STRATIGRAPHY OF THE HAMILTON GROUP OF NEW YORK.*

Part I.

G. ARTHUR COOPER.

INTRODUCTION.

The New York Hamilton has long been considered a well-known formation, but a detailed study of its parts shows that the current conceptions of these sediments are superficial and to a large degree inaccurate. Since the early Survey of New York State, 1836-1843, when the various stratigraphic units were defined for the first time, geologists, with one or two exceptions, have confined themselves chiefly to the collecting of Hamilton fossils and not to stratigraphic details. The result has been that for eighty-five years the Hamilton stratigraphy of the state has been neglected, and in its finer details is largely unknown.

Several factors have stood in the way of a more complete elucidation of the stratigraphy of the Hamilton Group. One of these is the extensive outcrop of these sediments, which forms an area about 260 miles long in an east-west direction, varying from 6 to 30 miles wide (see Fig. 1). In the early days of uncertain travel this belt was very formidable to see and understand but the advent of the automobile has now made possible a rapid examination of its most distant sections. Even more difficult than the spanning of distance has been the mastery of the Hamilton fauna. Fossils occur in great abundance and variety in nearly every horizon, the fauna probably exceeding 800 species, of which fully 300 are common throughout the State. Most of them have an extended vertical range and are of little value in detailed correlation, but various combinations in the faunules are characteristic of certain horizons. Furthermore, the beds are so nearly horizontal and the topographic relief of central and western New York so low that no single section exposes all of the Hamilton. It is therefore necessary to piece together the complete column from numerous short sections. In eastern central New York the simplicity of the structure is offset by

* Abstract of a dissertation presented to the Faculty of the Graduate School of Yale University, in candidacy for the degree of Doctor of Philosophy.

rapid and confusing shifts of facies. Add to all of these factors a heavy cover of glacial drift and vegetation, which makes the establishment of a complete, accurate vertical column the more difficult and slow of attainment.

The present paper summarizes the results obtained during three field seasons and is the first attempt at a comprehensive survey of Hamilton stratigraphy. The writer was prepared for these studies during the year 1925, which was devoted to an analysis of the fossil faunas of the Chenango Valley at Hamilton. The results of this study were presented as a Master's Essay to the faculty of Colgate University. The acquaintanceship with Hamilton fossils thus obtained made possible the comprehensive study summarized in these pages. Six weeks of the 1926 field season were spent in a survey of the stratigraphy of the Morrisville Quadrangle and the partial preparation of a geologic map of this area, which includes the type section of the Hamilton. One month of the following season was devoted to the completion of the Morrisville map. Then, starting from Lake Erie, all of the strata of the Hamilton were carefully traced eastward into the type section of the group at Hamilton village. The formations described by Hall and Vanuxem also were traced from their type sections into that of the group. Ten weeks of the 1928 season were devoted to perfecting the correlations established the year previous, and to carrying the investigations still farther eastward into the Unadilla Valley. A comprehensive survey of the Hamilton was thus attained from the shores of Lake Erie to the Unadilla Valley, a distance, in a straight line across the state, of nearly 200 miles.

These investigations were made possible by a grant from the Fairchild Fund of the Museum at Colgate University, Hamilton, New York. The writer is therefore under deep obligation to Mrs. Charles Fairchild of Cazenovia, New York, donor of the fund. He is under lasting obligation to Professor H. O. Whitnall of Colgate University for his generous administration of the fund and for his encouragement and interest in these investigations. All of the vast collection of Hamilton fossils obtained during the progress of the field-work are the property of Colgate University and form the bulk of the Lincklaen Memorial Collection. The writer also expresses here his deep indebtedness to Professor Carl O. Dunbar of Yale University, who suggested this problem and whose encouragement, advice, and criticism have been im-

portant factors in the success of the investigations. The aid and congenial companionship of Mr. C. B. Hunt, who assisted the writer for three weeks in the Unadilla Valley, are likewise gratefully acknowledged. The writer's thanks are also extended to Dr. Erwin Pohl for the use of his unpublished manuscript describing the "Paleontologic Zones of the upper Hamilton group in west central New York," and to Dr. Burnett Smith of Skaneateles, New York, and the New York State Museum for information concerning detailed correlations within the Skaneateles Quadrangle.

SUMMARY.

This paper is an abstract of a comprehensive study of the Hamilton Group between Lake Erie and the Unadilla Valley, comprising a redefinition of the group and a brief description of all its stratigraphic units. It has been necessary to redefine the Hamilton so that it now consists of the four formations, Marcellus, Skaneateles, Ludlowville, and Moscow. Following an outline of Middle Devonian stratigraphy and a discussion of the history of Hamilton nomenclature there is a short description of the type section of the group. All of the formations of the Hamilton are defined and their history and correlation discussed. In order to describe the stratigraphy more exactly, each of these formations has been subdivided into members and the characteristics and correlation of each of these across the state are considered. The paper is concluded with suggestions regarding correlations of the Hamilton of eastern New York and a discussion of current errors in correlation in western New York.

