chonetes lepidus, Ambocoelia umbonata, Leiorhynchus limitare, Dalmanites boothi, Phacops rana, and Styliolina fissurella*	23 ft.
Covered	....	22.0 ft.
Centerfield Ls.	.... A massive limestone one foot thick underlain by one foot of calcareous shale (see faunal list under Centerfield ls.). Covered below.	2.0 ft.

Overlying the Wanakah is a rather thin, fossiliferous limestone, called the Tichenor which would define the top of the Wanakah shale. This was found in the stream parallel to the West Bethany road one mile south of the East Bethany section. Moreover, the "Strophalosia" bed was traced south along this stream from the East Bethany section to a point near the Tichenor outcrop so that less than fifteen feet of beds are known to exist between the "Strophalosia" bed and the Tichenor. Weathered portions of the "Strophalosia" bed and the Tichenor occur together on top of the hill northeast of the bridge. This would indicate that the Wanakah shale is less than fifteen feet thick in this area. The total thickness of the Ledyard-Wanakah is approximately 103 feet in this quadrangle, with fifteen feet assigned to the Wanakah shale.

It can be seen from the remeasured section that the "Strophalosia" bed still represents a distinct change in the lithology and fauna so that the underlying Ledyard part of the section is a rather homogeneous unit and cannot be divided at any horizon below this bed.

These lower or Ledyard type beds consist of dark gray or dark brownish gray shales interfingering with gray fissile shales and a few rather thin limestones or concretionary zones. Weathering produces a light gray powder on the shales so that the exposures appear to be composed of a much lighter gray shale than is actually the case.

The fauna is a modified Leiorhynchus type which carries *Leiorhynchus laura* and *L. limitare* but in addition has some of the common species of *Chonetes* in greater abundance than the Levanna shales. The *L. limitare* is most abundant in the lower beds and reappears in the upper zones. The shales in the middle seem to contain mostly *L. laura*. *Ambocoelia umbonata* is very common in the lower beds exposed at East Bethany. A trilobite zone containing *Phacops rana* was also discovered in the lower dark shales. It is exposed at the East Bethany section on the small stream just north of the railroad. In contrast to the 19 Genera of ostracodes in the Centerfield limestone, the dark shales carry only *Ponderodictya bispinulata* in great abundance with *Quasillites sp., Richina sp.* and *Hollina sp.* in fewer numbers.

The "Strophalosia" bed is an argillaceous limestone, of light gray color and very fossiliferous, containing *Productella truncata* as the diagnostic and most abundant fossil. This bed is only six tenths of a foot thick but its fauna differs greatly from the dark shales below. It contains *Phacops rana, Mucrospirifer mucronatus,* and *Nuculites oblongus.* It does, however, contain the ostracode, *Ponderodictya bispinulata* which is so abundant in the dark shale below.

The beds above this have a different lithology and fauna. They would be classified as Wanakah in the terminology of Cooper. Although the entire section is not exposed, the beds are diagnostic enough to be identified from relatively poor outcrops. Bed 7 of the East Bethany section was identified in the stream one mile south and here the Tichenor limestone occurs about 100 yards to the east.

The basal part of Bed 7 consists of gray fossiliferous shales with abundant specimens of the coral *Stereolasma rectum* and the brachiopods, *Mucrospirifer mucronatus, Athyris spiriferoides* and *Rhipidomella vanuxemi.* Overlying this is an impure limestone containing abundant specimens of *Stereolasma rectum.*

The overlying Wanakah strata contain light gray shales and thin limestones with a fauna similar to that of the Tichenor, except for the lack of *Heliophyllum halli* and Bryozoa. *Pleurodictyum stylopora* does occur but its horizon was not located. The following is a list of fossils collected from the Ledyard-Wanakah.

Favosites argus	Nucula bellistriata
Pleurodictyum stylopora	Nuculites oblongus
Stereolasma rectum	N. triqueter
Ambocoelia umbonata	Pterochaenia fragilis
Athyris spiriferoides	Buchanopsis leda
Chonetes lepidus	Diaphorostoma sp.
C. setigerus	Euryzone itys
C. scitulus	Loxonema hamiltoniae
C. viscinus	Platyceras symmetricum
Leiorhynchus laura	Styliolina fissurella
L. limitare	Geisonoceras sublatum
Mucrospirifer mucronatus	Orthoceras sp.
Orbiculoidea lodensis	Tentaculites bellulus
Productella truncata	T. gracilistriatus
Rhipidomella penelope	Dalmanites boothi
R. vanuxemi	Phacops rana
Tropidoleptus carinatus	Hollia sp.
Buchiola retrostriata	Ponderodictya sp.
Leoptera laevis	Quasillites sp.
Modiella pygmaea	Richina sp.
Modiomorpha sublata	Plant remains

Tichenor Limestone Member

The Tichenor limestone overlies the Ledyard-Wanakah and extends from Seneca Lake to Lake Erie. Clarke (1903) applied the name to the limestone above his Canandaigua shale (= Ludlowville shale). Formerly, the Centerfield and Tichenor were believed to be the same limestone and were referred to as the Encrinal limestone. The present names were introduced when it was discovered that two separate limestones existed. In the Lake Erie area, Grabau (1917) suggested the name Morse Creek for the Tichenor which appears there as a thin limestone only one and one-half feet thick. Cooper found that the bed, when traced eastward, was only one of several limestones with intervening shale facies.

The type section is in Tichenor Point Ravine on Canandaigua Lake. This is approximately 40 miles to the east of the Batavia Quadrangle. At Tichenor Point, Cooper united the compact one foot of limestone with the ten feet of fossiliferous shale below. At Jaycox Run, in the Caledonia Quadrangle, it is also eleven feet thick with ten feet of shale capped by a one foot limestone layer. From here it thins to Lake Erie where it consists of a one and one-half foot hard pyritiferous, crinoidal limestone. The thickness varies principally because of the associated shale.

1 foot	at Seneca Lake
11 feet	at Canandaigua Lake
11 feet	at Jaycox Run
4.5 feet	at Murder Creek
2.3–4.6 feet	at Darien and vicinity

The member is nine feet thick in the eastern part of the Batavia Quadrangle and appears to thin toward the western part. Listed from east to west, the outcrops are:

1. The only complete exposure of the Tichenor is found in a small stream three quarters of a mile southeast of Pavilion Center. The stream is flowing southwest and joins Oatka Creek. The exposure may be found downstream from Branch Road.

Here the uppermost Ledyard-Wanakah shales are capped by a thin limestone three tenths of a foot thick. Above this, eight and two tenths feet of shale is assigned to the Tichenor because it is capped by a crinoidal limestone, one foot thick.

Numerous other localities occur where the outcrop is not as complete but weathering has freed its diagnostic fauna from the matrix so that it may be readily studied.

2. One and one-half miles southeast of East Bethany on a hilltop just north of the Transit and Keller Road junction.
3. The uppermost shale beds and overlying crinoidal limestone are exposed in a stream which is crossed by Route 63, one and one-half miles southeast of East Bethany. The outcrop may be examined just a few yards upstream (to the southwest) from the road. This section is excellent for the overlying Moscow formation.
4. Shallow well dredging one mile south of East Bethany, six hundred yards east of East Road. This affords excellent collecting, although the bedrock itself is covered by water.
5. Large pieces of the limestone bed and its fauna are found on top of a hill just north of the East Bethany section, approximately 200 yards east of Francis Road. A much better exposure occurs at the outcrop one mile south of the East Bethany section. This is in the stream bank just north of the West Bethany Road.
6. The westernmost exposure in the quadrangle can be found on Little Tonawanda Creek just south of the Gilhooley Road bridge, nine-tenths of a mile south of East Alexander.

Lithology and Fauna—Lithologically, the member consists of a series of calcareous shales interbedded with limestone beds. The limestone is a semi-crystalline, bluish gray bed. It is more argillaceous than the Centerfield. The Tichenor is also underlain by calcareous shales and argillaceous shales which are exceedingly fossiliferous. The corals are found in the resistant limestone beds as well as in the shales. The Tichenor must be treated as a series of beds because at outcrop 1, mentioned above, the resistant limestone bed is only one foot thick but at outcrop 2, mentioned above, the limestone is no longer a massive one foot bed but is composed of several thin limestones with shale between making a total measurement of one and seven tenths feet. This seems to represent lentils of shale interfingering with the limestone but its effect on the outcrop is to greatly reduce the resistance of the bed and give the effect of a different lithology.

Farther west, the limestone bed again becomes massive, measuring over one foot in thickness with no shale partings.

The fauna indicates a return of the Centerfield type of deposition and results in an abundant fauna similar to that of the Centerfield. Upon closer examination, the fauna is shown to be reduced in the number of species represented, (as noted by Grossman (1938) in his study of the Tichenor limestone) at Jaycox Run. Since the faunal study in this area was not detailed enough to warrant such a conclusion, the writer feels compelled to leave a critical analysis of this sort to other workers.

The coral, *Heliophyllum halli,* indicates the change to calcareous deposition. It is lacking in the shales and limestone below (in the Ledyard-Wanakah) and so is the most diagnostic fossil of the Tichenor. Many other types of corals as well as abundant Bryozoa, brachiopod and ostracode species may be found. The pelecypods and gastropods are all well represented.

Aulopora serpens
Craspedophyllum archiaci
Favosites arbuscula
F. argus
F. placenta (?)
Heliophyllum halli
H. halli var. confluens
Stereolasma rectum
Ambocoelia umbonata
Athyris spiriferoides
Brachyspirifer audaculus
Camarotoechia congregata
C. sappho
Chonetes lepidus
Cyrtinia hamiltonensis
Elytha fimbriata
Lingula spatula
Meristella barrisi
Mucrospirifer mucronatus
Pholidostrophia iowensis
Rhipidomella vanuxemi
Spinocyrtia granulosa
Spirifer sculptilis
Stropheodonta demissa
S. concava
Tropidoleptus carinatus
Fenestrellina planiramosa (?)
Reteporina striata (?)
Rhombopora hexagona
Crinoid fragments
Cypricardinia indenta
Nuculites oblongus
Diaphorostoma lineatum (?)
Loxonema delphicola
Pleurotomaria itys
Amphissites sp.
Bollia sp.
Bufina sp.
Ctenobolbina sp.
Ctenoloculina sp.
Euglyphella sp.
Healdia sp.
Jenningsina sp.
Jonesina sp.
Kirkbyella sp.
Ponderodictya sp.
Quasillites sp.
Richina sp.
Ropolonellus sp.
Strepulites sp.
Tubulibairdia sp.

Deep Run Member

This is the name applied to the brittle bluish shales that overlie the Tichenor limestone and underlie the Menteth limestone. It forms the uppermost member of the Ludlowville formation and extends from Seneca Lake to the Batavia Quadrangle.

Previously, Clarke (1885) had united the lower shales of this member with the Encrinal or Tichenor limestone. Later, (in 1904) he termed the whole shale sequence the "lower division" of the Moscow shale.

Cooper placed the Deep Run in the Ludlowville because it is overlain by the Menteth limestone. He discovered that the Menteth, when correlated to the Cayuga Lake section, is the basal bed of the Portland Point limestone. At Cayuga Lake, the Portland Point is the basal member of the Moscow formation. This places the Deep Run shales in the Ludlowville formation.

The type locality is Deep Run ravine, near Cottage City, Canandaigua Lake. Here it is 55 feet thick but rapidly thins westward until it wedges out in the Batavia Quadrangle. East of the type section it thins somewhat and measures 49 feet at Seneca Lake. East of Seneca Lake it is not distinguished but is correlated by Cooper with the King Ferry member (uppermost Ludlowville). Below is a table of thicknesses for the Deep Run, as measured by Cooper:

49 feet at Seneca Lake
55 feet at Canandaigua Lake
9 feet at Jaycox Run, Caledonia Quadrangle*
3 feet at Hills Gulch, Caledonia Quadrangle
* Grossman's measurement for the Deep Run at Jaycox Run is seven feet.

The Deep Run outcrops in the eastern part of the quadrangle, three-quarters of a mile southeast of Pavilion Center. Here it consists of three and six tenths feet of calcareous shale and is overlain by Menteth limestone six tenths of a foot thick. This section is outlined under the discussion of the Tichenor, (outcrop 1). Farther west at locality 2 (see Tichenor), five feet of calcareous shales were assigned to the Deep Run chiefly on faunal content although the overlying Menteth was reduced to a thin limestone measuring less than two tenths of a foot in thickness.

Lithology and Fauna—The shales are bluish gray, calcareous, irregularly bedded and fossiliferous with the weathered surface stained brown to yellow. The faunal content is significantly different from that of the shale members above and below it. Its pelecypods are very characteristic. Among those found were *Pterinopecten undosus* and *Aviculopecten princeps.* Specimens of the brachiopod, *Tropidoleptus carinatus,* are much smaller than those in the Moscow. A few of the species found in the shale are:

Ambocoelia umbonata
Camarotoechia congregata
Chonetes coronatus
C. mucronatus
C. setigerus
C. viscinus
Lingula sp.
Mucrospirifer mucronatus
Pentamerella pavilionensis
Tropidoleptis carinatus
Bryozoa
Aviculopectin princeps
Parallelodon hamiltoniae
Pterinopectin undosus
Greenops boothi
Phacops rana

Moscow Formation

Hall (1839) described the Moscow formation from the complete exposures near the village of Leicester (formerly Moscow). He reported that the shale and fossils are different from those below. He further described the color of the shale as bluish, in places olive, and locally, near the top as black. His references to the change in the sediments obviously applied to the difference between the Moscow shales and the underlying Ludlowville shales.

Hall's definition of the Moscow formation included that part between the "Encrinal" limestone and the Tully limestone. But what he did not know and what Cooper discovered later (1930) was that he had put the base of the formation on what is now termed the Tichenor limestone and thus had confused the Tichenor and Menteth limestones in their correlation from the Leicester section to the Canandaigua Lake section. Thus Cooper was forced to redefine the Moscow formation with the Menteth forming the basal limestone member.

Cooper recognized three members in the Moscow formation: the Menteth limestone, Kashong shale and Windom shale. It is proposed here to add a fourth member, the Leicester marcasite, as the uppermost member. The formation can be traced as far east as the Unadilla Valley and as far west as Lake Erie. The type section is only five miles east of the Batavia Quadrangle but significant changes in sedimentation occur to the west. These require the use of different criteria to distinguish the Kashong-Windom contact in the Batavia Quadrangle.

The formation thins irregularly from east to west. Cooper recorded the following thicknesses for the extent of its outcrop.

215 feet at Unadilla Valley
270 feet at Chenango Valley
140 feet at Cayuga Lake
165 feet at Canandaigua Lake
135 feet in the Caledonia Quadrangle*
70 feet at Darien and vicinity
60 feet at Cazenovia Creek
17 feet at Lake Erie

* The thickness of the formation is supplied by Grossman (1938). In the Batavia Quadrangle the formation is 72 feet thick.

Lithologically, the formation consists of bluish gray shales and thin limestones. The shales form a homogeneous unit and the Kashong and Windom members are differentiated upon their faunal content. A series of fossiliferous limestones occur at the top of the Kashong member and another series just below the Leicester marcasite.

Cooper differentiates the Kashong and Windom shale members upon a faunal zone called the "Ambocoelia-Chonetes Zone." The writer found that several horizons could possibly fit this definition but that a persistent limestone horizon could be identified in several outcrops across the quadrangle. This was chosen instead for the contact but has not been traced into the areas to the east or west to verify its stratigraphic importance.

