Charles C. Mook
Nov. 21, 1920.

Dr Charles R. Eastman
with the Author's Compliments

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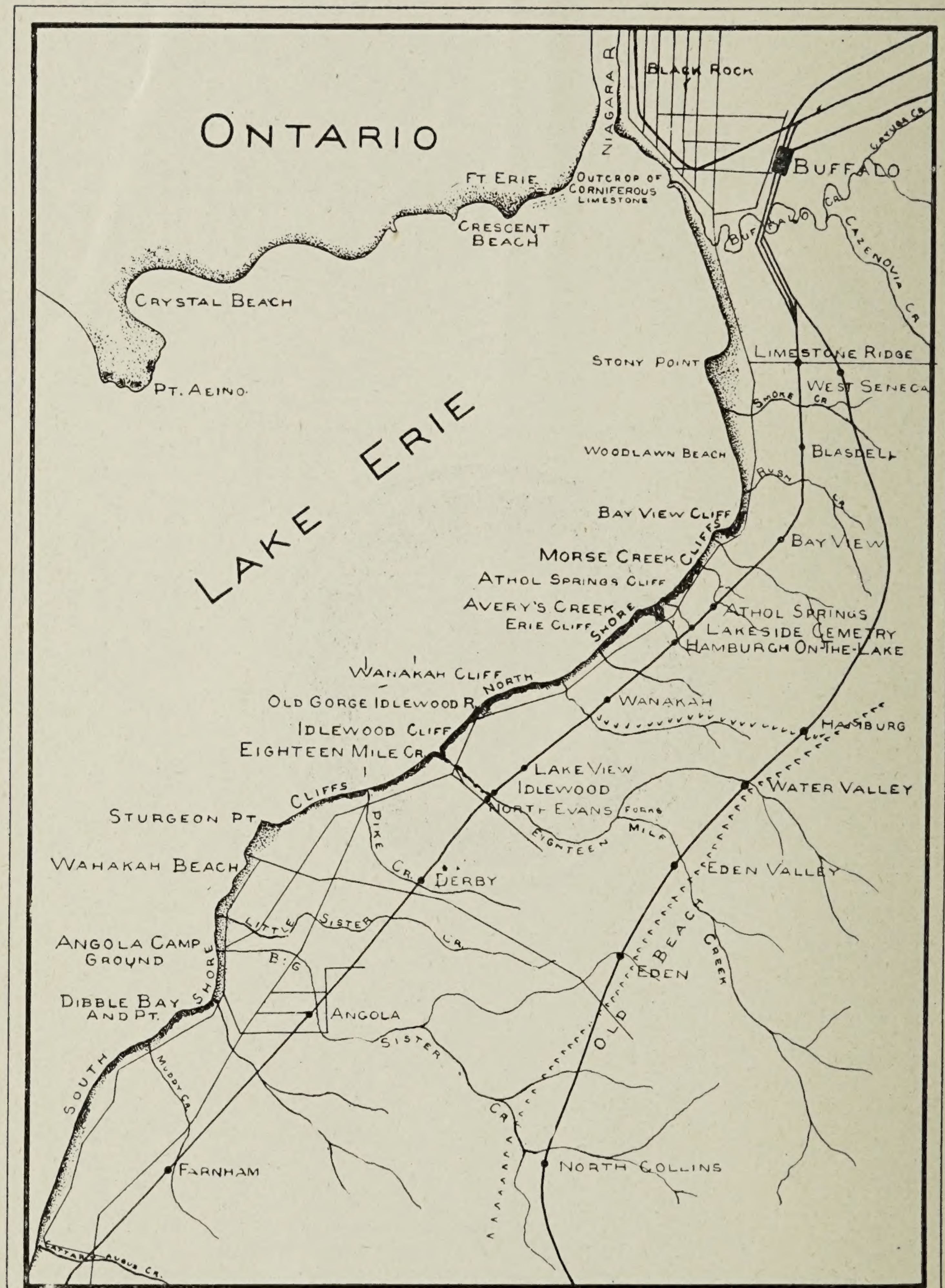

PLATE I.

Map of the Lake Shore of Erie County, New York, showing the position of the cliffs and streams.

Scale, 1 inch = 4 miles.

GEOLOGY AND PALÆONTOLOGY

—— OF ——

EIGHTEEN MILE CREEK

—— AND THE ——

LAKE SHORE SECTIONS

—— OF ——

ERIE COUNTY, NEW YORK.