GENERAL STRATIGRAPHIC RELATIONS OF THE HAMILTON GROUP.[1]

Outcrop

The Middle Devonian forms a broad outcrop belt extending east and west across the State from Lake Erie to Albany County, then makes an abrupt southward bend a short distance to the southwest of Albany and continues for some

[1] For full references to papers published up to 1917, see Nickles' Geologic Literature on North America, U. S. G. S. Bull. 746. The initials of the author and the date of the publication corresponding to that in the Index are here recorded.

distance nearly parallel to the course of the Hudson. It diverges slightly westward from the river in the vicinity of Kingston and crosses the New York-New Jersey line at Port Jervis (see Fig. 1).

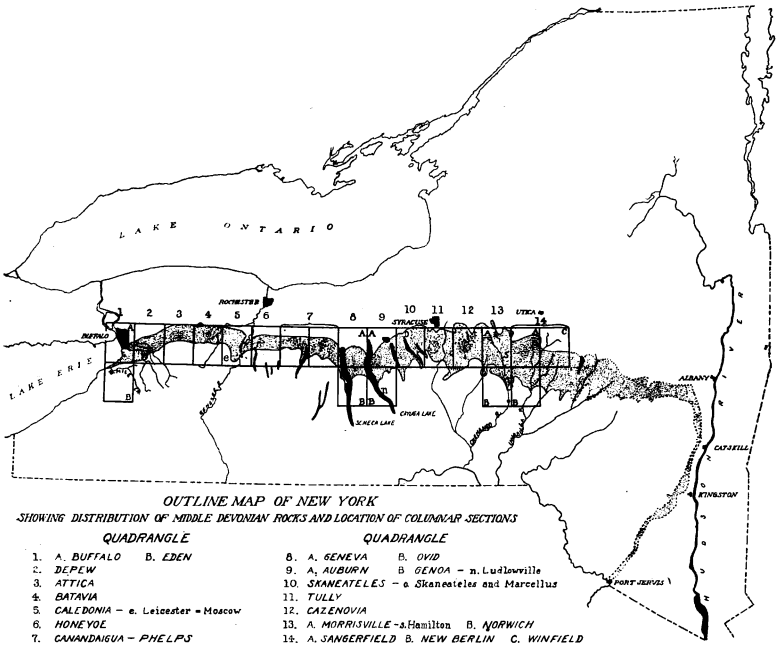

Fig. 1. Outline Map of New York. The numbers of the quadrangles correspond to the numbers of the columnar sections. Each columnar section is a composite diagram of more or less numerous exposures in the vicinity of the locality for which the column is named and in the corresponding quadrangle.

Structure.

The Middle Devonian rocks are remarkably simple in their structure, a fact that partly compensates for their varied facies and stratigraphic complexity. In the extreme western part of the state they are nearly horizontal, the prevailing dip being about 34 feet per mile to the southeast. Eastward for some distance the dip remains nearly the same but the direction changes to the southwest. In Onondaga Valley it has increased to 45-50 feet per mile to the southwest, in Chenango Valley it is 65-75 feet per mile, and in the Unadilla Valley

it is 80-100 feet per mile to the southwest.[2] In Schoharie Valley Prosser (99) records dips of 1°-4° to the southwest.

Small faults are common throughout the Hamilton rocks but rarely affect the topography or the stratigraphic relations. The largest fault known in these beds is the Clarendon-Linden fault described by Chadwick.[3] It has a throw of about 100 feet. Another fault having an estimated throw of 40 feet is known on the outlet of Keuka Lake (Wright, B. H., 84, p. 201). Undulations of the rocks are common and frequently cause confusion in the interpretation due to a duplication in the sequence of strata. An example occurs on Criss Creek 2 miles south of Union Springs, Cayuga Lake, where a low fold has duplicated the Mottville. Luther (10, p. 19) correlated the shale in the interval produced by the duplication with the Cardiff, but this stratum actually is not present on the shores of Cayuga Lake (Smith, B., 16, pp. 565-566). Prominent folds related to the Appalachian system have been described on Seneca and Cayuga lakes (Kindle, 04c, pp. 281-289; Luther, 10, p. 25).

Content.

The Middle Devonian has been separated into the Ulsterian and Erian divisions, the former including the Schoharie-Esopus Group and the Onondaga-Marcellus Group, the Erian including the Hamilton group alone. This paper is not concerned with the Schoharie-Esopus Group, but the writer believes that the Marcellus, and perhaps also the Onondaga, cannot be divorced from the Hamilton.

The Onondaga west of Schoharie County rests on a post-Oriskany erosion surface (Kindle, 13b). It is, in the lower part, a light gray massive limestone, in some places semicrystalline, becoming darker and shaly at the top. The Marcellus is thought by some writers to replace the Onondaga in eastern central and central New York, overlapping it to the west of Flint Creek (see Fig. 3). The Marcellus is the introduction to the great clastic wedge of the Hamilton. It is mostly black shale in the lower part but is replaced higher

[2] This figure is in excess of that of Prosser (97, p. 174). The discrepancy is due probably to the fact that Prosser's measurement is on the upper Hamilton (Windom member) while the figure recorded above was determined on the Mottville.