Menteth Limestone Member

The name Menteth was applied to a thin limestone in the ravines at Tichenor and Menteth Points at Canandaigua Lake. Clarke and Luther (1904) defined it here as the limestone bed which lies seventy-five feet above the Tichenor. This had been previously termed the "Encrinal" limestone by Hall (1839) in the Cayuga Lake region. Cooper (1930) redefined it as the basal bed of the Moscow formation. He correlated it with the basal beds of the Portland Point member farther east. Since the Portland Point (also defined by Cooper) forms the basal member of the Moscow in the Cayuga Lake area, this makes the Menteth limestone the basal member to the west.

The Menteth limestone has a stratigraphic position fifty-five feet above the Tichenor at Canandaigua Lake, but when traced westward, it approaches the Tichenor horizon due to the rapid thinning of the Deep Run. According to Cooper, after the disappearance of the Deep Run, the Menteth rests on the Tichenor but dies out before reaching Lake Erie.

If the Menteth is equivalent to the basal beds of the Portland Point to the east, the Portland Point would extend in outcrop from the Unadilla Valley in the east to the Depew Quadrangle. The Menteth forms the basal limestone of the Moscow to the west of Canandaigua Lake. Therefore it is here treated as correlating with the Portland Point and extends from Canandaigua Lake to Spring Brook. Thicknesses of the member from the Canandaigua Lake section to the west are:

15 feet at Canandaigua Lake (Portland
 Point including basal Menteth layer)
.6 foot at Jaycox Run
.5 foot at Hills Gulch

Identification of the limestone was made at two places. The easternmost outcrop is outcrop 1 (see Tichenor) where a limestone bed six tenths of a foot thick was found to overlie the Deep Run shales. Farther west at outcrop 2 (see Tichenor) the only limestone found to overlie the shales was a thin bed of shaly limestone less than two tenths of a foot in thickness. It is questionable whether this represents the Menteth horizon but no limestone was found in this section to conform with the characteristics of the Menteth, as observed in the outcrops to the east.

A rather massive limestone bed occurs at the top of the Tichenor in the western part of the quadrangle. This limestone, over one foot in thickness, may be either (a) the Menteth limestone lying directly upon the Tichenor, or (b) a massive lens of limestone of the Tichenor with the Menteth absent. The author feels that the latter is true because of the presence of a shale above the limestone bed which abounds in crinoid columnals. This is very similar to the Deep Run shales in the eastern part of the quadrangle and would suggest that the Menteth, not the Deep Run, terminates in the eastern part of the quadrangle.

LITHOLOGY AND FAUNA—The limestone appears as a dark bluish gray, fossiliferous bed with comparatively little recrystallization. This is markedly different from the "dark gray resistant cherty limestone" described by Grossman at Jaycox Run. An increase in the amount of clay present may account for the facies change from Jaycox Run to the two exposures in the Batavia Quadrangle. Most notable was the high Bryozoa content with the brachiopod fauna next in importance. A few specimens identified from the limestone are:

Camarotoechia congregata	Crinoid columnals
Chonetes coronatus	Paracyclas lirata
C. viscinus	Styliolina fissurella
Pentamerella pavilionensis	Phacops rana
Tropidoleptus carinatus	

Kashong Shale Member

This is the name proposed by Cooper for a shale sequence above the Portland Point and underlying the Windom shale. This was the equivalent of the Moscow shale as used by Hall and others. The type locality is in Kashong Creek, Seneca Lake but it extends from Cayuga Lake to the Western edge of the Depew Quadrangle.

The beds consist of soft shale with the brachiopods *Adolfia marcyi* and large specimens of *Tropidoleptus carinatus*. From its eastern limit to Canandaigua Lake its upper boundary is defined by four feet of hard sandy rock upon which the Windom shale was deposited with a basal zone of soft shale carrying *Ambocoelia umbonata* and *Chonetes mucronatus*. West of Canandaigua Lake the sandstone is absent but the *Ambocoelia-Chonetes* zone persists. Therefore the basal beds are defined, not by a lithologic change in sedimentation, but upon the *Ambocoelia-Chonetes* zone.

The Kashong has a maximum thickness of 85 feet in the Genesee Valley and thins to the east and west.

24 feet at Seneca Lake
45 feet at Canandaigua Lake
80 feet in the Livonia Salt Shaft
61 feet in the Caledonia Quadrangle
43 feet at Darien and vicinity
Disappears at western edge of Depew Quadrangle

In the Batavia Quadrangle the shale has a thickness of approximately 38 feet.

LITHOLOGY AND FAUNA—One of the best exposures of the Kashong shale is on the west branch of White Creek, southwest of Route 63. Less complete exposures of the member occur on Little Tonawanda Creek from Town Line road at West Bethany southeast to Route 20 but here the section is much more difficult to measure because of the effects of monoclinal structure.

The top of the member is defined in the Batavia Quadrangle by a group of thin limestones which are traceable over the entire distance. Cooper's *Ambocoelia-Chonetes* zone was not found but thick beds of *Ambocoelia umbonata* occur in several parts of the Windom so that the contact would be poorly chosen on this basis. The group of thin limestones contain *Adolfia marcyi* which places them in the Kashong. Above these limestones (in the Windom) is a thin pyrite bed. Frequently, the weathered rocks in normally poor exposures have a very good display of the limestone fauna with weathered limonitic nodules from the shales above as an excellent horizon marker.

The following description was compiled principally from the exposures on White Creek with the limestone faunal list supplemented from other definitely identifiable outcrops where weathering has allowed the fossils to be freed from the matrix.

The basal part of the member consists of a soft greenish to bluish gray, fossiliferous shale which is irregularly bedded and contains a large amount of ferruginous material. Most abundant are the crinoids and Bryozoa which decrease in number in the overlying strata. It is possible that the first foot or so which lies on the Menteth limestone may belong to the Menteth but no sharp faunal break is clear so its upper contact would be more difficult to define than the one used here. The shale zone continues for sixteen feet with bedding much more regular and shale appears more bluish in color. A few fossils identified from these shales are: *Chonetes coronatus, Chonetes viscinus, Mucrospirifer mucronatus, Nucula lirata* and *Platyceras sp*. At a horizon of ten and six-tenths feet, above the base of the member, the shale was noticeably darker gray and carried few forms compared to the bluish gray shales above and below. Apparently a slight change in sedimentation was sufficient to produce unfavorable conditions for the Moscow fauna.

The next fifteen feet consist of bluish gray shales with a few thin shaly limestones which usually measure one or two tenths of a foot. The calcareous beds often show heavy staining by limonite. The fauna in the shales consists of large forms of *Phacops rana,* and most abundant is *Tropidoleptus carinatus*. Others found were *Camarotoechia sappho, Paracyclas lirata* and many crinoid columnals.

The top nine feet are distinguished by three limestones each separated by four feet of shale. The lower and thinner limestone contains *Tropidoleptus carinatus* and *Atrypa reticularis*. The next limestone is five tenths of a foot thick and forms a falls in the stream. The shales just beneath it are extremely fossiliferous carrying large numbers of *Mucrospirifer* *mucronatus, Elytha fimbriata* (which had been found only in the Centerfield and Tichenor limestones in this area) and abundant crinoid columnals. The uppermost limestone bed is eight feet thick and forms the top bed of the Kashong. Specimens collected from the limestone and the underlying calcareous shale revealed the following fauna:

Mucrospirifer mucronatus	Cypricardella bellistriata
Chonetes mucronatus	Orthonota undulata
Palaeonillo tenuistriata	Liopteria conradi
Orbiculoidea sp.	Greenops boothi

This nine foot calcareous zone is traceable across the entire quadrangle and is identifiable in poor outcrops by its association with nodules of limonite from a thin pyrite bed one foot above.

The following is a complete list of fossils identified from the member.

Adolfia marcyi	Fenestella sp.
Ambocoelia umbonata	Crinoid columnals and plates
Athyris spiriferoides	Cryptonella retrostriata
Atrypa reticularis	Cypricardella bellistriata
Camarotoechia sappho	Grammysia arcuata
Chonetes coronatus	Grammysia sp.
C. mucronatus	Liopteria conradi
C. scitulus	Nucula lirata
C. viscinus	Orthonota undulata
Elytha fimbriata	Palaeonilo tenuistriata
Lingula spatula	Paracyclas lirata
Meristella barrisi	Platyceras sp.
Mucrospirifer mucronatus	Greenops boothi
Orbiculoidea sp.	Phacops rana
Tropidoleptus carinatus	Plant remains

Windom Shale Member

The name Windom was given by Grabau (1917) to seventeen feet of shale exposed near the village of Windom, Erie County. Grabau thought this was equivalent to the Ludlowville and Moscow formations farther east.

Cooper (1930) redefined the term as a member of the Moscow formation. This member when traced eastward was found to overlie the Kashong. In the Lake Erie section it is the only member present.

The type locality is approximately 40 miles to the west of the Batavia Quadrangle but the member extends from the Unadilla Valley in the east to Lake Erie in the west. In the eastern part of its exposures, the Windom is more arenaceous than the underlying Kashong and carries a pelecypod fauna in contrast to a brachiopod fauna in the argillaceous facies farther west. In western New York it is not unlike the underlying Kashong in lithology but has sufficient faunal differentiation to distinguish it from the shales below.

The member may be studied at the following locations:

1. One and one-half miles northwest of Pavilion on northeastward flowing stream, northeast of its intersection with Route 63.
2. West branch of White Creek, north of Route 20.
3. Three-eighths mile south of Bethany on eastward flowing stream, east of Center road.
4. Two and one-half miles west of Bethany on Little Tonawanda Creek, north and south of Route 20.

The following thicknesses have been measured by Cooper:

265 feet in Unadilla Valley
120 feet at Cayuga Lake
65 feet at Canandaigua Lake
50 feet in Genesee Valley
27 feet at Darien and vicinity
52 feet at Windom (Cooper 1930)
17 feet at Lake Erie

LITHOLOGY AND FAUNA—The thickness of the Windom on White Creek is 32 feet. The lower part, which is approximately twenty-one feet thick, is composed primarily of shale. These soft bluish-gray shales are very similar to the underlying Kashong but here *Chonetes mucronatus* and *Ambocoelia umbonata* predominate with fairly abundant specimens of *Mucrospirifer mucronatus* and *Stropheodonta inequistriata.* One and five-tenths feet from the base occurs a thin marcasite bed which contains nodules of marcasite, some of which contain the remains of organisms. A fossiliferous zone occurs fifteen feet from the base with numerous *Ambocoelia umbonata* and *Chonetes mucronatus.* This may possibly correlate with the Kashong-Windom contact of Cooper but it is only one of several such horizons and is only seventeen feet from the top of the member.

The upper eleven feet of the Windom is distinctly different from the lower portions. It contains a series of limestones or concretionary layers separated by soft shale. Both the shale and the limestone of this zone are exceedingly fossiliferous. One fossiliferous limestone occurs at the base of this upper section (eleven feet from the top). Another is found two feet above the first. Above this is more limestone and shale with the remaining upper five feet composed of soft argillaceous shale and concretionary layers.

The fauna of this zone is much more similar to that of the Hamilton limestones than it is to the shale fauna. Accompanying the large bryozoa and crinoid population are such brachiopods as *Brachyspirifer audaculus, Spirifer tullius, Atrypa reticularis, Athyris spiriferoides, Chonetes coronatus, Rhipidomella vanuxemi,* and *Stropheodonta inaequistriata.* Corals are also fairly abundant being represented by *Amplexus hamiltoniae, Heliophyllum halli* and *Pleurodictyum sp.*

The limestone zone is persistent across the entire quadrangle and, with the overlying resistant Geneseo black shales, forms small falls in the local streams.

The following fauna have been identified in the Windom:

Amplexus hamiltoniae
Heliophyllum halli
Pleurodictyum stylopora
Ambocoelia umbonata
Arthyris spiriferoides
Atrypa reticularis
A. spinosa
Brachyspirifer audaculus
Camarotoechia sappho
Chonetes coronatus
C. lepidus
C. mucronatus
C. setigerus
C. viscinus
Elytha fimbriata
Mucrospirifer mucronatus
Rhipidomella vanuxemi
Spirifer tullius
Stropheodonta concava
S. inaequistriata
Tropidoleptus carinatus
Crinoid columnals
Nuculites triquiter
Styliolina fissurella
Orthoceras sp.
Tentaculites gracilistriatus
Greenops boothi
Bufina sp.
Ctenobolbina sp.
Ctenoloculina sp.
Hollina sp.
Quasillites sp.
Ulrichia sp.
Bryozoa

Leicester Marcasite

The name, Leicester Marcasite Member is proposed for the marcasite zone which overlies the Windom member. The member is exposed to best advantage along the banks of Beards Creek, one-quarter mile northwest of Leicester, New York and is five miles east of the Batavia Quadrangle. The exposure at Beards Creek is suggested as the type locality because of the unusually thick lens (six inches) present there and the length of the exposure in the bank. Here it exhibits its characteristic thickening and thinning which is not so readily seen in smaller outcrops.

The member had previously been called the "Tully pyrite". Vanuxem (1839) applied the name Tully to the limestone formation farther east. The Tully limestone is absent in this area but the marcasite bed was thought to be the westward continuation of the limestone. Later it was found by Pohl (1930) and Cooper (1935) to correlate with the *Spirifer tullius-Vitulina* zone at the top of the Hamilton. Grossman (1938), who used the term "Tully pyrite", suggested Beards Creek as the standard of reference.

Since it was not equivalent in age to the Tully limestone, it is necessary to divorce the bed from any connection with the Tully. Its significant stratigraphic position at the top of the Hamilton and its diagnostic fauna make it an object of intense study. Extending from the west shore of Canandaigua Lake to Lake Erie, it forms a bed or series of beds of marcasite and pyrite. These beds or lenses measure up to six inches in thickness. They may be entirely lacking in any one section and reappear in the next.

Outcrops where the Leicester marcasite may be studied in the Batavia Quadrangle are listed in order from east to west.

1. One and one-half miles northwest of Pavilion on northwestward flowing stream, northeast of its intersection with Route 63.
2. West branch of White Creek, north of Route 20.
3. Three-eighths mile south of Bethany on eastward flowing stream, east of Center Road.
4. North of falls at Linden, near junction of eastward flowing stream and Little Tonawanda Creek.
5. Two and one-half miles west of Bethany on Little Tonawanda Creek, south of Route 20.

LITHOLOGY AND FAUNA—The beds are composed of marcasite and pyrite. Cooper (1935) refers to this as marcasite while Grossman (1938) found specimens from Jaycox Run that are composed entirely of pyrite. The lenses are yellowish brown, sometimes nodular with a sponge-like appearance under the microscope. When weathered, the material crumbles into a reddish brown limonitic powder which frequently stains the underlying rocks.

The lenses are extremely fossiliferous but the forms are much smaller than those in the beds above or below. Loomis (1903) terms this a dwarfed fauna. He rules out the possibility of their being young forms because a whole fauna cannot exist in immature forms alone and the uniformity of their size can only express adult growth. The Goniatites show a reduction in size but have the mature chambers as well as the primitive whorls.

He explains that the dwarfing agent has totally eliminated the corals and that the brachiopods are most uniformly and extensively dwarfed. Other groups are more variable and generally less dwarfed than the brachiopods. Loomis states that the sessile types or bottom dwellers are the most dwarfed since the iron tends to settle. Variation in dwarfing seems to be due to differing locomotive abilities. If we accept the hypothesis that the fauna is a dwarfed one, the genera are variations of the Hamilton forms.

Loomis (1903) has listed thirty-one forms from the Leicester marcasite.