A HAND-BOOK FOR THE USE OF STUDENTS AND AMATEURS

—— BY ——

AMADEUS W. GRABAU, S. B.,

Late Instructor in Palaeontology in the Massachusetts Institute of Technology.

BUFFALO, N. Y.
PUBLISHED BY THE BUFFALO SOCIETY OF NATURAL SCIENCES.
1898.

Dedication.

To
WILLIAM OTIS CROSBY,
Teacher, Investigator and Author,
the friend who first offered me encouragement
in my studies, and whose kindly interest
and criticism have been a constant
help, this work is grate-
fully dedicated.

PREFACE.

This book is intended as the first of a series of hand-books of local geology, which treat the subject with special reference to the needs of the student. The advantage of beginning the study of geology with the special consideration of a selected field, instead of the general text-book study, must be apparent, even though it seems like a complete inversion of the normal order of procedure.

In order that the student who comes to the field without a preliminary training in geology may take up the subject intelligently, the first portion of the introductory chapter of Part I. is devoted to a brief consideration of the elementary geological principles involved in the structure of the region under consideration. Hence no apology is needed for the introduction of such matters here. In chapters one and two the eight sections of the most important portion of the gorge of Eighteen Mile Creek and those of the Lake Shore, are considered in detail. Lists of fossils found in the various beds are not given, but such lists will be found in the author's paper on the "Faunas of the Hamilton Group of Eighteen Mile Creek and Vicinity."* As far as this guide treats of the Hamilton group, it is based directly on that paper, and constant references are made to it in the text.

In chapter three of Part I., an attempt is made to present in popular form the succession of geological events in this region, as revealed in the sections described in the earlier chapters.

*16th Ann. Rept. N. Y. State Geologist for 1896, Albany 1898 (in press). This paper has precedence over the present one in date of communication.

Part II. may be considered an elementary text book of the Palæontology of this region, as described in Part I. The introductory chapter treats of the general principles of Palæontology, and discusses the methods of fossilization. Chapter I. is devoted to the methods of collecting fossils from the beds of this region, and preparing them for study. Chapter II. treats of the fossils themselves. A brief description of the structural characters of each class precedes the discussion of the genera and species in that class. The generic descriptions are given with some detail, but under the species, only the leading features are mentioned, these, together with the illustrations, being intended chiefly as aids in the identification of the species. References to the most important works are given, and these should be consulted as much as possible. The magnificent volumes of the Palæontology of New York, contained in all the larger libraries, are of special importance to the advanced student, and the descriptions and illustrations there given, deserve the most careful study. The species considered are those which have been collected by the author, and those which have been previously described as coming from the Eighteen Mile Creek or Lake Shore region. A few descriptions have been introduced, of species recorded from Erie County only, but the association of which led to the inference that they belonged somewhere in the beds described in Part I. While all the species, which have so far come under the author's notice as found in the beds discussed, have been included, no pretension of completeness is made. It remains for the local student to discover new forms for this region, and to find new associations for those here described.

The plant remains from this region are not described, as the material obtained is very unsatisfactory, with the exception of the spores, which are discussed on pages 15 and 16, of Part I.

The etymology of the generic names is, in almost all cases, taken directly from S. A. Miller's admirable reference book: "North American Geology and Palæontology."

A number of species included in Chapter II. have never been described in print, but have simply been illustrated in the "Illustrations of Devonian Fossils," published in the Palæontology of New York series. In the case of these species, the descriptions here given were made up from the illustrations and explanations of the plates of the above book.

The localities given for the fossils are those described in Part I. Fossils quoted from West Hamburgh and Hamburgh-on-the-Lake probably come from Avery's Creek.

Chapter III. deals with the problems of the distribution and migration of marine invertebrates, and in Chapter IV. a glossary of Palæontological terms is given. The list of reference works of both general and special character is added in the hope, that it may meet the demand of many who wish to extend their study beyond what is given in the succeeding pages.

I wish in this place to acknowledge my indebtedness to numerous friends for aid received in the preparation of this guide. In the field-work, I have had the constant and able assistance of my brother, Mr. P. L. Grabau. For special courtesies received in the field I am under obligation, among others, to Mr. A. J. Hutchinson and family of North Evans, to Dr. F. W. Hinckel of Athol Springs, and to Mr. Truman G. Avery of Hamburgh-on-the-Lake. In the preparation of the drawings for Part II., I have received the very able assistance of Mr. John A. Hutchinson, who made pen and ink copies of all the gastropods and cephalopods, besides numerous other forms. Acknowledgements for assistance in this part of the work are also due Mr. I. C. Hanscom, Miss A. D. Savage and Miss K. B. Wentworth. Unless otherwise stated, the figures of Part II. are reproduced, either directly or by drawings from the volumes of the Palæontology of New York, through the courtesy of the officers of that survey. The use of the plates for the figures in the introduction of Part I. was courteously granted by the Massachusetts Institute of Technology.