[3] Chadwick, G. H., Large Fault in Western New York, Bull. Geol. Soc. Am., 31, 117-120, 1920.

by dark grey shale. The sediments of the Skaneateles, Ludlowville, and Moscow, which succeed the Marcellus successively, are calcareo-argillaceous muds in the western part of the state, increasing in coarseness to reach the grade of siltstone in the vicinity of Canandaigua Lake, arenaceous shales at Cayuga Lake, and coarse arenaceous shales, argillaceous sandstones, and thin-bedded, frequently cross-bedded sandstones in the type locality of the Hamilton and east of it.

Thickness.

The thickness of the Hamilton increases from 285 feet at Lake Erie to 655 feet at Canandaigua Lake, 680 feet at Cayuga Lake, 1,126 feet at Skaneateles Lake, 1,115 feet in the Onondaga Valley, 1,465 feet in the Chenango Valley, 1,550 feet in the Unadilla Valley, and 1,680 (?) feet in the Schoharie Valley (Grabau, 06, p. 213). (See Figs. 4 and 5.) The increase in thickness toward the east and the increasing coarseness of the sediments in the same direction is taken to indicate approach to the old shore of Appalachia, which was the main source of the sediments. The maximum thickness of the Hamilton is in Pennsylvania, indicating that the axis of the geosyncline lay southwest of eastern New York. The outcrop belt of the Hamilton therefore runs from the Buffalo axis obliquely across the deeper part of the geosyncline to the old Appalachian shore of Middle Devonian time. This obliquity of the Hamilton outcrop to the axis of the geosyncline may have an important bearing on the ultimate interpretation of the stratigraphy and sedimentation of the Hamilton group.

Upper Limit of the Hamilton.

The upper limit of the Hamilton in Central New York is the zone of *Hypothryidina venustula* (Hall) [*H. cuboides*] which is generally accepted as the base of the Upper Devonian. This zone is at the base of the Tully limestone (see Figs. 4 and 5), which is a thin wedge extending from the east side of Canandaigua Lake at least as far east as the village of Sherburne on the east side of the Chenango Valley. This limestone unconformably overlies the Hamilton and wherever it is present clearly delimits the summit of the group. East of Sherburne the characteristic limestone has been replaced by the Sherburne sandstone, but the Hypothyridina zone still

persists at the base of the sandstone, clearly marking the top of the Hamilton as far east as the village of Mt. Vision in Otego Valley (Prosser, 99, pp. 180-193). New localities of the Tully limestone were discovered on West Brook 2 miles south of Sherburne, where it is represented by nearly 50 feet of limestone, sandstone, and blue shale, and in a small gully flowing down the south side of Hunts Mountain into Nigger Hollow Brook, 1 mile south of Sherburne. *Hypothyridina* was also found at the base of the Sherburne sandstone in a small gully 3 miles south of the settlement at Columbus, north of New Berlin. It is evident that the lower part of the Sherburne at its type locality and probably for a considerable distance eastward is actually a clastic phase of the Tully. East of Mt. Vision the top of the Hamilton is marked by the *Vitulina-Spirifer tullius* zone as far east as Summit in eastern Otsego County (see Figs. 4 and 5), but east of this place the upper limit of the Hamilton cannot be considered well known, since it is difficult to distinguish the base of the Sherburne lithologically and faunally from the top of the Hamilton, and here the *Vitulina-Spirifer tullius* zone has not been identified.

In the western part of the state the horizon of the Tully limestone is represented by the "lenticular Pyrite" (Loomis, 03, p. 892) which carries a dwarfed Hamilton fauna. It may be followed westward from the east side of Canandaigua Lake as far as Spring Brook in Erie County (Houghton, F., 14). Thus the top of the Hamilton is as clearly marked off in the western part of the state as it is in the central and eastern central portions.

Unconformity at the top of the Hamilton.

In central and western New York the Hamilton is overlain unconformably by the Tully limestone and the Geneseo shale. The evidence for this unconformity is seen in the westward disappearance of successive faunal zones of the upper Hamilton. East of Otisco Lake the uppermost zones of the Hamilton are, in order, (1) the *Vitulina-Spirifer tullius* zone, (2) *Spirifer-Atrypa* zone, (3) *Ambocoelia praeumbona* zone. In the Cayuga Lake region the uppermost (*Vitulina-Spirifer tullius*) zone is absent but a remnant of it appears in the 12 feet of black shale beneath the Tully on Kashong Creek, Bellona. Traced westward from here, however, the zones

disappear in the order named so that the *Ambocoelia praeumbona* zone forms the summit of the Hamilton at Lake Erie.