UPPER DEVONIAN

Disagreement exists as to the contact of Middle and Upper Devonian formations in New York State. According to Cooper et al. (1942, p. 1735) "A slight break in sedimentation occurs at the top of the Hamilton resulting from formation of a shoal on the site of Lake Erie probably in connection with movements of the Cincinnati arch. At any rate the movement is shown in a slight break traceable nearly to Schoharie Valley where all evidence of disconformity is lost."

Another break, at least a faunal one, has been claimed in recent writings. This is the Geneseo-Genundewa break (Genesee Group) where the Genundewa limestone represents a greater amount of time than do the shales

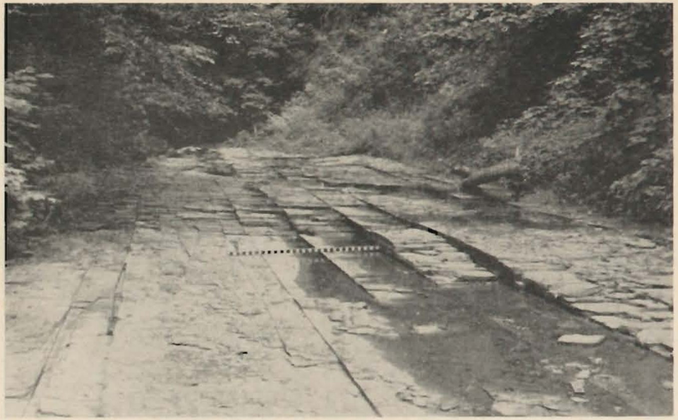


Figure 5

Figure 6

Figure 7

Figure 8

PLATE IV. Structures in the Upper Devonian Formations; Jacobs staff is horizontal. *Fig. 5*—Jointing (N 40° W) in Rhinestreet, 1½ miles S.W. of Wyoming, N. Y. *Fig. 6*—Broken anticline (axis N-S) in Rhinestreet 2 miles west of Linden. *Fig. 7*—Portion of broken anticline (axis N 21° E) in Hatch, 1 mile N.W. of LaGrange. *Fig. 8*—Anticlinal character of Gardeau, ½ mile N.W. of Warsaw.

above and below. The Geneseo is dated as Middle Devonian while the Genundewa is placed in Upper Devonian. The writer questions the validity of this because of a lithologic inseparability of the two. This problem will be discussed in more detail under the appropriate formations.

GENESEE GROUP

Lardner Vanuxem (1942) applied the term "Genesee slate", to the rocks which underlie the "Portage Group" and overlie the Tully limestone. In succeeding years the names Genesee beds, Genesee shale, and Genesee group were supplied to these beds but the boundary between was placed at the top of the "Lower Black Band" and by others at the base or ten to fifteen feet below the base of this "Band".

In 1903, J. M. Clarke introduced Middlesex black shales for the "Lower Black Band" and Rhinestreet black shale for the "Upper Black Band" both of which he included in the Portage Group. In 1904, Clarke and Luther applied the term Genesee beds to the strata between the overlying Middlesex shale and the underlying Tully limestone. They divided the Genesee Group into the Standish flags and shales (at top but not present here), West River shale, Genundewa limestone and Genesee shale.

The term Genesee was used in a broad sense meaning the group and in a restricted sense when applied to the lowermost black shales. This twofold use persisted until Chadwick (1920) proposed to replace the restricted Genesee shale with the name, Geneseo black shale. The latter usage is followed in the present work. In the Batavia Quadrangle the Genesee Group is made up of the Geneseo black shale, which overlies the Leicester marcasite of the Moscow formation and contains the Genundewa limestone member at the top, and the overlying West River shale.

The beds of the Genesee Group constitute one of the most intriguing problems in Devonian stratigraphy. The committee on Devonian Correlation (Cooper et al., 1942) place the Geneseo and Tully formations in the Taghanic Stage (Middle Devonian). The Genundewa limestone and West River are formations of the Genesee Group, the Finger Lakes Stage of the Upper Devonian. The Geneseo is separated from the Genundewa limestone because of the postulated presence of a disconformity at the top of the Geneseo. They believe the accumulation of the Genundewa limestone represents considerable time and a distinct break in black shale deposition. The relation of the Geneseo and Genundewa will not be discussed in detail here, but it is sufficient to say that the Genundewa limestone is not a single bed but consists of lenses which are not persistent and are separated by typical Geneseo black shale. Grossman in his study of the Genesee Group (1944, p. 58) states:

> "A widespread submarine disconformity might be indicated by the Styliolina beds (Genundewa limestone) on the assumption that the disposition of great multitudes of Styliolina involved a long time.

The significance of these lentils in defining a continuous break in western New York is doubtful however, because of the highly irregular and only local occurrence of the pteropod lenses."

The United States Geological Survey in 1936 at the request of W. H. Bradley, adopted Genesee group to include the following formations: Standish sandstone (absent in Batavia Quadrangle), West River shale, and Geneseo shale (redefined to include the Genundewa limestone lentil at the top). This group is included in the Upper Devonian. In this report the Genundewa will be designated as the upper member of the Geneseo black shale formation and the group will be considered upper Devonian in age.

The type locality of the group is at the exposures along the Genesee River in the gorge just south of Mt. Morris. The group decreases in thickness from east to west.

174 feet at Canandaigua Lake
165 feet at Livonia salt shaft
155 feet in Caledonia Quadrangle
15 feet at Lake Erie

Local sections studied show a decrease in thickness from over 60 feet in the eastern part to less than 35 feet in the western part. Both measurements were made well inside the borders of the quadrangle so that the change in thickness is well over 25 feet. Details of sedimentation and fauna will be discussed in more detail on the following pages.

GENESEO FORMATION

Geneseo Black Shale

As mentioned above, the name Geneseo was used by Chadwick (1920) to distinguish the black shales of the group from the group itself since the name "Genesee" had applied to both. He designated the 84 feet of black shales of Fall Brook as the type locality. Fall Brook is just south of Geneseo and only 12 miles east of the quadrangle.

The formation extends from Chenango Valley to Lake Erie. To the east of the Chenango Valley the beds laterally grade into coarser clastics to which the name Sherburne is applied. The black shale increases in thickness westward from there until it reaches a maximum in the Canandaigua Lake area. From there it thins westward until it measures only a few inches at Lake Erie. The following thicknesses have been reported:

35 feet at Casenovia Valley
75 feet in the Geneva Quadrangle
90 feet at Seneca Lake
111 feet at Canandaigua Lake
92 feet at Murder Creek
3 feet at Cazenovia Creek
8 inches at Lake Erie

The thickness of these sections includes the Genundewa limestone beds at the top of the formation. They will be discussed as a distinct member of the formation.

In the Batavia Quadrangle, the formation thins from east to west. Sections measure over 33 feet in the eastern part of the area but thin to 25 feet in the west. The following sections are considered as excellent exposures for the study of this formation. From east to west they are:

1. Two miles southwest of Pavilion on southeasterly flowing stream which crosses the Hudson Road just at the Genesee-Wyoming County line. Section is exposed in the stream north of the road except for the lower portion of the Geneseo which is covered.
2. West branch of White Creek has excellent exposure of formation just north of Route 20 with the Genundewa limestone member exposed in the stream on both sides of the road.
3. Three-eighths mile south of Bethany on eastward flowing stream, east of Center Road.
4. At Linden, the falls in Little Tonawanda Creek and section to the north.
5. Two and one-half miles west of Bethany on Little Tonawanda Creek, south of Route 20.
6. One and one-quarter miles southwest of West Bethany on northward flowing stream. Outcrop just south of Route 20.

LITHOLOGY AND FAUNA—The formation is composed of four types of beds, one distinct from the other three and thus treated separately as the Genundewa limestone member. The others are (1) black fissile shales, (2) dark gray concretionary beds and thin limestones. The black shales demonstrate a distinct change in sedimentation from the underlying soft bluish shales of the Hamilton. Their resistent nature and fissile character resulted in the term "slate" being applied to them by early geologists. Interbedded with these are thinner zones of less fissile, lighter shales which are still much darker than the Hamilton type. Both types of shale are often found coated with iron stains and the fissile type has concretions of pyrite-marcasite in the beds. The dark gray shale is almost entirely lacking in the western sections mentioned above.

The fauna is greatly reduced when compared to the formation below but in zones of the lower portion such brachiopods as *Chonates lepidus, C. setigerus,* and *Leiorhynchus quadricostatus* occur in large numbers. The pteropod, *Styliolina fissurella* is probably the most abundant form being found at almost all horizons and in great numbers.

The third type of bed observed in this area is the concretionary bed or a continuous limestone equivalent. It is usually composed of shaly limestone which is almost as dark as the surrounding shales. At section number 4 (Linden) the first ten feet are composed of alternating black shales and concretionary beds less than one foot apart. No fossils were noted in these. The next five feet is composed only of black shale. Above this the alternating black shales and concretions again occur at approximately the same interval with the uppermost limestones becoming continuous but unlike the overlying Genundewa limestone in appearance and fauna.

Lateral changes are most outstanding. The dark gray shales thin rapidly to the west while the concretionary beds become thicker until at section 5 (Little Tonawanda Creek) a resistant limestone forms a low falls at a horizon twelve feet above the Leicester marcasite. Another eleven feet of Geneseo exists above this with several more thin limestones exposed in the stream bank. Apparently there is sufficient calcareous material to form the continuous limestone while to the southeast only concretions were formed.

The Geneseo shales contain the following common fossils in the Batavia Quadrangle:

Chonetes lepidus	Pterochaenia fragilis
C. mucronatus	Styliolina fissurella
C. setigerus	Tentaculites gracilistriatus
Leiorhynchus quadricostatus	Cephalopoda
Lingula spatula	Plant remains

For the complete fossil list of this and other Upper Devonian groups, see Chadwick (1935).

Genundewa Limestone Member

For many years the uppermost limestone beds were referred to as the *Styliola* limestone because they contain great numbers of the pteropod *Styliola* (*Styliolina*) *fissurella*. In 1903, Clark referred to the formation as the "Geneseo shale including the Genundewa limestone". Later he treated the limestone as a distinct unit and it remains so if treated as the basal unit of the Upper Devonian. If the correlation of Bradley (1936) and the United States Geological Survey is used, the Genundewa limestone is included in the Geneseo shale. The latter correlation is used in this report and the reasons are discussed below.

The type locality is at Bare Hill, formerly Genundewa Hill, Canandaigua Lake which is forty miles east of the quadrangle. The member extends from Seneca Lake to Lake Erie and consists of limestone beds and black, bituminous shale. The thickness generally decreases toward the west. A total of sixteen feet have been assigned to the member in the Canandaigua Lake area while six feet exist at Fall Brook and only six inches at Lake Erie.

Lithology and Fauna—The Genundewa is composed of beds of limestone with interbedded Geneseo-type black shale. The limestone beds range in thickness from one tenth to almost one foot. They consist of crystalline dark brownish gray, nodular limestones with some beds more argillaceous. Usually three or four beds are found with the thickest beds as the uppermost layer. The top limestone forms the cap rock of the falls at Linden.

The irregularity of these beds was noted by Grossman (1938) who pointed out the possible error in using the limestones for horizon markers. Nothing assures the worker that the beds can be correlated over any reasonable distance. The thicknesses assigned to the Genundewa are measured from the lowermost to the uppermost limestone containing *Styliolina fissurella* in profusion. Changes in this thickness seem to depend upon the variations of the interbedded shale. The limestone beds are usually four in number, the first three are from one-tenth to five-tenths feet in thickness while the uppermost bed is the thickest and probably recognized by earlier workers as "the Genundewa limestone." This top layer of limestone has a very irregular appearance. The surface is covered with nodules which contain abundant *Styliolina fissurella.* This would indicate the nodules are not concretions. Beds of dark shale conform to the upper nodular surface. In general, the overlying shales are unlike the "Geneseo type".

Within the limestone beds, *Styliolina fissurella* is by far the most abundant form. Others are:

Lingula spatula	Bactrites aciculum
Pterochaenia fragilis	Orthoceras sp.
Lunulicardium encrinitum	Plant remains

West River Shale

The name West River was given by Clarke and Luther (1904) to the dark gray and black shales between the Genundewa limestone and the Standish flags and shales (absent here). The West River was included in their "Genesee beds or group" as they used the term in the broad sense. Previously the West River had been called the "Upper Genesee shale" but the new name was applied to exposures in West River Valley in Yates County. The type locality is approximately 50 miles to the east of the quadrangle.

The formation crops out from Cayuga Lake to Lake Erie. To the east its equivalents are the Sherburne and Standish sandstones. These sandstones interfinger westward with the West River so that its lithology is quite different from that in this area. The following thicknesses demonstrate its changes in facies.

46 feet at Canandaigua Lake
71 feet at Livonia salt shaft
60–70 feet in Caledonia Quadrangle
12 feet at Lake Erie

The presence of the Standish sandstone tongues probably accounts for the eastward thinning of the shales between Canandaigua Lake and the Caledonia Quadrangle. In the Batavia Quadrangle, the West River thins from an estimated 40 feet on the eastern edge of the area to 20 feet farther west. When these measurements are compared to those obtained by Grossman in the Caledonia Quadrangle, the westward thinning seems extremely rapid. Several explanations are possible for this change. First, the westernmost section measured by Grossman occurs in Rocky Creek which is four and one-half miles east of the Quadrangle border. Rapid change in thickness may be the case. Secondly, the sections measured in the Caledonia Quadrangle are up to six miles farther south than those in the Batavia Quadrangle. Measurements are usually compared in an east-west direction with little thought of the north-south distribution of the outcrops or well sections studied. Perhaps this may also partially explain the "rapid thinning" since the Devonian formations do generally thicken to the south.

Sections where the West River may be studied are:

1. Three-quarters mile southeast of Pavilion in westward flowing stream, one quarter mile west of Perry Road—Route 63 intersection. Here only lower beds are exposed but when this section is correlated with section (Cashaqua) one-half mile to northwest, the maximum thickness possible for the West River would be forty feet.
2. Two miles southwest of Pavilion on southeasterly flowing stream which crosses the Hudson Road just at the Geneseo-Wyoming County line. The formation is exposed in the stream north of the road and north of a falls with the cap rock of Genundewa limestone.
3. At Linden just south of the falls in Little Tonawanda Creek.
4. One and one-quarter mile southwest of West Bethany on northward flowing stream. Outcrop is south of Route 20.

LITHOLOGY AND FAUNA—The West River shale is composed of dark gray and black shales. The basal two feet are dark gray shale; the next thirteen feet consists of alternating dark gray and black shales with a concretionary bed at the seven foot horizon in the formation. Similar concretionary beds were noted in several outcrops of the West River. Usually a thicker fissile bituminous bed is found toward the top which is very similar to the overlying Middlesex black shales. This bed may be from one to three feet thick and is overlain by dark gray shales to the top of the formation. In the westernmost exposure (section 4 above) thin limestones appear in the upper part of the formation.

Although the gray shale is more fossiliferous than the black bituminous beds, the fauna is not very abundant and poorly preserved. Such forms as the pteropod, *Styliolina fissurella,* the brachiopod, *Orbiculoidea lodensis* and *Pterochaenia fragilis* are the most common in the dark gray shales. The following fossils were found:

Orbiculoidea lodensis
Buchiola retrostriata
Lunulicardium curtum
Pterochaenia fragilis
Styliolina fissurella
Bactrites gracilier
Plant remains

NAPLES GROUP

In 1885, Clarke substituted the term "Naples beds" for that part of the section above the Genesee Group. The section above has been called the Portage Group. The formations in the region of Naples, Ontario County, could not be subdivided so Clarke substituted the name Naples. He described what was later termed the Naples fauna which he then attempted to trace to the east and west. To the east this fauna was replaced by the Ithaca fauna but it can be traced to the west. By 1903, Clarke had divided the Naples beds into several units, the Middlesex black shale being the basal one and the Wiscoy shale the topmost one.