For criticisms, while the work was passing through the press, my thanks are due to Professor W. O. Crosby and to Dr. R. T. Jackson. To Professor Irving P. Bishop of Buffalo, special acknowledgements are due for the care and labor he has gratuitously given to the preparation of the photographs from which the full page plates of Part I. are made. Finally, to Dr. Lee H. Smith and the other members of the publication committee, my thanks are due for the liberality which they have shown in the number and character of the illustrations.

In conclusion it should be mentioned that a portion of this paper was prepared during the author's connection with the Massachusetts Institute of Technology, and that a series of the fossils described in Part II., is contained in the collection of that institution. Another series is to be found in the collections of the Buffalo Society of Natural Sciences. Other specimens, from which illustrations and descriptions were prepared, are contained in the Student Palæontological collection at Harvard University. The types of the new species, unless otherwise noted, are in the author's collection.

Harvard University,
Cambridge, Mass., Feb. 12, 1898.

CONTENTS OF PART I.

LIST OF PLATES.

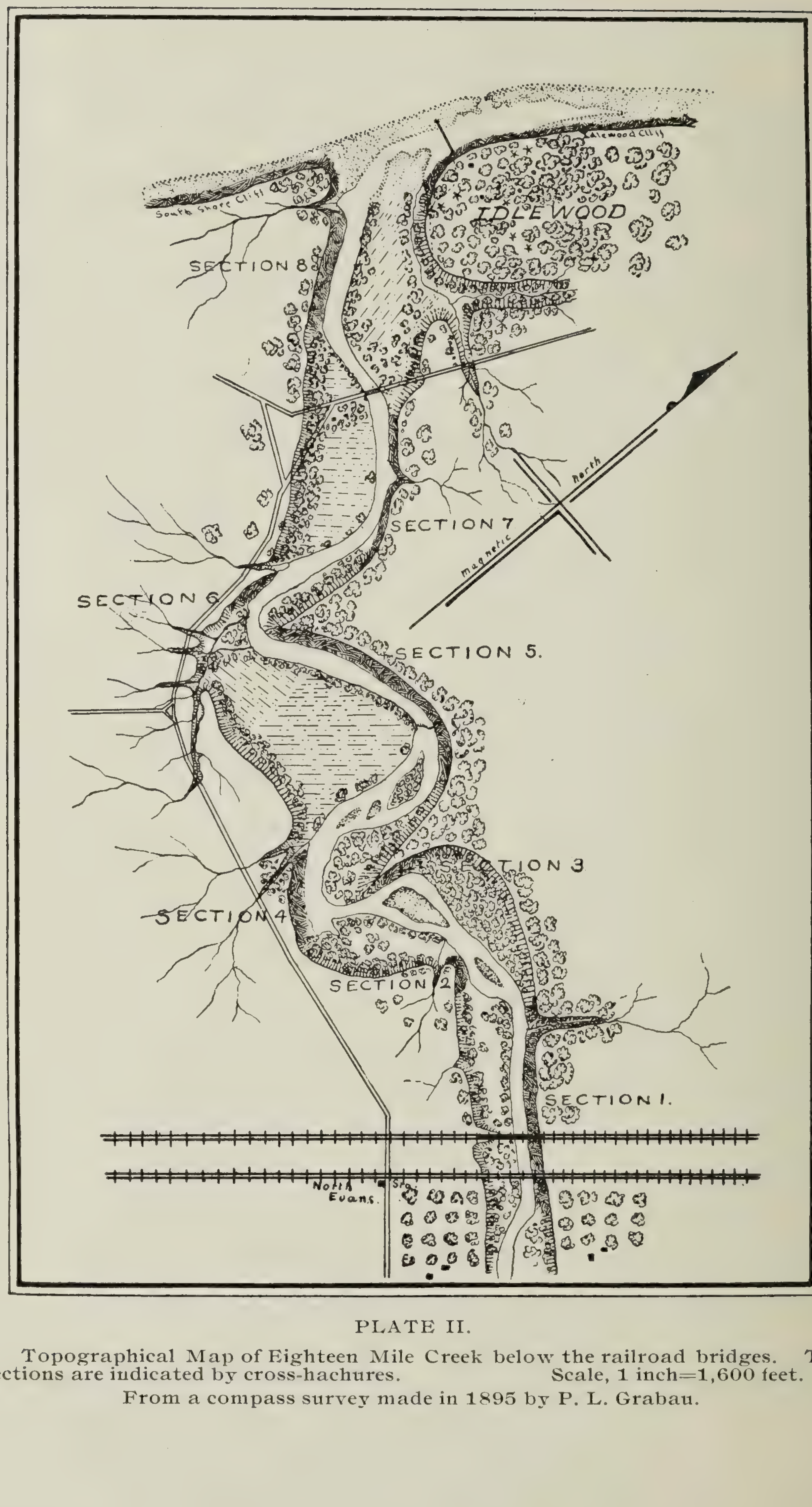

PLATE II.

Topographical Map of Eighteen Mile Creek below the railroad bridges. The sections are indicated by cross-hachures. Scale, 1 inch=1,600 feet.

From a compass survey made in 1895 by P. L. Grabau.

PART I.

GEOLOGY.

There rolls the deep where grew the tree;
O earth, what changes hast thou seen!
There, where the long street roars hath been
The stillness of the central sea.

—*Tennyson.*

INTRODUCTION.

Ever since the publication of the New York State Geological Reports, Eighteen Mile Creek and the shore of Lake Erie has been classic ground for the stratigraphist and palæontologist. Probably no other locality is so frequently referred to in the literature of the Middle Devonian of this country, as is this, under one of the following names: "Eighteen Mile Creek," "Shore of Lake Erie," "Hamburgh, Erie County," "West Hamburgh," or "Hamburgh-on-the-Lake."

The exposures in this area represent a continuous section, from near the base of the Middle Devonian to near the top of the Upper Devonian, and the total thickness of these beds is only a few hundred feet. Furthermore, the beds exposed represent deposits made at a considerable distance from the land, which was the source of the mechanical sediment. The conditions of the water in this area were consequently more uniform, and the deposits less complex than was the case in regions nearer to the old shore line. For these reasons the study of the Middle and Upper Devonian beds is profitably commenced in this locality. The sections furthermore, on account of the limited thickness of the formations, enable the student to take a more comprehensive view of the whole series than is possible farther east, in which direction the old shore-line is to be sought.