In Ohio and Ontario the typical New York development of the Hamilton is not known. Stauffer (16b, p. 485) has correlated the Tichenor of Lake Erie with the Prout limestone, which forms the summit of the Hamilton in Ohio, and Shimer and Grabau (02, pp. 163-167) have correlated the same stratum (the Tichenor) with the Encrinal limestone of the Widder beds. It is here suggested that the correlation of the Prout and Widder beds is with the older Centerfield limestone of western New York rather than with the younger Tichenor of Lake Erie. There is much more agreement between the fauna of the Centerfield and those of the Widder and Prout. If the suggested correlation be correct it will be seen that the summit unconformity magnifies in time value to the west, since nearly all of the Ludlowville and the entire Moscow is then absent in Ohio and Ontario.

Unconformity at the base of the Hamilton.

Following the work of Clarke and Grabau it has been commonly believed that the Onondaga limestone grades upward into the Marcellus shale (here recognized as the basal Hamilton) with the Marcellus overlapping the Onondaga toward the west. Although this interpretation finds some support in the interfingering of Marcellus and Onondaga in Central New York, Chadwick has found evidence of an unconformity between the Onondaga and Marcellus in eastern New York.[4] It is therefore possible that there was an interruption in sedimentation at the end of Onondaga time, but it is equally possible that Chadwick's unconformity is actually only a marginal break such as would be expected in the shore region and did not affect sedimentation in the deeper and more distant portion of the geosyncline. In such an instance part, at least, of the Onondaga in western New York would be equivalent to the lower part of the Marcellus and should be referred properly to the Hamilton. However, till the true significance of the "break" is understood, the division line between the Hamilton and the Onondaga is drawn at the base of the Marcellus.

[4] Chadwick, G. H., New Points in New York Stratigraphy, Bull. Geol. Soc. Am., 38, 160, 1927 (abstract).

PREVIOUS WORK.

The sediments of the Hamilton group were described first in the preliminary and later in the final reports of the First Geological Survey of New York, between 1837 and 1843. Of these the works of Vanuxem and Hall are the most important since the type sections of the formations of the Hamilton were described by them.

For many years following the Survey period, investigators in these sediments concerned themselves mainly with the collection and description of the numerous fossils for which these beds are so well known. This period of paleontography terminated with the appearance, in 1888, of Paleontology of New York, Volume 7, but during this interval Hall, assisted by Clarke, Beecher, Simpson, and others, made known most of the Hamilton fossils, and left these sediments lean ground for the discovery of new species.

The late Nineties and the early part of the Twentieth Century saw the completion of important stratigraphic investigations in the Hamilton rocks of a more or less local nature. At this time Williams (90, pp. 481-500) clearly defined the top of the Hamilton at the base of the Tully limestone. This placed the Genesee (Geneseo) shale and the Tully limestone in the Upper Devonian. At this time also Prosser (93, 95, 97, 99) carried on his important reconnaissance studies in the Hamilton east of the Chenango Valley and established the upper limit of the group in this part of the state. Grabau (98a, 99) and Cleland (03a) published their valuable analyses of the Hamilton faunas of the Eighteenmile Creek and Cayuga Lake regions respectively, and Clarke (J. M., 94) and Luther (94) described the faunal and stratigraphic sequence in the Livonia salt shaft During this period Bishop (I. P., 97), Lincoln (D. F., 97) and Luther (97a) published reports on the economic geology of Erie, Seneca, and Onondaga Counties.

Between 1900 and 1915, Clarke (J. M., 04b; 05c) and Luther (06, 09, 10, 11, 14), separately and in collaboration, surveyed a considerable number of quadrangles underlain, in large part, by Middle Devonian rocks, but the brevity and the vagueness of the descriptions of formations in these reports make them of little value to anyone interested in detailed correlation. In 1906 Grabau (06) described the geology of the Schoharie Valley, and in 1915 the same author (15b) published an abstract promising a discussion of Hamil-

ton stratigraphy in western New York, but this has not yet appeared. Grabau (17, 17c, 19) has also discussed Hamilton stratigraphic problems in three more recent papers, suggesting correlations in eastern and western New York.

HISTORY OF HAMILTON NOMENCLATURE.

The first use of the name Hamilton was by Vanuxem (40, p. 380), as follows:

"*Hamilton Group.* In this group we have shales and sandstone, the former dark blue, olive, etc. West Hamilton is the locality where it is well characterized, also Cazenovia, Pompey Hill, ... being one of the south rocks whose range is uninterrupted through the district ....."

In the western and central parts of the state, Hall recognized two divisions, the Moscow and Ludlowville shales, the former being the younger. Vanuxem (40, p. 380), in central and eastern central New York, recognized, besides the Hamilton Group, the Skaneateles shale below and the Moscow shale of Hall above.

Although Hall in 1842 (42a, p. 57) had used the name Ludlowville Group to include the Marcellus, Skaneateles, Ludlowville, and Moscow shales, the Survey geologists united all of the strata between the top of the Upper Marcellus of Vanuxem (now Cardiff) and the base of the Tully limestone under the designation Hamilton Group, thus abandoning the previous restricted use of the term.