The name, Naples, seems to have fallen into disuse until revived by Chadwick in 1935. In his classification, the Naples is restricted to the lower part of the section to which it had been applied by Clarke. Chadwick divided his restricted Naples into the Enfield or Attica member above (which includes Hatch and Rhinestreet) and Ithaca or Sonyea member below (which includes Cashaqua and Middlesex shales). These four formations occur in this area and are described in detail below.

Reason for the division into the Naples group is a faunal one. Chadwick (1935) lists about 400 species in the black shales of the Naples Group. Of these, 185 are restricted to the Group itself, eighty-nine have persisted from Hamilton time and 40% of these continued on. Approximately forty-five originated in Genesee but only 30% of these persisted beyond.

Sedimentation seems to have been one of gradual change for the Middlesex and Rhinestreet were dominantly black shale, not unlike the "Genesee type" of disposition. The Cashaqua and Hatch were characterized by gray shales and eventually fine clastics heralding the coarser materials to follow in the overlying Portage beds. This group seems to represent a transition in facies from the black shale to the clastics which were moving westward from the Catskill delta region.

The group can be traced, according to Chadwick, from Lake Erie where it measures a total of 225 feet, through all the facies changes to a maximum of nearly 5000 feet of Catskill continental strata forming the main mass of the Catskill mountains. In the Batavia Quadrangle the thickness measures approximately 320 feet.

Middlesex Black Shale

This name was applied by Clarke (1903) to the basal part of his Naples Group. Previously it had been the upper part of the "Genesee black slate" (Hall, 1839) and later the "Lower black band" of Clarke's (1885) Portage Group.

The Middlesex is named for abundant exposures in the town of Middlesex, Yates County and extends from Seneca Lake to Lake Erie. In the eastern part it is decidedly arenaceous with thin flags but westward it assumes thin bedded, bituminous, black shale characteristics.

The following thicknesses indicate the general thinning toward the west as well as the interfingering eastward with coarser clastics.

15 feet at Gorham
35 feet at Middlesex
25 feet at Honeoye Lake

40 feet in Livonia salt shaft
20–30 feet in Caledonia Quadrangle
6 feet at Lake Erie

Locally the shales thin from fifteen feet in the eastern part of the Quadrangle to ten feet in the westernmost section measured. The following localities are best suited for study of this formation.

1. Two miles southwest of Pavilion on southeasterly flowing stream which crosses the Hudson Road just at the Geneseo-Wyoming County line. The formation is exposed in the stream north of the road and north of a falls with the cap rock of Genundewa limestone.
2. One mile northeast of Linden in westerly flowing stream, just north of Smith Road and west of Marsh Road.
3. One-half mile northwest of Linden in easterly flowing stream, just east of Silver Road.
4. One and one-quarter miles southwest of West Bethany on northward flowing stream. Outcrop is south of Route 20.

Lithology and Fauna—The formation consists of two black fissile zones of resistant shale separated by dark gray soft shales. The marked jointing and resistant nature of these beds results in falls and narrow valleys.

The shale yielded only the pteropod, *Styliolina fissurella* and occasional evidences of plant life. (For faunal lists, see Chadwick 1935, and J. M. Clarke 1904). The large amounts of bituminous material present in these shales probably originated in the same manner as that in the overlying and underlying black shales. Absence of abundant fauna, the extremely fissile character, the presence of the dark gray shale zone, and absence of concretionary beds, distinguish the Midlesex from the Geneseo black shale.

Cashaqua Shale Formation

Named by Hall (1840) for exposures on Cashaqua Creek. In 1933 it was combined by Chadwick with the Middlesex shale and called Sonyea.

The Cashaqua shales consist of soft bluish gray and greenish gray shales which extend from Seneca Lake to Lake Erie. In the eastern portion, the beds are more arenaceous but westward the shale becomes dominant with a few flags near the top and a few thin layers of black shale in the lower zone. The formation thins to the west from Canandaigua Lake.

230 feet at Canandaigua Lake
190 feet in Caledonia Quadrangle
110 feet in Letchworth Park
33 feet at Lake Erie (Eighteenmile Creek)

Exposures in the Batavia Quadrangle indicate a thinning from 110 feet in the east to 90 feet in the west. Although few sections show a complete section of the formation, the following outcrops are considered excellent for its study. From east to west they are:

1. Wyoming, in southeasterly flowing stream, Cashaqua exposed for one mile upstream (from the village line west).
2. One and one-half miles northwest of Linden in easterly flowing stream; intermittent exposures from point just east of Silver Road, westward to Erie Railroad.
3. One and one-quarter miles southwest of West Bethany in northerly flowing stream.
4. Two and one-quarter miles southwest of West Bethany in westerly flowing stream. Contact with overlying Rhinestreet shale in stream bank just north of Dry Bridge and Chaddock Road Junction.

Lithology and Fauna—The Cashaqua is characterized by soft, somewhat fissile, olive gray and bluish gray shales. Thin limestone, concretionary beds and dark gray to black shales also occur. Upon weathering, a bluish or brownish coating covers the exposed surfaces. The fauna is more abundant than in the black shales of the older formations, but most of the forms are poorly preserved (see Plate III fig. 4).

The first 30 feet of shale are soft, colored shales with a few concretionary beds. For the next 20 feet the gray shales are interbedded with dark gray and black shales with only one concretionary bed noted. Following this is a 25 foot zone of gray shale and numerous concretionary horizons with a few thin limestone lentils. Most of the fossils found were confined to this zone and more particularly to the shales above and below the concretionary and limestone beds. Speciments of the pelecypod, *Buchiola retrostriata,* and the cephalopod *Bactrites aciculum,* as well as plant remains were found. The fossils were collected at a limestone horizon near the bottom of this zone. Possibly this horizon is correlative with the Parrish limestone lentil farther east. (The Parrish lentil occurs in the Canandaigua Lake area and eastward. There it rests 50 feet from the top of the formation.) The upper part of the formation contains gray shales with dark gray and black shales increasing in amount in the last few feet.

Flags, which appear in the Cashaqua to the east and south, are absent here but many of the beds which are called "shale" in the hand specimen are composed of very fined grained quartz.

Apparently the coarser material failed to reach this area. The black shales are like those characteristic of the overlying Rhinestreet and the underlying Middlesex shales. The limestone and concretionary beds are believed to be nonpersistent because it was difficult to trace them for even short distances. The zones described above showed less variation and were recognizable from one section to another.

The following fossils were found:

Buchiola retrostriata
Styliolina fissurella
Plant remains

Rhinestreet Shale Formation

Named by John M. Clarke (1903), the Rhinestreet overlies the Cashaqua and underlies the Hatch gray flags and shales. Both upper and lower contacts are gradational and no distinct break in sedimentation is apparent. It is composed of black, fissile and dark gray shales.

To the east the Rhinestreet and Hatch are contemporaneous with the Enfield shale. Westward, the Hatch has increasing amounts of black shale until in the Attica region it is indistinguishable from the Rhinestreet. Luther (1903) unknowingly included both the Rhinestreet and Hatch equivalents in his measurements of the Lake Erie section. Chadwick (1919) corrected this by combining the two formations under the name Attica. The westward equivalent of the Rhinestreet is, therefore, the lower portion of the Attica. It extends from Seneca Lake to Attica, New York (western edge of Batavia Quadrangle) and the type locality is at Rhinestreet, north of Naples in Ontario County. At Rhinestreet, approximately 32 miles east of the area, the formation is only 21 feet thick but it thickens persistently to the west.

1 foot at Seneca Lake
21 feet at Canandaigua Lake (Rhinestreet)
50 feet in Caledonia Quadrangle

The Rhinestreet attains its maximum thickness in the Batavia Quadrangle before it loses its identity. It thickens from 70 feet at the eastern edge to approximately 85 feet.

Many excellent exposures of the formation occur in this area. Only a few will be listed.

1. One and one-half miles north of LaGrange, on northerly flowing stream paralleling and to the east of the LaGrange Road.
2. Two miles northwest of LaGrange, in northerly flowing stream, paralleling and to the west of the Cowic Road.
3. One mile northwest of Wyoming on stream flowing southwest into village. (Good exposures also in streams on west side of Oatka Creek Valley, south of Wyoming.

Lithology—The Rhinestreet is black shale only in part. It can be divided into three portions. The lower portion (measuring 20 feet) is composed of extremely black, bituminous, resistant beds. The middle (45 feet) contains alternating bands of black and gray shale. Above this, the top portion (15 feet) is composed of black fissile shales.

If the formation is treated as a unit, the amount of black shale decreases from the base to the middle beds. Above this, the trend is reversed and black shale deposition increases until it reaches a maximum at the top of the formation.

Not all black shale beds in the Rhinestreet are fissile. Some are calcareous with very weak bedding planes. A few concretionary beds occur in the lighter shales but only one was noted in the black shale and it was found in the upper portion.

The fauna was again reduced in number during this time. Only evidences of plant life were recognized and poorly preserved, unidentifiable specimens were found in the lighter shales. For fossil lists see J. M. Clarke and D. Dana Luther (1904) or G. H. Chadwick (1935).

Hatch Formation

The Hatch formation was the name given by J. M. Clarke (1903) to the flags, gray shales and black shales which overlie the Rhinestreet. The Hatch is overlain by the Grimes sandstone in the southeastern part of the Quadrangle and in its absence, by the Gardeau formation. The Hatch beds had been considered lower Gardeau by Hall but were separated by Clarke and Luther because of the Naples fauna they contained.

The formation extends from Seneca Lake to Attica, New York, with its type section at Hatch Hill near Naples. Eastward its equivalent is the upper beds of the Enfield formation while westward, the increasing black shales make it lithologically like the underlying Rhinestreet so the two are called the Attica shale.

Upper and lower contacts are gradational except where the Grimes occurs. These contacts consist of alternating beds of fine and coarser grained clastics, of dark and light shales. Divisions were made on the basis of the lithology alone and perhaps another worker at the same outcrops would choose a different horizon, perhaps as much as five feet higher or lower. It is necessary to be consistent from one stream outcrop to another. It is also necessary to judge what the dominant sediment was at any particular place in the section.

The formation thins westward from its type locality.

290 feet at Naples
185–190 feet in the Caledonia Quadrangle

In this area it thins from 160 feet to less than 100 feet on the western edge of the sheet. This rather rapid change is caused by thinning and interfingering of the black shales from the west.

Many streams in the Warsaw-Wyoming and Linden-Dale valleys show complete sections. Those listed below are chosen for their accessibility as well as completeness of the section.

1. One and one-half miles northwest of LaGrange on northerly flowing stream, paralleling and to the west of the Cowic Road.
2. One and one-half miles northwest of Wyoming on stream flowing southwest into the village.
3. One mile north of Dale in stream on east side of valley.
4. Two and three-quarter miles north of Attica Center on northwestward flowing stream. Outcrop is east of road bridge.

LITHOLOGY—Sections in the eastern part show four types of sediments. The two most abundant are gray shales and black shales. Thin flags and concretionary beds are found in upper part but represent a small percentage of the column. The formation comprises two distinct units; the lower black and gray shale beds, 90 feet thick, and the upper gray shales interbedded with concretions and flags.

In the western section, however, the upper unit has almost disappeared. Only black and gray shales are found. Black bituminous beds, similar to those of the Rhinestreet, are common. They comprise much more of the section here than they do farther east. But there is sufficient light shale to distinguish the Hatch from the underlying Rhinestreet.

According to Clarke (1904), the fauna is representative of the Cashaqua types but in decreased quantity. No specimens were collected from these beds.

FORMATIONS ABOVE THE NAPLES GROUP

Four formations overlie the Naples Group. No group name is applied to them, although they belong to the Chemung Stage. They had previously been included in the Portage Group but Chadwick (1933) returned the name, Portage, to a formational status.

The following are recognizable units in the Batavia Quadrangle: the Grimes sandstone, Gardeau flags and shales, Nunda sandstone and Wiscoy shale. Contacts are gradational and facies changes are rather rapid so that tracing these units, with the lack of good faunal horizons, is exceedingly difficult.

Flags in the upper Hatch beds represented the beginning of an invasion of coarser clastics into this area from the east. The Grimes sandstone is present in the eastern part of the quadrangle but is lost in the sections west of Wyoming. Coarser clastics occur in the upper part of the Gardeau and the Nunda represents the climax of this type of sedimentation. Wiscoy shales bring a return of the finer clastics and the black shales interfinger from the west. In the Lake Erie sections, the fine grained equivalent of the Grimes and Gardeau is the Angola shale.

GRIMES SANDSTONE

The Grimes was named by Luther (1902) for the sandstones which overlie the Hatch in Grimes Gully near Naples, New York, 35 miles to the east of this area. Hall (1840) had included it first in his Gardeau Group and later (1843) in his Portage or Nunda Group.

The sandstone is a recognizable unit from Seneca Lake to the Warsaw-Wyoming Valley. The westward thinning is demonstrated by the following thicknesses:

75 feet at Seneca Lake
50 feet at Naples
25 feet in the Caledonia Quadrangle

Streams on the southeast side of the Warsaw-Wyoming Valley have rather massive beds of fine grained sandstone which form falls in the gullies. West of here sandstone beds do occur but they are not persistent and may be represented by one or two beds of sandstone in one section, several thin beds in another or none at all in the third. This type of deposition indicates either unstable condition of the bottom with possible vertical movements in small areas, or deltaic deposition of the clastics when poured out from a much closer shoreline into shallow water, or both. In general the thickness decreases from four feet in the east to one or two feet farther west. At exposure No. 2 below, the Grimes is represented by two massive sandstone beds, two feet thick each and separated by a one-half foot shale parting.

The irregular nature of the Grimes is demonstrated by the following exposures:

1. One mile northwest of LaGrange in northward flowing stream, parallel to and west of the Cowic Road.
2. Two miles northeast of Warsaw, in northwesterly flowing stream, paralleling the extension of Burke Hill Road.
3. One mile northeast of Dale in stream flowing into Little Tonawanda Creek just north of the town.

Lithology—The Grimes in this area consists of gray layers of fine grained sandstone from one-tenth to one foot in thickness, some of which are compact, calcareous and argillaceous. Light gray shales separate these beds. The thicker sandstone beds occur as a distinct change in sedimentation, while in other sections where the sandstones are thinner, the contacts are gradational. No fauna was noted in these beds.

Gardeau Formation

Gardeau was used by Hall (1840) as a Group name for the strata in the Mount Morris section along the Genesee River. This included the Rhinestreet, Hatch, Grimes, Gardeau (of Chadwick, 1933) to the Table Rock sandstone. J. M. Clarke (1908) later moved the Gardeau and Portage contact upward about 200 feet placing it above the Grimes sandstone. Chadwick (1933) restricted the term Gardeau and called the overlying beds Table Rock sandstone and Letchworth shale.

Measured sections in this quadrangle showed no division of Clarke's Gardeau possible. No sandstone beds (Table Rock) are present, so if Chadwick's terminology is used, the section might be considered as Angola shale. But this Angola includes the Nunda sandstone (or Chadwick's Portage) so that use of the term Angola would be incorrect. It is necessary to apply the name Gardeau as Clarke had used it.