Structure.—It should be borne in mind, that the gorge of Eighteen Mile Creek is simply a deep, broad trench, cut into the strata, which before the cutting of the gorge, continued without interruption. In the walls of the gorge, where not obscured by vegetation, the cut edges of the strata appear on opposite sides, the portion of the beds cut out between, having been removed by the stream. This process of gorge cutting by natural agencies may be compared to artificial trench cutting for laying water pipes, where the sides of the trench commonly show the cut edges of the layers of sand, gravel or rock, which before cutting, were continuous. The tools with which nature cuts are: rock fragments, broken off by frost action, and carried by the stream over the bed-rock; loose stones and sand which the current sweeps along, and cakes of ice, which in early spring, float down stream. The mode of cutting the natural trench differs from that employed in cutting the artificial trench, in that it consists of a scraping, graving and pounding action, instead of a digging and blasting action. The results are similar in both cases, but the time occupied by nature in doing the work is vastly longer than that occupied by man in cutting a trench of similar magnitude by his more improved methods. But as nature has all eternity at her disposal, it matters not how slow she works.

While the trench is slowly deepened and widened, the atmosphere attacks the cut sides and breaks up the exposed portions of the strata. This is accomplished by the mechanical activity of freezing water in the fissures and between the layers, which are pried apart by the growing ice crystals, as well as by the chemical activity of the atmospheric gases and moisture, which cause the decomposition or decay of the rock. Thus the sides are degraded from perpendicular naked precipices to gently descending soil-covered slopes. The bed of Lake Erie may be regarded as such a natural trench of excessive width as compared with its depth. The opposite side of this trench is formed by the cliffs of the Canadian shore, though these, from the direction of the trench and the dip of the strata, consist of a different kind of rock. The New York bank of this trench is kept more or less fresh by the continual cutting of the waves, which has gone on ever since the waters of Lake Erie filled the trench and converted it into a lake.

V.