Hall (43, table, p. 517) originally considered the Hamilton to be upper Silurian (Ludlow) in age, but in 1847 (p. xvii) suggested that "from a paleontological point of view the deposits down to the Oriskany should be included in the Devonian." De Verneuil (47a, pp. 366-370) in the same year further indicated the Devonian affinities of the Hamilton and pointed out the close faunal relationships between the Marcellus shale, Hamilton group, Tully limestone, and Genesee shale. Sharpe (48, p. 153) independently arrived at the same conclusions. Hall (51d, pp. 288, 308), following the lead suggested by De Verneuil and Sharpe, extended the Hamilton group to include the Marcellus shale, Tully limestone, and Genesee shale. This broader usage was adopted until 1890 when H. S. Williams (90, p. 485) established the equivalence of the Tully limestone with the "Cuboides Schich-

ten" and the Iberger Kalk of Germany and Belgium, which are at the accepted base of the Upper Devonian in those places. Williams thus excluded the Tully limestone and the Genesee (Geneseo) shale from the Hamilton, but continued the Marcellus-Hamilton association. Some writers (Grabau, 99, p. 233) used the name Hamilton in a restricted sense, i.e., for the Skaneateles and Ludlowville, but not exactly as defined by Vanuxem.

Dana (J. D., 63, p. 288) in his "Manual" had been using the name Hamilton in two different ways, one with a chronological sense, the Hamilton Period, and the other as a stratigraphic term, Hamilton group. These and other irregularities in geological nomenclature led Clarke and Schuchert (99i) to reorganize the stratigraphic nomenclature of the State, reviving many old names, among them the term Erian, to serve in a chronological sense for the time included in the Marcellus and Hamilton.

In a revision of the stratigraphy of the state Clarke (03g, p. 22) felt a need for the subdivisional terms that had been long in disuse and therefore revived the names Skaneateles, Ludlowville, and Moscow as subdivisions of the Hamilton, and the Marcellus was set out as a division correlative with the Hamilton. This grouping persisted until Schuchert[5] placed the Marcellus in his "Onondaga-Marcellus group" on the basis of the stratigraphic relationships of these groups described by Clarke (1901).

The results of the present study emphasize the close faunal and stratigraphic relationships of the Marcellus with the Hamilton and show that the Marcellus is actually a facies of the Hamilton. Therefore the Marcellus has been returned to its former position at the base of the Hamilton and is considered as a formation of the same value as the others of the Hamilton (see diagrams, Figs. 4 and 5).

THE TYPE SECTION.

The type section of the Hamilton Group as originally defined was the "village of West Hamilton," but in the final reports it was given as the "Town of Hamilton." It is not clear, and fortunately makes little difference, whether Vanuxem referred to the rocks in the immediate vicinity of the village or to those of the township as a whole, as it will

[5] Pirsson, L. V., and Schuchert, C., A Textbook of Geology, Pt. II, p. 309, 1924.

be shown that all of the rocks to which he referred, and the only available good exposures in the township, are those of the Skaneateles.

The stratigraphy of the township may be summarized briefly as follows: the village is underlain by the Marcellus (Cardiff) formation and the basal member of the Skaneateles (Mottville) occurs in the ravines about the village. The latter is also exposed along the old canal 0.4 mile north of the railroad station. College Hill is composed nearly completely of Skaneateles shale 470 feet thick, exposed in Dart Glen, the quarry behind the new gymnasium, and in the old quarry on the hill south of the University. The latter has been in operation since Vanuxem's time (see Vanuxem, 42, p. 157; Prosser 97, pp. 96-97). The top of the Skaneateles descends below the level of the valley at Earlville, 6 miles south of Hamilton. In Sangerfield Valley the Skaneateles is the only well exposed rock. In Pleasant Creek Valley little of the Ludlowville is exposed. The latter formation is well displayed south of Earlville but only the bottom of it appears anywhere in the portions of the Chenango and Sangerfield valleys in the township. The Moscow forms the summits of the hills in the southern part of the township and is not available for detailed study.

It is clear from the map (Fig. 2) then, that the only available outcrops upon which Vanuxem could base his name Hamilton were those of the Skaneateles formation. He also cited the rocks in the vicinity of Cazenovia and Pompey Hill as examples of the Hamilton. But these, as well as his type Hamilton of 1840, represent the identical sequence found at Skaneateles Lake and on the shores of Cayuga Lake between Levanna and Aurora. Vanuxem thus inadvertently proposed two different names, Skaneateles and Hamilton, for the same sequence, but since the name Hamilton was elevated into group rank in the Final Reports, and has long since been in common use, there is nothing to be gained by pressing the priority of the name Skaneateles.

Clarke and Luther (04b, p. 18) considered the exposures about Hamilton to be Ludlowville, stating that the original Hamilton was actually Ludlowville in age, and therefore substituted this name for the term Hamilton in a restricted sense. These authors fell into the same error at Pratt Falls, Cazenovia Quadrangle, a section which is clearly at the base of the Skaneateles. Clarke, therefore, was incorrect in his cor-

relation but the name Ludlowville is intrenched in the literature and there is little advantage in attempting to upset this usage.