The Gardeau is composed of shale, and heavy flags. It overlies the Grimes sandstone and is overlain by the Nunda sandstone. The name is from an old Indian reservation in Livingston and Wyoming counties, southeast of this area. Its extent is not well defined. In the Canandaigua Lake area it is known as the West Hill flags and shale. To the west it is correlated with part of the Angola in the Lake Erie section. In general, the thicknesses decrease to the west. The West Hill at Canandaigua Lake measures 550 feet while in the Genesee Valley section it is 428 feet. Measured sections in the Batavia Quadrangle show a decrease from over 300 feet in the central part to 200 feet at the western edge.

Because of the thickness of the formation, few streams have a complete section. But since the overlying Nunda sandstone is more resistant, unusually complete exposures do occur where the Nunda forms the underlying rock of the upland areas. The following sections are most complete.

1. Two miles northeast of Warsaw, in northwesterly flowing stream, paralleling the extension of Burke Hill Road.
2. North of Warsaw in streams on west side of valley.
3. One and one-quarter miles north of Dale in stream on west side of valley.
4. One mile northwest of Attica Center in stream flowing through the village.

LITHOLOGY—Black fissile shales, soft gray shales and flags are characteristic of the Gardeau. The lower portions have black shales, gray shales and very thin flags. This is found in the first 70 to 80 feet. Above this the bituminous beds become very thin, the flags are a little heavier and the formation is more resistant. The uppermost 50 feet is composed of heavier flags, some ranging to four tenths of a foot with almost no black shale seams. The shales are blue-gray to olive brown and probably contain silt size particles of quartz. There are light bluish gray sandstones and flags that weather to brownish or olive brown color. This description applies to the sections in the east-central part of the Quadrangle but is generalized to cover all outcrops. Westernmost outcrops have more black, bituminous shale, fewer flags and are thinner. It is impossible to correlate sections four or five miles apart because of these changes so that it is necessary to follow its outcrop from stream to stream. This is true of the lower contact in the western exposures; the upper contact is rather sharp and easily identified.

NUNDA SANDSTONE

The name was introduced by Clarke and Luther (1908) to replace "Portage sandstones" as defined by Hall. It was named from the exposures at Nunda, New York (12 miles southeast of the area) where 215 feet of blue-gray sandstone beds occur. It is overlain by Wiscoy formation. The formational name Nunda was applied when "Portage" was elevated to a Group status.

Chadwick (1933) changed the name of this formation to Portage and returned the name of Nunda to the group. G. A. Cooper et al. (1942)

in the N. R. C. correlation chart have used Nunda for the sandstones in the Canandaigua Lake area with Portage shale as its equivalent in the Genesee Valley. Chadwick may be correct in applying the term Portage as Hall used it and elevating the name "Nunda" as a group term but the use of both terms for equivalent beds seems unnecessary and confusing. The author, therefore, will use the name, Nunda, for the formation and avoid the term Portage.

The Nunda extends from the Canandaigua Lake area to west of the Batavia Quadrangle. It correlates to the east with the lower portion of the Wellsburg shale and sandstone and to the west with the uppermost part of the Angola shale.

100 feet at Canandaigua Lake
(Highpoint Sandstone)
215 feet in the Nunda area

The formation is over 180 feet thick in the southern part of the Quadrangle and thins to 160 feet in the exposures at Attica Center. The following exposures are most suitable for the study of this formation.

1. Lowermost beds outcrop on top of Burke Hill (northeast of Warsaw). Exposures are found in uppermost reaches of the streams flowing westward into the Warsaw-Wyoming Valley. Best one is in stream two miles northeast of Warsaw where it is crossed by the Burke Hill Road.
2. The Nunda southwest of Wyoming is exposed in a westward flowing stream one and one-half miles southeast of Dale.
3. Exposures occur all along the Linden-Dale Valley especially south of the village.
4. In northwesterly flowing stream, two miles northeast of Attica Center.
5. In northwesterly flowing stream through Attica, just west of the village.

LITHOLOGY—Three gradational zones may be observed in the Nunda. The lower consists of thick flags, calcareous sandstone beds (over one foot) and gray shale. Thin beds of black, bituminous shale do occur but in minor amounts. Most important is the calcareous nature of the sandstones. The worm burrow *Scolithus verticalus* is exceedingly abundant and appears in the sandstone beds only. This lower part of the formation measures about 50 feet.

The middle zone shows a marked decrease in the amount of sandstone. It is composed of beds one to two feet thick but separated by as much as five feet of gray shale. No bituminous beds are present and all the sandstones are non-calcareous. *Scolithus verticalus* occurs here also. The middle zone usually measures about 60 feet.

The uppermost zone has thinner sandstone beds with the sandstone and shale in about equal proportions. The beds become thicker toward the top until they attain a thickness of over two feet. Both shale and sandstone are non-calcareous as in the middle zone and total over 60 feet. The beds are rather barren of fossils except for the worm burrow but no attempt was made to collect fossils.

Wiscoy Shale

The Wiscoy shale and sandstone overlies the Nunda in this area and was named by Clarke (1899) for the exposures at the falls in Wiscoy Creek of Alleghany County (20 miles south of this area). The Prattsburg sandstone is its equivalent to the east while westward it is divisible into the Pipe Creek black shales (below) and the Hanover shales (above).

Recognizable west of Canadaigua Lake, the Wiscoy extends into the Lake Erie area where further division is possible.

225 feet in Naples region
(Prattsburg sandstone)
170–190 feet in Wyoming and Erie Counties

In the Batavia Quadrangle the Wiscoy is approximately 200 feet thick. Only the lowermost part of the formation is completely exposed in this area, although the entire formation is present. Upper beds are displayed in small scattered outcrops so that correlation between them is impossible and the lithology is only generally known. Two of the best exposures are:

1. Two miles southwest of Dale in upper reaches of northeasterly flowing stream, that is west of school No. 15 and northeast of school No. 7.
2. Two miles northeast of Attica Center, in northwestward flowing stream where road crosses stream (basal beds only).

Lithology—The intermittent outcrops show great variation in lithology for the Wiscoy. The lowermost beds are composed of gray shales with some black bands, which extend for 70 feet in the section. Above this over 70 feet of black bituminous shales, interbedded with calcareous shales and limestones occur. In this zone, dark bluish gray shale is interbedded with argillaceous limestones with the limestone increasing in percentage until beds over one foot thick are formed. Little is known of the overlying strata contained in the Wiscoy but occasional outcrops indicate some sandstone beds, flags and gray to black shales.

Nodules of marcasite are found in the black bituminous beds. Some of these range up to two inches in length and one inch in diameter.

CANADAWAY GROUP

This is the name applied by G. H. Chadwick (1933) to the strata overlying the formations of the Chemung Stage. The Canadaway includes all the strata from the Dunkirk black shale to the Cuba sandstone. It had been previously called "Chemung" by earlier writers when "Chemung" was thought to overlie Hall's "Portage" in the Genesee Valley. Chadwick (1935) proved that the Portage and Chemung were of the same age and the "Chemung" in this area was younger than the Chemung farther east. Thus he applied the name Canadaway for the group and the faunal assemblage was termed the "Canadaway fauna". The Dunkirk is the youngest formation present in this area.

Dunkirk Shale

J. M. Clarke (1903) designated the black shales above the West Hill as the Dunkirk. Above this is the Portland gray shale, part of which was placed in the Dunkirk by Chadwick (1924).

The formation receives its name from the exposures at Dunkirk, on the shore of Lake Erie, 56 miles southwest of the area. It outcrops from Lake Erie to Mansfield County, Pennsylvania, where the facies interfingers with the Mansfield beds which are continental.

Little is known of the thicknesses of the Dunkirk shale. At Holland, New York, 14 miles southwest of the Batavia Quadrangle, it measures over 160 feet. Its thickness in this Quadrangle probably is well over 200 feet because of the eastward thickening of sandstones in this part of the section. Both the lower and upper contacts of the formation are estimated. It is possible that still younger strata occur on top of the Dunkirk but no proof exists, hence the strata will be treated as Dunkirk entirely.

Only two small outcrops occur in the southwestern corner of this area. They are:

1. Eastward flowing stream, one and one-half miles northeast of Orangeville Center. Outcrop is west of Crook Road.
2. Two miles northeast of Orangeville Center where northeasterly flowing stream crosses Buffalo Road. Outcrop is just south of road.

Lithology—Dark gray shale is most abundant with black bituminous shale beds in the lower part. This is characteristic of the lowermost 50 feet exposed but approximately 60 feet is believed to be covered below this. Twenty-five feet of lighter gray shales with thin flags are found above the dark gray shales. These beds are similar in appearance to the Cashaqua. At the top is 10 feet of sandstone beds, each over five-tenths of a foot thick, interbedded with light and dark gray shales. These sandstone beds may be the equivalent of Clarke's Portland. No fossils were found. The highest point in the area is still 60 feet above this but no rock exposures could be found.

STRUCTURE

Introduction

The rock formations in western New York have a general dip to the south. The oldest formations outcrop to the north and lie on the Pre-Cambrian Canadian shield. Successively younger formations appear to the south. This southerly dip is approximately 30 feet per mile. Minor undulations are known to occur which cause substantial deviations. The regional dip increases to 60 feet in the southern part of the State where the undulations are more evident.

In the Batavia Quadrangle, one set of undulations has a northeast trend while another trends almost east-west. They are so gentle that they are discovered only by careful observation.

A flexure is known to exist in the west-central part of the quadrangle, (Chadwick, 1920). Its importance lies in its effect on the regional stratigraphic correlations and its distance from other comparable structures. The flexure dips to the west and strikes just east of north. This is believed to be of a different origin from the regional features discussed above. Structures of a local nature consist of well-developed joint systems and broken anticlines. Both seem to have a regional trend and will be discussed in more detail on succeeding pages.

The Batavia Quadrangle is situated north and west of the folded Appalachian belt. It is also east of the anticlinal structures in Ohio. Structures in the Batavia area will have to be correlated with or differentiated from both of these regions. The possibility of origins in the Pre-Cambrian basement must not be overlooked.

STRUCTURES IN OHIO

According to Ver Steeg (1944) the major structural features of Ohio are the Cincinnati arch, the Parkersburgh-Lorain syncline, the Cambridge arch, and a few other related folds in the eastern portion of the state. The alignment is north-south. The faults in Ohio have little throw, and strike a few degrees east or west of north. They are chiefly normal and related to the major warping.

More than two-thirds of the minor folds described by Ver Steeg fall in the quadrant N 0°–90° W. They show a shift in direction from almost north-south in northeastern Ohio to east-west in the southern portion of the state. A corresponding change is noted in the orientation of jointing in the coal beds and, in general, the joint sets are not parallel to the axes of the folds. The importance of the orientation of the joints with respect to the folds will be demonstrated on the following pages.

The Cincinnati arch, Parkersburgh-Lorain syncline and Cambridge arch have a trend about N 10° W. East of the Cambridge arch (which is in the vicinity of Akron and Cleveland) the normal east dip of the formations is broken by minor flexures which trend generally northwest. In southeastern Ohio the two trends are nearly at right angles to each other. The major structures are not parallel with the Appalachian folds nor are they in line with those of the Michigan Basin.

Most of the joints are vertical or nearly so and give no definite clue to the forces which produced them because it is difficult to distinguish them as tension or shear joints. About the joints, Ver Steeg (1944 p. 137) says:

> "Whether a particular set of joints was formed by tension or shear is none too clear. All we can be sure of is that these joint systems were caused by regional stresses in brittle rocks under conditions in which lateral relief was easier than upward relief. Sets of nearly vertical joints may be formed by tensile stresses in gently folded sediments, showing a close relation to the folds. One set—the strike joints—parallels the general strike of the folds, and the other—the dip set—follows the direction of dip. . . It is probable that many joints in Ohio are of the tension type. On the other hand, observations in the field show that a great number of well-developed joint faces are not ragged and irregular, like those one might expect in tension fractures, but cut across lithologic irregularities with smooth planes, such as are produced by shearing stresses."

With few exceptions, the faults in Ohio are not of great throw and they cannot be traced any great distance. The Bowling Green-Findlay fault, which has a length of 12 miles and an estimated throw of 200 feet, is most important. The faults have a general trend, approximately north-south, but ranging somewhat east or west of north.

Ver Steeg considered the Ohio structure to be a westward extension of foreland structures in western New York and Pennsylvania.

STRUCTURE IN NORTHWESTERN PENNSYLVANIA AND CENTRAL NEW YORK

A broad southward plunging synclinal trough is present in central New York. The regional dip, according to Wedel (1932), instead of being due south is southeast, west of the Dansville meridian. East of Seneca Lake the dip to the south has a small westward component. Between Dansville and Seneca Lake the dip is to the south.

In south-central New York, according to Wedel, a series of low parallel

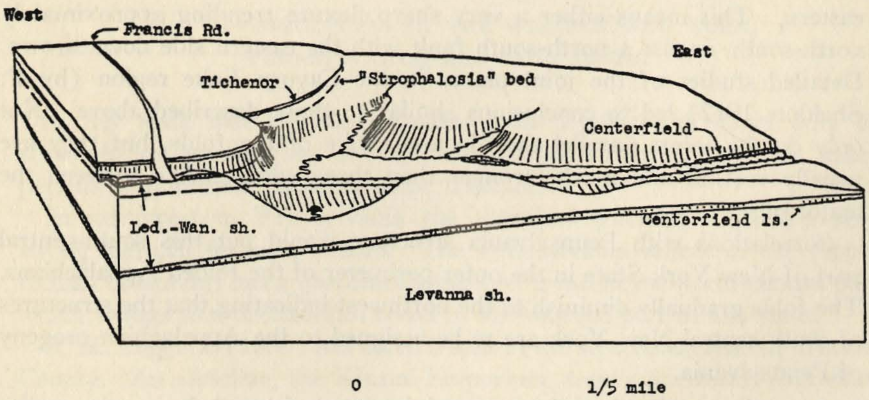


Fig. 9—SECTION THREE MILES WEST OF EAST BETHANY

but persistent folds are found. These dip from 0° to 10° and are usually small. The folds south of the Pennsylvania line trend about N 80° W in the eastern portion but swing to N 60° E in the west.

The dip on the south flank of the anticlines is usually much more pronounced than those on the north flank. The net effect is the increase of regional dip above average for the area. The folds in this area seem to be correlated with and a northward continuation of the structures in north-central Pennsylvania.

The direction of jointing in the area falls into two main groups or sets, the strike joints and the dip joints. Apparently these two sets are conjugate and form a system. Tabulation of percentages of joints in the area indicates that the strike of the joints also changes from east to west. For instance, the direction of the dip joints changes from due north in the eastern part of the area to about N 45° W in the western. The strike joints change from N 80° W to about N 55–60° E. This progressive variation in the strike of joints corresponds almost exactly with a similar change in the trend of the axes of the folds.

In a more recent study of regional jointing in the Paleozoic strata of east, central and southern New York, J. M. Parker (1942) has found that the major joint systems do change in trend from east to west. There is, however, a lack of consistent relationship of the joints to other structures.

Parker—(1942 p. 382) says:

> ". . . the tracing of a dip set across the area into the strike position, indicates that the joints formed independently of, and earlier than, the folds, faults and regional dip."

There are some indications of possible major faulting. Throws of 100 feet are indicated by some stratigraphic correlations, but sharp flexures may also account for this. According to Wedel, one such structure may exist between Seneca Mills and Cascade Mills one mile to the east. Here the western side has Tully limestone 100 feet higher than that on the eastern. This means either a very sharp flexure trending approximately north-south, or else a north-south fault with the eastern side downthrown. Detailed studies of the joint planes in the Cayuga Lake region (by P. Sheldon, 1912) led to conclusions similar to those described above. Not only do the joints parallel the dip and strike of the folds, but they are usually vertical and much stronger than those which strike between the major sets.

Correlations with Pennsylvania structure would put this south-central part of New York State in the outer perimeter of the folded Appalachians. The folds gradually diminish to the northwest indicating that the structures of south-central New York are to be assigned to the Appalachian orogeny of Pennsylvania.

According to Sheldon, the master joints were formed during the earlier part of the folding which took place here during the Appalachian revolution.

The joints are younger than the faults which were formed during the same orogeny, since the faults displace some joints.

Working in Steuben and Yates Counties, (western portion of the area covered by Sheldon and Wedel), Bradley and Pepper (1938) found the gentle folds swinging to a northeast-southwest trend. Again the measurements of the joint directions clearly indicate the pattern established by the earlier workers.

Bradley and Pepper date the faulting in the area as occurring when the Gowanda and overlying shales were being deposited. This is concluded because of the penecontemporaneous deformation in the formation.

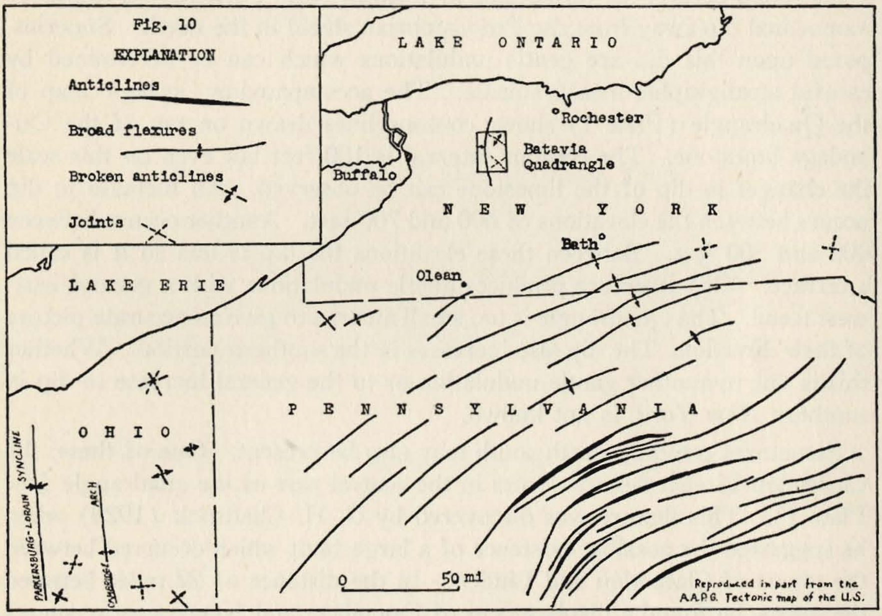


Fig. 10—STRUCTURES IN THE WESTERN NEW YORK, PENNSYLVANIA, AND OHIO REGION

Yet they state that faulting increases with depth which could only be accomplished by faulting during deposition followed by one or many periods of movement along the same fracture.

In northwestern Pennsylvania the anticlinal-synclinal folds are very strong and can be easily traced. The Pennsylvania salient of the Appalachian mountains has a northeast-southwest trend in the north-central part which swings to a north-south trend in the western part of the state.

R. M. Leggette (1936) has noted a split in the structural trend in Warren County. An anticline, the Kinsua-Emporium, trends northwest-southeast. This and parallel structures may swing toward Lake Erie and eventually parallel those of northeastern Ohio. Warren County is perhaps a key area, structurally speaking, where both Appalachian structures and structures of the stable platform type, such as those in Ohio, are found.

In McKean County, just to the east of Warren, definite anticlinal and synclinal trends are found. Such structures as the Bradford and Simpson anticlines indicate a close relationship with the Appalachian structures farther east. Therefore, it seems likely that structure in northwestern Pennsylvania and western New York may be related to the Ohio structure, to the Appalachian structure of Pennsylvania, or be a resultant of these two.

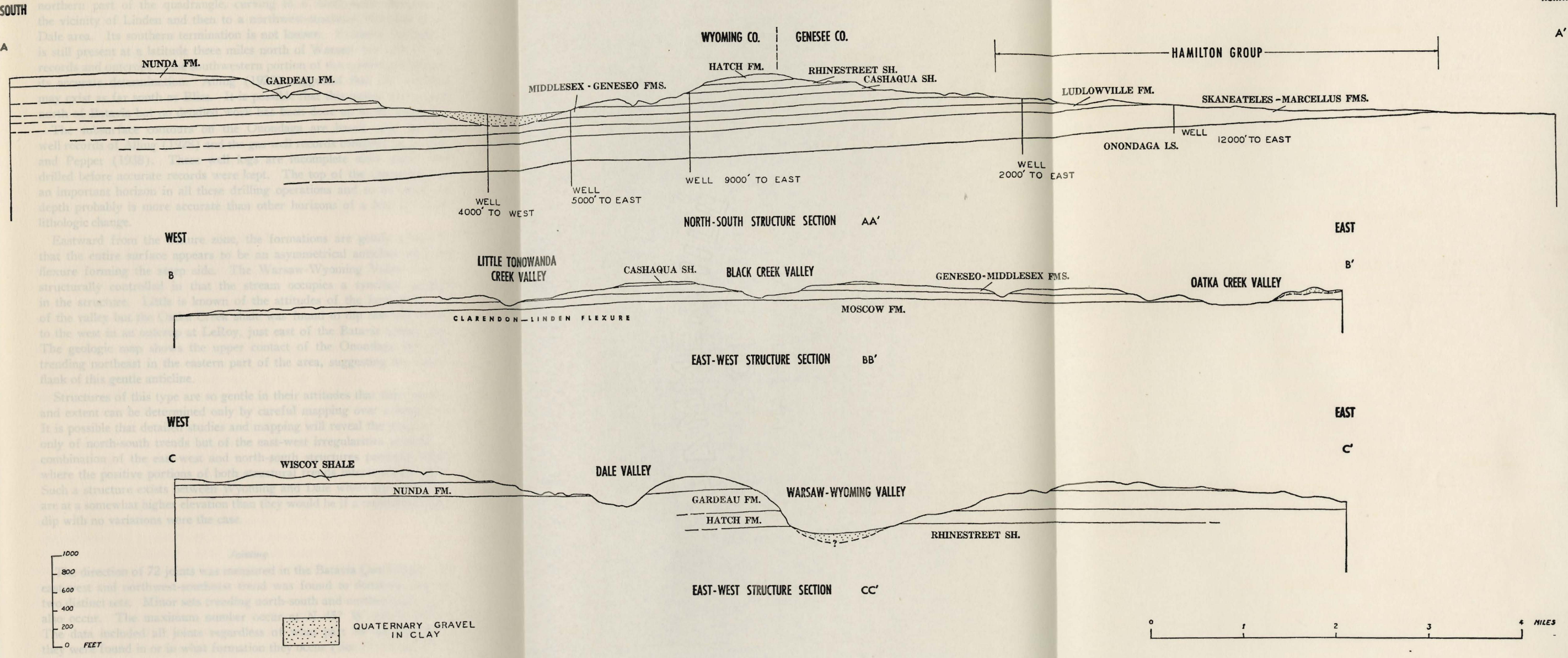
Major Structures of the Batavia Quadrangle

As stated before, the formations in western New York have a southerly monoclinal dip away from the Pre-Cambrian shield in the north. Superimposed upon this dip are gentle undulations which can be determined by careful stratigraphic measurements. The accompanying Geologic map of the Quadrangle (Plate I) shows contour lines drawn on top of the Onondaga limestone. The contour interval is 100 feet but even on this scale the changes in dip of the limestone can be observed. An increase in dip occurs between the elevations of 600 and 700 feet. Another occurs between 400 and 500 feet. Between these elevations the dip is less so it is called a terrace. This structure produces gentle undulations with a general east-west trend. The Quadrangle is too small an area to give an accurate picture of their direction. The dip also increases in the southern portions. Whether this is due to another gentle undulation or to the general increase in dip in southern New York, is not known.

Structures trending north-south may also be present. One of these, the Clarendon-Linden flexure occurs in the central part of the quadrangle (see Plate I). This flexure was discovered by G. H. Chadwick (1920) when he suggested the possible existence of a large fault which occurred between the towns of Clarendon and Linden. In the distance of 22 miles between the towns, he found a displacement of Onondaga and Niagara escarpments with the western side farther north. In the vicinity of Linden the formations to the west were at a much lower elevation than had previously been supposed. This led to the supposition of a fault in the area with the downthrown side on the west. Re-examination of the problem led Chadwick, (1932) to modify his previous statement by calling the southern portion, the Linden monocline and regarding the northern part as the Clarendon fault; the whole structure constituting the Clarendon-Linden displacement.

Careful study of the outcrops in the quadrangle supplemented by the subsurface stratigraphy indicates the existence of the flexure but with no apparent fracture. The formations dip to the west up to three degrees (Plate III Fig. 3) with a stratigraphic displacement of over 100 feet in the Linden area. This dip fully accounts for the position of formations in every case. Furthermore, the Nunda sandstone may be traced from

PLATE II


SOUTH
A
NORTH
A'
WYOMING CO.
GENESEE CO.
HAMILTON GROUP
NUNDA FM.
GARDEAU FM.
HATCH FM.
RHINESTREET SH.
CASHAQUA SH.
MIDDLESEX - GENESEO FMS.
LUDLOWVILLE FM.
SKANEATELES - MARCELLUS FMS.
WELL
12000' TO EAST
ONONDAGA LS.
WELL
2000' TO EAST
WELL 9000' TO EAST
WELL
5000' TO EAST
WELL
4000' TO WEST
NORTH-SOUTH STRUCTURE SECTION AA'
WEST
B
EAST
B'
LITTLE TONOWANDA
CREEK VALLEY
CASHAQUA SH.
BLACK CREEK VALLEY
GENESEO-MIDDLESEX FMS.
OATKA CREEK VALLEY
CLARENDON—LINDEN FLEXURE
MOSCOW FM.
EAST-WEST STRUCTURE SECTION BB'
WEST
C
EAST
C'
WISCOY SHALE
NUNDA FM.
DALE VALLEY
GARDEAU FM.
HATCH FM.
WARSAW-WYOMING VALLEY
RHINESTREET SH.
EAST-WEST STRUCTURE SECTION CC'
1000
800
600
400
200
0 FEET
QUATERNARY GRAVEL
IN CLAY
0
1
2
3
4 MILES

Warsaw northwest across the structure to a point north of Dale with no evidence of a break whatsoever. The flexure trends N 10° E in the northern part of the quadrangle, curving to a north-south direction in the vicinity of Linden and then to a northwest-southeast direction in the Dale area. Its southern termination is not known. Evidence indicates it is still present at a latitude three miles north of Warsaw but lack of well records and outcrops in the southwestern portion of the quadrangle prevent its accurate determination. Alling (1928) suggested that the structure may exist as far south as Bliss. It is possible that this passes into a fault north of Batavia but no detailed work has been done up to the present.

The subsurface contours on the Onondaga are based upon the salt well records of Alling (1928) and the gas well records compiled by Bradley and Pepper (1938). These well logs are incomplete since many were drilled before accurate records were kept. The top of the Onondaga was an important horizon in all these drilling operations and so its record of depth probably is more accurate than other horizons of a less noticeable lithologic change.

Eastward from the flexure zone, the formations are gently arched so that the entire surface appears to be an asymmetrical anticline with the flexure forming the steep side. The Warsaw-Wyoming Valley may be structurally controlled in that the stream occupies a synclinal position in the structure. Little is known of the attitudes of the formations east of the valley but the Oatka Creek shale was found to dip one-half degree to the west in an outcrop at LeRoy, just east of the Batavia Quadrangle. The geologic map shows the upper contact of the Onondaga limestone trending northeast in the eastern part of the area, suggesting the eastern flank of this gentle anticline.

Structures of this type are so gentle in their attitudes that their position and extent can be determined only by careful mapping over a large area. It is possible that detailed studies and mapping will reveal the position not only of north-south trends but of the east-west irregularities as well. A combination of the east-west and north-south structures produces domes where the positive portions of both structural trends intersect each other. Such a structure exists between Wyoming and Dale where the formations are at a somewhat higher elevation than they would be if a normal southerly dip with no variations were the case.

Jointing

The direction of 72 joints was measured in the Batavia Quadrangle. An east-west and northwest-southeast trend was found to dominate forming two distinct sets. Minor sets trending north-south and northeast-southwest also occur. The maximum number occur at N 45° W and N 75° E. The data included all joints regardless of what part of the quadrangle they were found in or in what formation they occur (See Pl. IV fig. 5).

The jointing is much more apparent in the black shales than in any other type of sediment. All fractures are clean breaks with no evidence of distinction between shear and tension in their origin. The joint faces are almost all vertical with a few showing hades up to three or four degrees. These were in the area of the Clarendon-Linden flexure.

An apparent structural relationship exists between the jointing and the structures mentioned previously. In areas where the structure is known to exist, the jointing, in many places, parallels the structure. South of Dale, the trend of the jointing changes as does the valley itself and the Clarendon-Linden flexure. Larger valleys seem to be controlled by the major structures, while small streams may have a course which follows one or more sets of joints. This control is also more apparent where streams are cutting rapidly into bedrock where a major stream, like Oatka Creek and Little Tonawanda Creek has a deep valley with small streams flowing into it with a steep gradient. The streams flowing into Oatka Creek south of Wyoming, clearly show the control of drainage by the jointing.

Broken Anticlines

The broken anticlines are a minor structural feature found in central and western New York. In this quadrangle they are exposed in streams cutting Upper Devonian strata. While the outcrops showing these folds are not large, their size does not seem to be over a mile in length or over 100 yards wide. The term, broken anticlines, has been applied to the structures because the beds dip away from an axial plane and are usually fractured at the crest (see Plate IV Figs. 6 and 7). Small streams may have their course controlled by this structure so that the stream flows parallel to or on top of the crest. In other cases, however, the stream direction may be at right angles to the axis of the fold. These anticlines are known to exist over a wide area in New York State and are found in formations of Silurian and Devonian age.

The axes of the anticlines have a definite trend in the Batavia Quadrangle. Twenty-four were discovered and two-thirds of these have a northwest trend. The rest have scattered trends with no apparent minor direction. The northwesterly trending anticlines fall into two groups; those which trend about N 45° W and those which strike N 65° W. It must be noted that one of the major joint directions is N 45° W. The relationship of the joints to the anticlines is not, however, well understood.

Just what forces produced these structures and when this occurred is not known. It is possible that they have their origin in movements resulting from solution of salt in the Silurian rocks beneath. It is difficult to correlate this theory with the obvious structural trend which exists in this area. This trend suggests that more widespread forces produced the structures than mere removal of salt lenses from the strata below.

The structures certainly were not formed by a release of the rock load by stream erosion. If this were the case, the axis of the anticline would parallel the stream course and in many instances that stream is at right angles to the anticline and the broken beds can be seen to disappear into the bed rock of the stream bank.

The author believes that no definite conclusions can be drawn from the meager evidence at hand but that most of the evidence indicates an origin connected with possible faults in the Pre-Cambrian basement rocks. Movement along hypothetical faults in the basement rocks may not be entirely vertical. Instead a horizontal component might produce stresses which would form those broken anticlines. The following evidence is used to support this theory:

1. The direction of trend suggests a plane of tension at an angle of 45° to the Clarendon-Linden flexure.

2. Drilling on these structures indicates that the anticline becomes a fault in depth. Continued movements along faults in the basement rock could best explain this phenomenon.