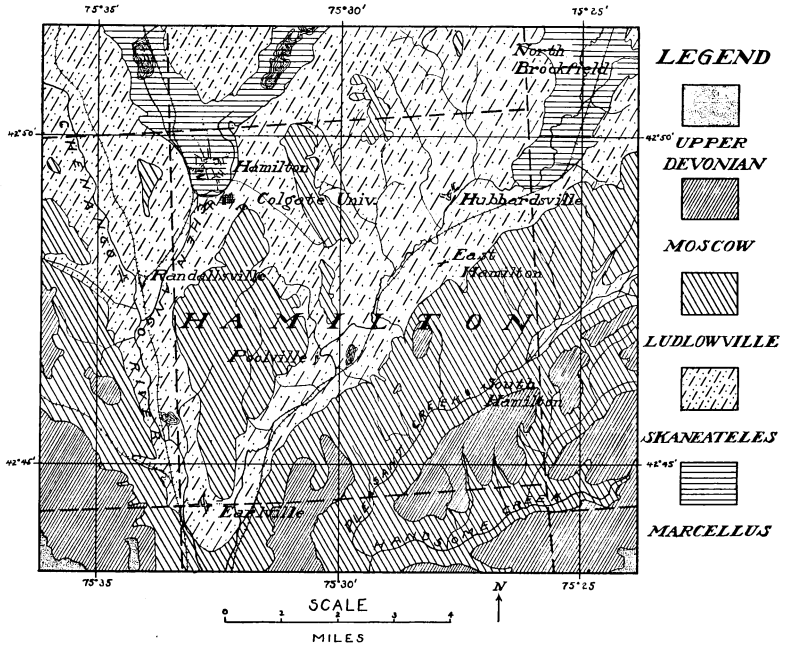

Fig. 2. Geologic Map of Hamilton Township.

STRATIGRAPHIC UNITS.

The stratigraphic units of the Hamilton group recognized as a result of the present field studies are described briefly below (see Figs. 4 and 5). Several of them have been introduced by other investigators but many new divisions are here proposed in order that the stratigraphy may be defined more precisely. The attempt has been made to locate accurately the type section and other easily accessible exposures of the new units proposed. It is impossible in this brief preliminary paper to cite faunal lists proving the necessity for the subdivisions, but it is thought that the numerous localities of the various strata mentioned will sufficiently aid those interested in following the correlations until the extended report with its faunal lists can be published.

Marcellus Formation.

To the west of Flint Creek the entire Marcellus formation consists of a relatively thin layer of black shale, not divisible into units, but in the central and eastern parts of the state it becomes much thicker and is clearly divisible into a number of well defined members. In a like manner the Marcellus is marked by a decided change in facies when followed from west to east. In the western part of the state the "Marcellus or Leiorhynchus fauna" is dominant but in the passage eastward it is replaced by the Hamilton fauna, except in the lowest part of the formation.

The Marcellus has undergone considerable revision since the name was proposed first by Hall (39, p. 295). The term was first used to include the shale at Marcellus between the top of the Onondaga limestone and the horizon marking the first appearance of a true Hamilton fauna. A thin band of limestone (subsequently termed the Stafford limestone) occurred in the midst of Hall's Marcellus and was used as a plane of reference in discussions of these rocks. In 1840 Vanuxem (40, p. 379) described a lower, black, fissile shale and an upper blue-black or dark gray shale, the former being the lower Marcellus, and the latter the upper Marcellus. In 1904 Clarke and Luther (04b, pp. 14-17) subdivided the Marcellus into the Marcellus and the Cardiff in a region east of the eastern limit of the typical Stafford limestone. But they fell into confusion because farther west 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 (B., 16). Since the Stafford is actually the equivalent of the basal bed of the Skaneateles it is necessary to exclude this member from the Marcellus.

Clarke (01, pp. 115-138) considered the lower part of the Marcellus (Union Springs member of this paper) of eastern and central New York to be the equivalent of the upper part of the Onondaga limestone of western New York, the passage beds being represented by the alternating limestone and black shale at Union Springs and Flint Creek. The discovery by Chadwick[6] of an unconformity between the Onondaga and

[6] Chadwick, G. H., New Points in New York Stratigraphy, Bull. Geol. Soc. Amer., 38, 160, 1927 (abstract).

Marcellus may necessitate an interpretation for these relations entirely different from that of the "Marcellus-Onondaga overlap."