3. Since a portion of the northwesterly trending anticlines coincide in direction with a major joint set, it is possible that this joint direction served as a plane of weakness along which the beds moved to release stresses.

SUMMARY

A survey of the structures in the Batavia Quadrangle, or more generally in western New York, indicates a closer relationship with the Ohio area than with central New York and Pennsylvania. At first, it might appear that the structural changes might be of a gradational character between these two extremes. Closer inspection, however, reveals basic differences between the structures in the Batavia area and those present in central New York.

Let us, first of all, examine the joint systems in Ohio, Pennsylvania, central New York and the Batavia area. While the joint sets may be parallel to regional folds in some places, in other areas they are not. Ver Steeg pointed this out in Ohio and Parker found this to be true in southern New York. Sheldon suggests that the jointing is earlier than the faults in central New York. We can then assume that a joint pattern existed before the time of the Appalachian orogeny. It is difficult to understand why such a joint system would not be present during the later Paleozoic Periods since many minor disturbances undoubtedly did affect the sediments in a minor way. The broken anticlines also suggest that a joint pattern existed and that stresses in some instances were relieved by buckling along a major joint direction.

The major structures have a north-south alignment in Ohio, and east-west trend in central New York. The Clarendon-Linden flexure trends just east of north in the Batavia area. It may be due to movements in the

Pre-Cambrian basement rock and is strikingly similar to the Bowling Green-Findlay fault, both in trend and probable amount of throw.

Minor folds in Ohio trend northwest as do the broken anticlines in the Batavia area. In both cases, they are not parallel to the major structure.

The structures in the Batavia Quadrangle seem to be the result of vertical movement. If faulting is present in depth in the Clarendon-Linden flexure, the more resistant formations, such as the Onondaga limestone or the Lockport dolomite (Silurian in age) may have fractured. Then the less competent beds were not broken but distorted to form the flexure as observed in the Batavia area.

It is possible that minor basins and domes existed in western New York during the Silurian and Devonian time. The stratigraphic correlation problems of many formations and members within a short geographic distance, such as that between Seneca and Canandaigua Lakes, represents something more than a coincidence. Possible movements occurred during sedimentation and continued the structural trends already existing. The relations of these interdependent factors is not fully understood but it is firmly believed that detailed studies of sedimentation and structures may shed new light on existing stratigraphic and paleontological problems.

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THE PLANKTON ALGAE OF THE SOUTHEAST END OF CHAUTAUQUA LAKE

By

BERNICE McKEAN GIEBNER

"JAMESTOWN COMMUNITY COLLEGE fills a need long felt by the citizens of Jamestown. Milton J. Fletcher in 1927 and 1932 was alert to the importance of a Junior College serving the Jamestown area, and so recommended in his Reports as Superintendent of Public Schools. In 1933 the Y.W.C.A., through its President, Secretary, and Chairman of the Committee, George B. Pitts, Jr., and others developed plans for the City College which opened in January, 1934. During 1934 it became possible to offer courses for college credit, and the Jamestown College Center was established under the sponsorship of Alfred University, with the cooperation of the Federal Emergency Relief Administration.

When federal funds were withdrawn in 1937, the College Center was reorganized under the joint sponsorship of Alfred University, the Citizens' Committee, and the Jamestown Board of Education. Early in 1950, the State University of New York and the City Council of Jamestown jointly established Jamestown Community College, incorporating the former Alfred University Extension as the Liberal Arts Division and adding a Technical Program.

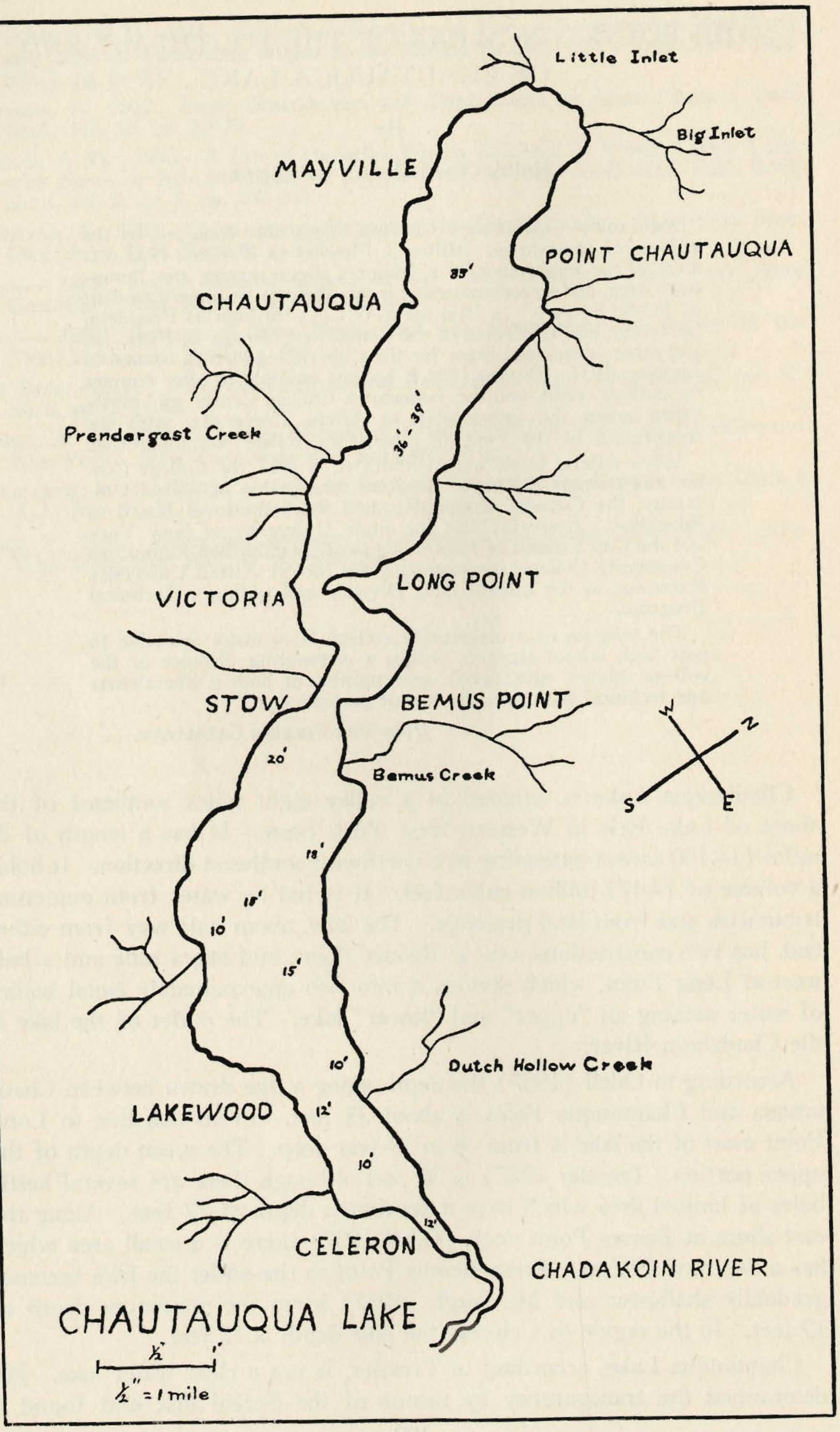
The purpose of a community college is to make available to post high school students within a commuting distance of the college, higher educational opportunities of both a liberal arts and technical nature at the lowest possible cost."

from THE COLLEGE CATALOGUE.

Chautauqua Lake is situated in a valley eight miles southeast of the shore of Lake Erie in Western New York State. It has a length of 21 miles (14,160 acres) extending in a northwest southeast direction. It holds a volume of 14,472 million cubic feet. It is fed by water from numerous tributaries and from land drainage. The lake, about half way from either end, has two constrictions, one at Bemus Point, and one a mile and a half west at Long Point, which divides it into two approximately equal bodies of water making an "upper" and "lower" lake. The outlet of the lake is the Chadakoin River.

According to Odell (1937) the depth along a line drawn between Chautauqua and Chautauqua Point is about 35 feet. From this line to Long Point most of the lake is from 36 to 39 feet deep. The mean depth of the upper portion (Tressler 1937) is 30 feet although there are several kettle holes of limited area which have a maximum depth of 77 feet. Along the east shore at Bemus Point dock (Odell 1937) there is a small area which has a depth of 29 feet. From Bemus Point to the outlet the lake becomes gradually shallower and McVaugh (1937) gives the maximum depth as 19 feet. In the region of Celoron, the lake depth is 12 feet.

Chautauqua Lake, according to Tressler, is not a clear water lake. He determined the transparency by means of the Secchi disc and found a


Little Inlet
Big Inlet
MAYVILLE
POINT CHAUTAUQUA
35'
CHAUTAUQUA
Prendergast Creek
36'-39'
LONG POINT
VICTORIA
STOW
BEMUS POINT
W
N
S
E
20'
Bemus Creek
18'
15'
10'
15'
10'
Dutch Hollow Creek
LAKEWOOD
12'
10'
12'
CELERON
CHADAKOIN RIVER
CHAUTAUQUA LAKE
½
1
½" = 1 mile

marked correlation between transparency and the amount of organic matter present. He states that the transparency gradually increased until July 20, 1937, when it then reached a maximum of 3.5 meters. On this date the least amount of organic matter was recorded. The lowest transparency occurred on August 24, 1937, when the organic matter was highest and the highest transparency was in December 1936, when the organic matter was lowest. In every month except May 1937, the transparency decreased as the organic matter increased.

The water of Chautauqua Lake is of medium hardness. During the winter (1936–1937) Tressler found that the water at all depths gave an alkaline pH reaction with the methyl orange alkalinity test. He found that a decrease in alkalinity began in January 1937 and continued until summer, when a slight rise occurred and that during the summer the water to a depth of three meters below the surface gave a decided alkaline pH reaction. The surface pH of 7.3 rose during that summer to a maximum of pH 8.8 in late August and then declined in September. Tressler states that at the beginning and end of summer the water to a depth of eight meters was alkaline, but that during mid-summer the water at the same depth was neutral or only slightly alkaline. His data show that the surface water was nearly always less alkaline than the bottom water and that during June and July the bottom water was slightly acid (pH 6.8) and then became somewhat alkaline in August.

According to McVaugh (1937), the bottom of the "Lower Lake" is muddy or sandy and the shore sandy or gravelly with a few marshy areas. He states that the most extensive weed beds occur in the lower east portion of the lake. The predominant plants are *Elodea canadensis, Potamogeton Robbinsii, Potamogeton amplifolius, Potamogeton Richardsonii, Myrophylium exalbesscens, Vallisneria americana,* and *Najas flexis.* I, also, have checked these plants.

The figures in Table I show the period of ice coverage during the years 1944–1949.

TABLE I

Year	Months	Open Period	Total Days
1944–1945	Nov. 23 to Mar. 22	....	121
1945–1946	Nov. 25 to Mar. 16	....	113
1946–1947	Nov. 27 to Mar. 27	....	121
1947–1948	Dec. 4 to Mar. 17	....	105
1948–1949	Dec. 26 to Mar. 26	Feb. 27	85

The average period of ice coverage during the years 1944–1949 was 109 days. There was a short open period in 1949 around February 27. This is in general agreement with Tressler who states that the period of ice coverage in 1936–1937 was 112 days extending from December 1, to April 15, with an open period from January 1–22.

The writer selected the region from the outlet of the lake to a mile beyond the Celoron dock for collecting samples of plankton algae. A few samples were taken near Lakewood, New York. The water here is shallow and this is the reason for choosing this area; and the plankton algae are particularly abundant. Collections were made by towing a #20 bolting silk net from a boat during summer, and by collecting from the shore during early spring and late fall. Whenever possible the collections were examined in the living condition. When this was not feasible, the collections were preserved in Transeau's solution: 6 parts water, 3 parts of 95% alcohol, and 1 part formalin.

The present report is a survey of the genera and species and seasonal variation of some plankton algae in the lower portion of Chautauqua Lake as represented at Celoron. This report deals with the Myxophyceae, Heterophyceae, Chrysophyceae and the unicellular and colonial Chlorophyceae, omitting the consideration of such filamentous Chlorophyceae as Zygnemataceae and Oedogonaceae which can be identified only in the fruiting condition. Only the most numerous forms of the Bacillarieae are recorded. Previous knowledge of the algae of Chautauqua Lake was based on the limnological studies made by Tressler and Bere (1936–1937) and by Tressler, Wagner and Bere (1940). These reports are mainly concerned with listing algal genera and give brief accounts of seasonal variations.

The figures in Table II show the distribution by classes of the various genera and species reported for the lower portion of Chautauqua Lake. Although many of the algae have previously been reported, several genera and species are new records for Chautauqua Lake. These are indicated by an asterisk.

TABLE II

Classes	Genera	Species
Myxophyceae	19	61
Heterophyceae	1	3
Chrysophyceae	4	6
Chlorophyceae	41	121
Total	65	191

MYXOPHYCEAE

Anabaena catenula (Kuetzing) Bornet and Flahault
Anabaena circinalis (Kuetzing) Rabenhorst
Anabaena flos-aquae (Lyngbye) Brebisson
Anabaena lemmermanni P. Richter
Anabaena microspora Klebahn var. **robusta** Lemmermann
Anabaena planctonica Brunnthaler
Anabaena spiroides Klebahn
Anabaena spiroides Klebahn var. **crassa** Lemmermann
Aphanizomenon flos-aquae (Lemmermann) Ralfs

Aphanocapsa elachista W. & G. S. West
Aphanocapsa elachista var. **conferta** W. & G. S. West
Aphanocapsa elachista var. **planctonica** G. M. Smith
Aphanocapsa grevillei (Hassall) Rabenhorst
Aphanocapsa rivularis (Carmichael) Rabenhorst
Aphanothece clathrata W. & G. S. West
Aphanothece prasina A. Braun
Aphanothece saxicola Naegeli
*__Calothrix Castellii__ –(Massalongo) Bornet & Flahault
Chroococcus dispersus (V. Keissler) Lemmermann
Chroococcus dispersus var. **minor** (Kuetzing) Naegeli
Chroococcus limneticus Lemmermann
Chroococcus limneticus var. **distans** G. M. Smith
Chroococcus limneticus var. **elegans** G. M. Smith
Chroococcus limneticus var. **purpureus** Snow
Chroococcus minutes (Kuetzing) Naegeli
Chroococcus turgidus (Kuetzing) Naegeli
Coelosphaerium dubium Grunow
Coelosphaerium kuetzingianum Naegeli
Coelosphaerium naegelianum Unger
Dactylococcopsis antarctica Fritsch
Dactylococcopsis rhaphidioides Hansgirg
Dactylococcopsis smithii R. & F. Chodat
*__Gloeocapsa magma__ (Brebisson) Rabenhorst
*__Gloeothece rupestris__ (Lyngbye) Bornet
Gloeotrichia echinulata (J. E. Smith) P. Richter
Gloeotrichia natans (Hedwig) Rabenhorst
*__Gomphosphaeria aponina__ Kuetzing
*__Gomphosphaeria lacustris__ Chodat
*__Holopedium geminatum__ Lagerheim
*__Holopedium irregulare__ Lagerheim
Merismopedia convoluta Brebisson
Merismopedia elegans A. Braun
Merismopedia glaucum (Ehrenberg) Naegeli
Merismopedia punctata Meyen
Merismopedia teniussima Lemmermann
Microcystis aeruginosa Kuetzing
Microcystis aeruginosa var. **major** (Wittrock) G. M. Smith
Microcystis flos-aquae (Wittrock) Kirchner
Microcystis pseudofilamentosa Crow
Microcystis pulverea (Wood) Migula
Microcystis pulverea var. **incerta** (Lemmermann) Crow
*__Nostoc pruniforme__ (Linnaeus) Agardh
Oscillatoria lacustris (Klebahn) Geitler

Oscillatoria limosa Kuetzing
Oscillatoria princeps Vaucher
Oscillatoria splendida Greville
Oscillatoria tenuis C. A. Agardh
***Pleurocapsa fluviatilis** Lagerheim
***Pleurocapsa fuliginosa** Hauck
***Plectonema wollei** Farlow
***Tolypothrix distorta** (Hofman-Bang) Kuetzing
***Tolypothrix tenuis** Kuetzing

HETEROPHYCEAE

Botryococcus braunii Kuetzing
Botryococcus protruberans W. & G. S. West
Botryococcus sudeticus Lemmermann

CHRYSOPHYCEAE

Dinobryon bavaricum Imhof
Dinobryon setularia Ehrenberg
Dinobryon stipitatum Stein
***Rhizochrysis limneticus** G. M. Smith
***Synura uvella** Ehrenberg
***Uroglena volvox** Ehrenberg

CHLOROPHYCEAE

***Apiocystis brauniana** Naegeli
***Characium curvatum** G. M. Smith
***Chlorella vulgaris** Beyerinck
***Closteriopsis longissima** Lemmermann
Closterium acerosum (Schrank) Ehrenberg
Closterium lunula (Mueller) Nitzsch var. **coloratum** Klebahn
Closterium moniliforme (Bory) Ehrenberg
Closterium venus Kuetzing
***Coccomyxa dispar** Schmidle
Coelastrum microporum Naegeli
Coelastrum reticulatum (Dangeard) Senn
Coelastrum sphaericum Naegeli
Cosmarium granatum Brebisson
Cosmarium laeve Rabenhorst
Cosmarium logiense Bissett
Cosmarium protractum (Naegeli) DeBary
Cosmarium rectangulare var. **hexagonum** (Elfving) W. & G. S. West
Cosmarium regnelli Wille
Cosmarium reniforme (Ralfs) Archer
Crucigenia apiculata (Lemmermann) Schmidle

Crucigenia apiculata var. **eriensis** Tiffany & Ahlstrom
Crucigenia fenestra Schmidle
Crucigenia irregularis Wille
Crucigenia lauterbornei Schmidle
Crucigenia retangularis (Naegeli) Gay
Dictyosphaerium ehrenbergianum Naegeli
Dictyosphaerium planctonicum Tiffany & Ahlstrom
Dictyosphaerium pulchellum Wood
*Dimorphococcus lunatus** A. Braun
*Errerella bornhemiensis** Conrad
*Euastrum denticulatum** (Kirchner) Gay
*Eudorina elegans** Ehrenberg
*Eudorina unicocca** G. M. Smith
*Geminella minor** (Naegeli) Heering
Gloeocystis ampla Kuetzing
Gloeocystis gigas (Kuetzing) Lagerheim
Gloeocystis parolinana (Meneghini) Naegeli
Gloeocystis vesiculosa Naegeli
Golenkinea radiata Chodat
*Gonium pectorale** Mueller
*Hydrodictyon reticulatum** (Linnaeus) Lagerheim
Kirchneriella contorta (Schmidle) Bohlin
Kirchneriella lunaris (Kirchner) Moebius
Kirchneriella obesa (W. West) Schmidle
Kirchneriella obesa var. **aperta** (Teiling) Brunnthaler
Kirchneriella obesa var. **major** (Bernard) G. M. Smith
*Micractinium pusillum** Fresenius
*Myrmecia aquatica** G. M. Smith (Little known algae. **The cells had** the appearance of and are reported as being **M. aquatica.**)
Nephrocytium agardhianum Naegeli
Nephrocytium limneticus G. M. Smith
Nephrocytium lunatum W. West
Oocystis borgei Snow
Oocystis crassa Wittrock
Oocystis lacustris Chodat
Oocystis parva W. & G. S. West
Oocystis pusilla Hansgirg
Oocystis submarina Lagerheim
*Pandorina morum** Bory
Pediastrum araneosum Raciborski
Pediastrum araneosum var. **rugulosum** (G. S. West) G. M. Smith
Pediastrum biradiatum Meyen
Pediastrum boryanum (Turpin) Meneghini
Pediastrum boryanum var. **longicorne** Raciborski

Pediastrum duplex var. clathratum (A. Braun) Lagerheim
Pediastrum duplex var. gracilium W. & G. S. West
Pediastrum simplex Meyen
Pediastrum simplex var. duodenarium (Baily) Rabenhorst
Pediastrum tetras (Ehrenberg) Ralfs
Phacus longicauda (Ehrenberg) Dujardin
Phacus pleuronectes (O. F. Mueller) Dujardin
*Pleodorina californica Shaw
Quadrigula closterioides (Bohlin) Printz
Quadrigula lacustris (Chodat) G. M. Smith
Scenedesmus acutiformis Schroeder
Scenedesmus arcuatus Lemmermann
Scenedesmus arcuatus var. platydisca G. M. Smith
Scenedesmus denticulatus Lagerheim
S. bijuga (Turpin) Lagerheim
Scenedesmus bijuga var. alternans (Reinsch) Borge
Scenedesmus denticulatus. Lagerheim
Scenedesmus dimorphus obliquus (Turpin) Kuetzing
Scenedesmus longus var. naegeli Brebisson
Scenedesmus opoliensis P. Richter
Scenedesmus quadricauda (Turpin) Brebisson
Scenedesmus quadricauda var. longispina (Chodat) G. M. Smith
Scenedesmus quadricauda var. maximus W. & G. S. West
Scenedesmus quadricauda var. parvus W. & G. S. West
Schroederia ancora G. M. Smith
Schroederia setigera (Schroeder) Lemmermann
Sphaerocystis schroeteri Chodat
Spondylosium ellipticum W. & G. S. West
Spondylosium monilforme Lund
Spondylosium planum (Wolle) W. & G. S. West
Spondylosium pygmaeum (Cooke) W. West
Staurastrum apiculatum Brebisson
Staurastrum brevispinum Brebisson
Staurastrum chaetoceras (Schroeder) G. M. Smith
Staurastrum cuspidatum Brebisson
Staurastrum curvatum var. elongatum G. M. Smith
Staurastrum dejectum Brebisson
Staurastrum dubium West
Staurastrum floriferum W. & G. S. West
Staurastrum gracile Ralfs
Staurastrum grallatorium Nordstedt
Staurastrum longiradiatum W. & G. S. West
Staurastrum paradoxum var. parvum West
Staurastrum pelagicum W. & G. S. West

*Stylosphaeridium stipitatum** (Bachman) Geitler & Gimesi
***Tetradesmus wisconsinensis** G. M. Smith
Tetraedron gracile (Reinsch) Hansgirg
Tetraedron limneticum Borge
Tetraedron lobulatum (Naegeli) Hansgirg
Tetraedron minimum (A. Braun) Hansgirg
Tetraedron quadricuspidatum (Reinsch) Hansgirg (The spines are stouter than in the figure given by Pascher but the basic cell structure appears to place it in this species.)
Tetraedron regulare Kuetzing
Tetraedron tumidulum (Reinsch) Hansgirg
***Tetrastrum heteracanthum** (Nordstedt) Chodat
***Tetrastrum staurogeniaeforme** (Schroeder) Lemmermann
***Ulothrix zonata** (Weber & Mohr) Kuetzing
***Volvox globator** Linnaeus
***Volvox mononae** G. M. Smith
***Westella botryoides** (W. West) Wildemann

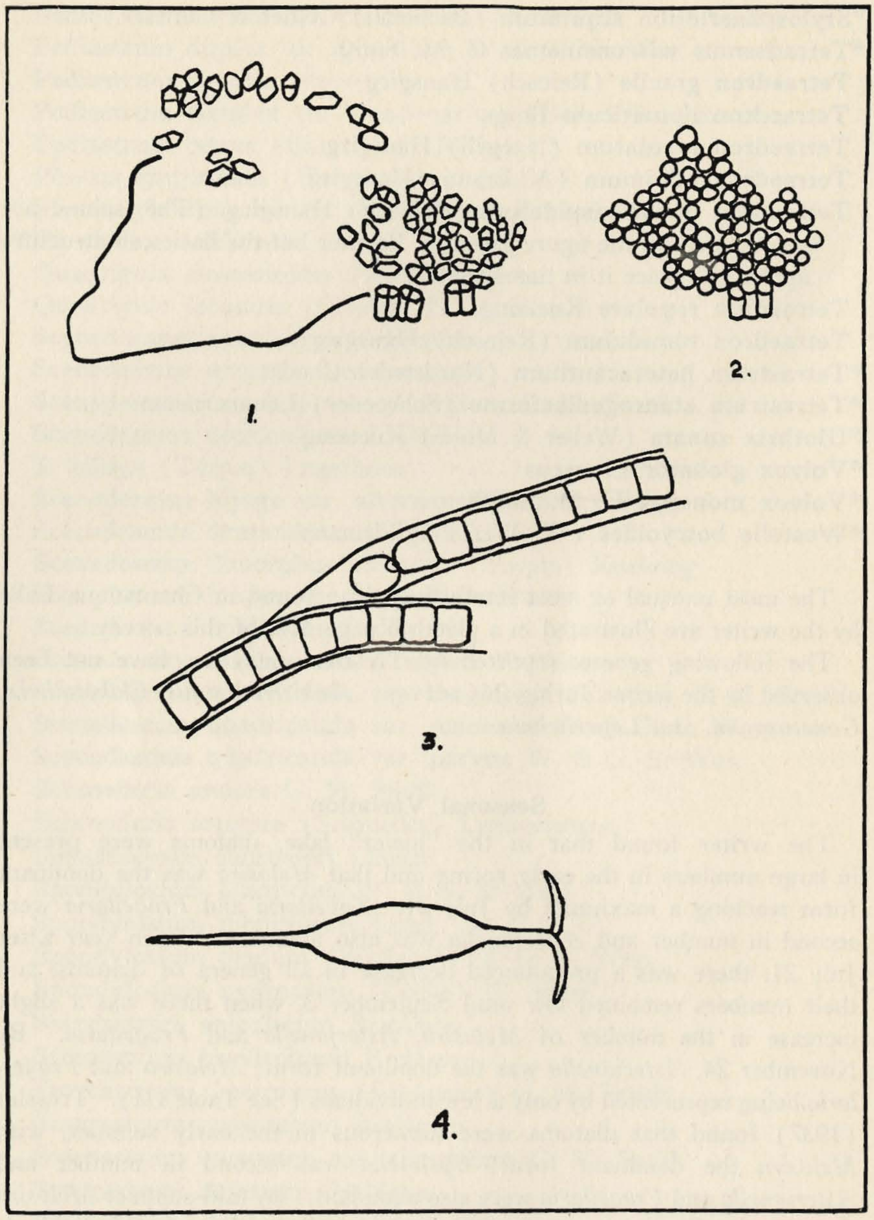
The most unusual or most interesting algae found in Chautauqua Lake by the writer are illustrated in a plate on page 418, of this survey.

The following genera, reported by Tressler and Bere, have not been observed by the writer during this survey: *Ankistrodesmus, Elakatothrix, Gonatozygon,* and *Lagerheimia.*

Seasonal Variation

The writer found that in the "lower" lake, diatoms were present in large numbers in the early spring and that *Melosira* was the dominant form reaching a maximum by July 21. *Tabellaria* and *Fragellaria* were second in number and *Asterionella* was also abundant. Each year after July 21, there was a pronounced decrease in all genera of diatoms, and their numbers remained low until September 3, when there was a slight increase in the number of *Melosira, Asterionella* and *Fragellaria.* By November 24, *Asterionella* was the dominant form; *Melosira* and *Fragellaria* being represented by only a few individuals (See Table III). Tressler (1937) found that diatoms were numerous in the early summer, with *Melosira* the dominant form; *Cyclotella* was second in number and *Asterionella* and *Fragellaria* were also abundant. By mid-summer *Melosira* was the dominant form and of the other forms only a few individuals were represented. *Melosira* decreased in mid-August and *Fragellaria* was again abundant.

The Myxophyceae in the lower lake almost entirely disappear in winter and they were never very abundant in the spring or early part of summer. In this study, they gradually increased in number until about July 21, after which they decreased slightly. By August 20, they have returned

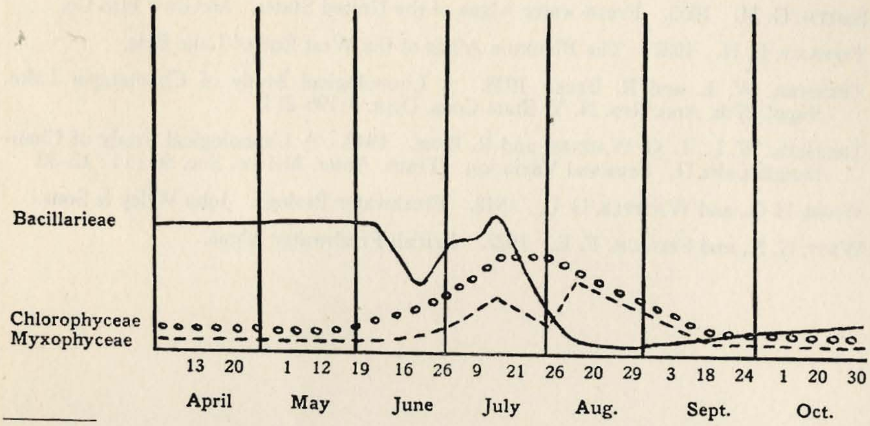


EXPLANATION OF PLATE

Fig. 1 *Holopedium irregulare* Lagerheim
Fig. 2 *Holopedium germinatum* Lagerheim
Fig. 3 *Tolypothrix tenius* Kuetzing
Fig. 4 *Schroederia ancora* G. M. Smith

and a maximum established with *Coelosphaerium, Anabaena, Aphanizomenon, Microcystis* and *Aphanocapsa* being the dominant forms (See Table III). *Gleotrichia echinulata* (J. E. Smith) P. Richter appeared on July 7, and gradually increased until it reached a maximum on August 3 caus-

FIGURE 1 *



* Data based on above findings—derived by comparing the abundance of Bacillarieae, Chlorophyceae and Myxophyceae by their appearance in my collections by month for each year then comparing my results with the findings of Tressler. For example: if the blue-greens in my collection were abundant at a certain day or week of a certain month of a year, then I check it against the same time for the following years.

ing a bloom along the shore. On August 13, 1949 *Anabaena* was abundant enough near the shore to form a bloom. By September 17, 1949 *Microcystis* had replaced *Anabaena*.

The writer agrees with Tressler that during the summer members of the Chlorophyceae are well represented. They make their appearance early in March and gradually increase in numbers until a maximum is reached around July 21. After that their numbers gradually decrease until, by the beginning of October, they are about as numerous as in the early part of March. (See Figure I.) No single genus was dominant, but on June 26 *Volvox, Eudorina,* and *Pandorina* were abundant and reached their maximum on July 10. At this same time *Dictyosphaerium* which had gradually been increasing reached its maximum, while *Coelastrum* became abundant about August 6.

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