In this paper the name Marcellus is used in the same way as Vanuxem employed it in 1840 and it is placed in the Hamilton group as a formation correlative in rank with the Skaneateles and the other formations. The upper limit of the Marcellus is the base of the Stafford and Mottville members and the lower limit is the Onondaga limestone. The type section is in Slate Hill, about 1 mile south of Marcellus, and a complete section is exposed in Jackknife ravine on the northeast slope of this hill. The following subdivisions have been identified:

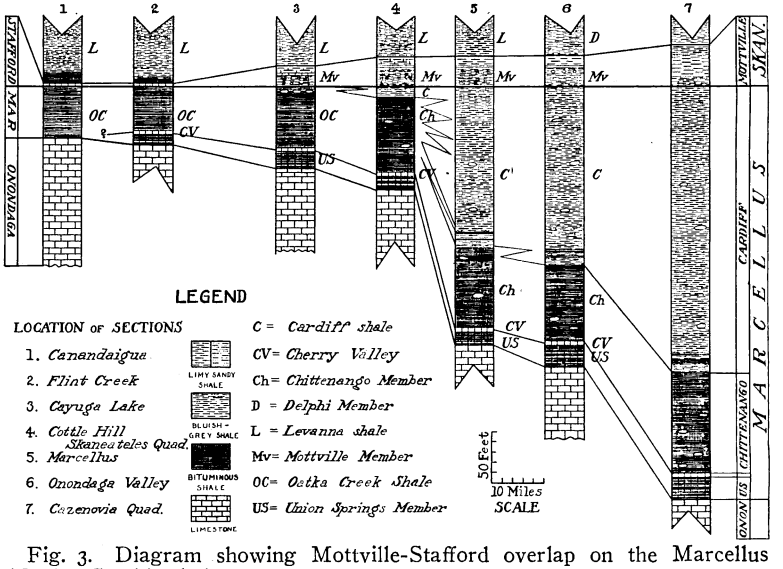

Fig. 3. Diagram showing Mottville-Stafford overlap on the Marcellus (Oatka Creek) shale.

Oatka Creek shale.—West of Cayuga Lake the Stafford limestone is underlain by black shale which is markedly calcareous and fossiliferous, especially in the western part of the state. In these characters this shale differs from the black shale above the Cherry Valley limestone in eastern central and eastern New York. It also represents a longer time interval than the black shale of the east, probably being the equivalent of the Chittenango and Cardiff shales in the east.

The type section is below the Main Street bridge over Oatka Creek, LeRoy, where the whole section, 30 feet thick, is exposed. The Oatka Creek shale thickens both east and west of the type section (see Figs. 3, 4 and 5). Other exposures are in the bed of Conesus Creek at Ashantee, Genesee Valley, and on Flint Creek 1½ miles northeast of Orleans. At all of these localities, as in the type section, the Oatka Creek is separated from the Hamilton by the thin Stafford limestone.[7]

Chittenango member.—This name is applied to the jet-black, fissile shale above the Cherry Valley limestone from eastern New York nearly to Cayuga Lake. The rock readily crumbles to paper-thin flakes so that some outcrops appear as a pile of thin chips. Huge septaria and smaller calcareous concretions are abundant. The shale is non-calcareous and nearly barren of fossils. It is separately designated because of these last two characteristics and because it represents only a part of the time interval of the Oatka Creek shale of western New York.

The type section for this member is in a small gully 0.7 mile north of the village of Chittenango Falls where the entire section, 120 feet thick, is exposed. At the top it "interfingers" with the blue-black shale of the Cardiff. The Chittenango is well exposed along the Manlius-Cazenovia road 1.3 miles south of Oran; on Oneida Creek, above Stockbridge Falls; and in the hills north of Bridgewater and West Winfield.

Cherry Valley member.—In 1903 Clarke (03g, p. 26) applied this name to a thin band of limestone intercalated in the Marcellus shale of Cherry Valley. This layer is characterized by a great number of large ammonoids which early earned the name "Agoniatites Limestone" for the bed. The rock is a black limestone having a hackly fracture, and crumbling easily on exposure to lumps about the size of a cobble. It is marked everywhere by an orange-red rust, which fills cavities and stains the surface. The limestone is 3 feet thick at Oneida Creek, but thins to 1½ feet at Union Springs.

East of Union Springs the Cherry Valley limestone is well developed and contains the characteristic cephalopods, but at Union Springs, and on Flint Creek above Phelps, *Agoniatites* is very rare. West of Flint Creek the Cherry Valley or its equivalent is unknown, although Clarke reports some of the

[7] The Oatka Creek shale is the First Leiorhynchus zone of Cleland (03a, p. 22; faunal lists on pp. 95-105). The definition of a Leiorhynchus fauna may be found in Cleland 03a, p. 23.

characteristic Cherry Valley fossils from the top of the Onondaga in the Water Works tunnel at Stony Point, Lake Erie.[8] Clarke believed that it "actually coincides with and merges" into the Onondaga limestone west of Flint Creek (Clarke, J. M., 01, p. 137). This view, however, is now challenged by Chadwick.

Union Springs member.—This new name is applied to the thin alternating beds of black limestone and sooty shale between the top of the Onondaga limestone and the Cherry Valley limestone. The type section is in the upper part of Wood's Quarry, 1 mile south of Union Springs (Cleland, 03a, pl. 4), Cayuga Lake, where the relation of this member to the Cherry Valley may be studied. East of the type section it increases in thickness, and the relative amount of shale to limestone also increases. At the type section the member is 17 feet; at Marcellus it is 13 feet, and at Oneida Creek above Stockbridge Falls it is 25 feet thick. Traced westward the relative proportion of limestone to shale increases and the member thins noticeably, being only 9 feet thick on Flint Creek a short distance above Phelps. West of Phelps this member is not known.

Cardiff shale.—In their report on the Canandaigua-Naples quadrangles Clarke and Luther (04b, p. 16) named the grey upper Marcellus, the Cardiff shale. Their type section, near the settlement of Cardiff in the Onondaga Valley, extends upward from the black Chittenango shale to the fossiliferous Mottville member of the Skaneateles. Clarke and Luther erroneously supposed this dark grey shale to be identical with a similar shale that lies above the Stafford limestone in western New York, and so defined the Cardiff as being above the Stafford. But since the Mottville has been traced to Cayuga Lake, where it directly overlies the Oatka Creek shale, it is evident that the Cardiff has disappeared, probably by a westward gradation into black shale (see Fig. 3). The Oatka Creek shale is thus probably the depositional equivalent of the Cardiff and the Chittenango.

A striking change in facies is seen as these Cardiff beds are traced east and west from their type section. In Chenango Valley and eastward the Cardiff shale is represented by three members, a sandy Solsville member separating an upper and lower grey shale member. West of Chenango Valley the

[8] For faunal lists of the Cherry Valley member see Clarke, J. M., 89b, 01, pp. 124-125.

sandy member disappears and the entire sequence is one of nearly homogeneous, dark grey shale. Still farther westward it becomes black shale and forms part of the Oatka Creek shale. The eastward change in facies in the Chenango and Unadilla Valleys is attended by a marked change in the faunal facies. The dark shales of the Cardiff are characterized by a "Leiorhynchus fauna," but as these become sandier in the eastern part of the state, true Hamilton forms replace those of the Cardiff, and in the upper part of the Marcellus formation (Pecksport and Solsville members) in Unadilla Valley Hamilton species predominate. In the vicinity of Schoharie and Catskill the jet-back Marcellus is succeeded directly by strata having a Hamilton fauna, the Mount Marion beds, suggesting that the replacement of the "Leiorhynchus or Marcellus facies" by that of the Hamilton is complete in the eastern part of the state.

Bridgewater member.—This name is applied to the shale between the Chittenango member and the base of the Solsville. The lower part is a soft, fissile, slightly arenaceous shale especially characterized by *Leiorhynchus limitare, Conularia,* and *Styliolina fissurella.* The succeeding zone is coarser nonlaminated shale. In this division *Leiorhynchus laura* is common and is associated with many typical Hamilton fossils, showing the change in faunal facies to the east. No continuous sequence of this member is exposed in the Unadilla Valley, so that a number of ravines must be visited in order to construct a complete section. The lower part, including the transition with the Chittenango, is shown in Wordens Gulf 1¼ miles west of West Winfield, the middle of the section is exposed in a gully behind the buildings of the Rose Farm ¾ mile north of West Winfield, and the upper part and its contact with the Solsville are exposed on the Seabridge Farm 2¼ miles west of Bridgewater. Markham and Fork Mountains at Unadilla Forks are almost completely composed of the Bridgewater shale, the Solsville member being close to the top of these elevations.

Solsville member.—This member, 45-50 feet thick, of sandy shale, fine sandstone, and a calcareous sandstone, is transitional with the soft Bridgewater shales below. It is characterized by typical Hamilton fossils in an unusual assemblage. Common forms are: *Nephriticeras maximum, Paracyclas lirata, Gosselettia triquetra, Pterinea flabellum,* and *Conularia continens.* The member forms ridges on the sides of the hills north of

Solsville. The falls in Woods gully, 2 miles northwest of Solsville (Morrisville Quadrangle), is the type section. The Solsville also occurs in Reilley's Quarry 4 miles northwest of Bridgewater, and forms ridges on each side of the Unadilla Valley as far south as Leonardsville. It is not known west of Pine Woods, Morrisville Quadrangle.

Pecksport member.—The hard, resistant Solsville is succeeded by soft arenaceous shale that crumbles to small fragments when exposed. In the Morrisville Quadrangle this bed is characterized by *Leiorhynchus laura* in association with many typical Hamilton fossils. The type section is in the Livermore gully, 1 mile east of the railroad switch at Pecksport, where it is 153 feet thick. Eastward the member thins to 90 feet at Button Falls south of Leonardsville. At this place it is a coarse sandy shale abounding in typical Hamilton pelecypods, especially *Grammysia alveata.* The upper part of the Pecksport is transitional with the Mottville of the Skaneateles. West of the type section this member can be identified positively only as far as Pine Woods. It is thus coextensive with the Solsville. West of Pine Woods the Pecksport has graded laterally into fine arenaceous shales characterized by *Leiorhynchus laura,* forming the upper part of the Cardiff shale and not being divisible from it.

(*To be continued*)