The rocks of this region are shales and limestones, with sandy layers in the upper portion of the exposed series. The shales predominate, and commonly split into thin laminæ or lenticular pieces, which lie essentially parallel to the bedding plane. These shales weather into clayey soil by the solution of the carbonate of lime, which here commonly forms an important cementing constituent. In this clayey soil we find a return to the more primitive condition of the material, for these slates were beds of clay before they assumed their present consolidated character. This clay, which was spread out over what was formerly the ocean floor, was derived from the disintegration of the rocks which formed the land at that period of the earth's history, rocks which were constantly attacked by the waves on the shore, the rivers and streams along certain lines on the surface of the land, and the atmosphere, wherever they were exposed. When the streams had brought their load of debris into the sea, where the waves and shore currents could distribute it, an assortment took place, the coarsest material being deposited near shore and the finer farther out to sea, in direct proportion to the degree of its fineness, and the strength of the current. It was only the clay—the result of the chemical decomposition of the rocks, and the finest rock flour—the result of the most effective comminution of the rocks, which were carried out into the comparatively quiet water at a distance from shore, and there deposited to form beds of mud. The empty shells of dead animals, which were strewn over the bottom of the sea in this region, as well as many still occupied by the animals, were buried in this accumulating mud, just as empty shells are buried on the modern beach, and as living mussels are buried more or less deeply in the fine material deposited off shore. The fine mud gradually found its way between the valves and filled the space once occupied by the soft parts, a condition characteristic of the occurrence of most bivalve shells on modern mud-flats. When in the course of time the mud became a shale, the shells became incorporated

Fig. i.—Anticlinal fold near St. Abb's Head, Scotland. (Geikie).

Fig. ii.—Synclinal fold near Banff, Scotland. (Geikie).

in the rock as fossils. The solid condition of most of the shells now found fossil in these rocks is due to the great induration which the filling of mud between the valves has undergone.

By the time that the mud-beds had completely hardened they had been raised above the surface of the ocean. This is indicated by the crowded condition of the strata about the enclosed concretionary masses, a condition which points to settling or shrinking of the strata, after the loss of the contained water, which could only occur after elevation. The elevation was probably due to those crust-movements which are termed "epeirogenic," and which produce extensive changes of level without involving the formation of mountains. The mountain-building or "orogenic" movements, which occurred towards the close of Palæozoic time, and to which the Appalachian ranges owe their existence, unquestionably affected this region. The initial inclination or "dip" which the strata had at the time of their deposition was accentuated, and the very slight undulations of the strata, which are observable in several places in Western New York, and of which slight indications occur in the Eighteen Mile Creek region, were probably produced at that time. Other structural features, common in mountainous regions were produced, the most pronounced of which are the folds and faults, which occur in a number of places as noted beyond. A *fold*, as the name implies, is a bend in the strata. A simple arch is called an *anticlinal fold* (fig. i.). When it is inverted, *i.e.* when it bends downward, it is called a *synclinal fold* (fig. ii.). When the strata are bent upwards, or downwards, and then continue as before, in other words, when the fold represents only half of an anticline or half of a syncline, it is called a *monoclinal fold* or *flexure* (fig. iii. and Plate XVI.).

A *fault* in stratified rocks, consists of a displacement of the beds along a plane of fracture, which is called the *fault plane*. Occasionally the fracture or fault plane is vertical (fig. iv.),

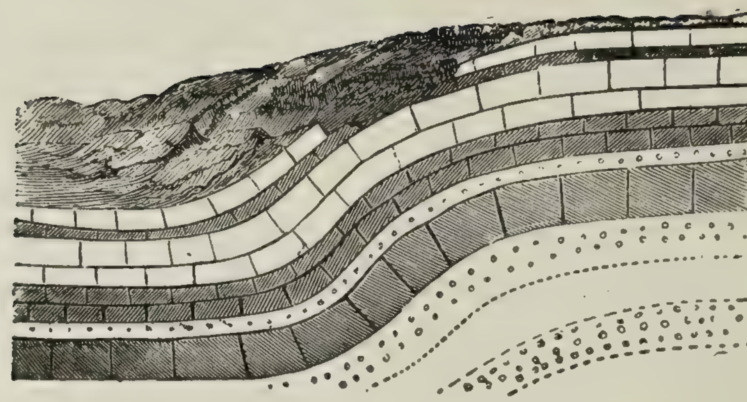

Fig. iii.—A monoclinal fold or flexure. (Powell).

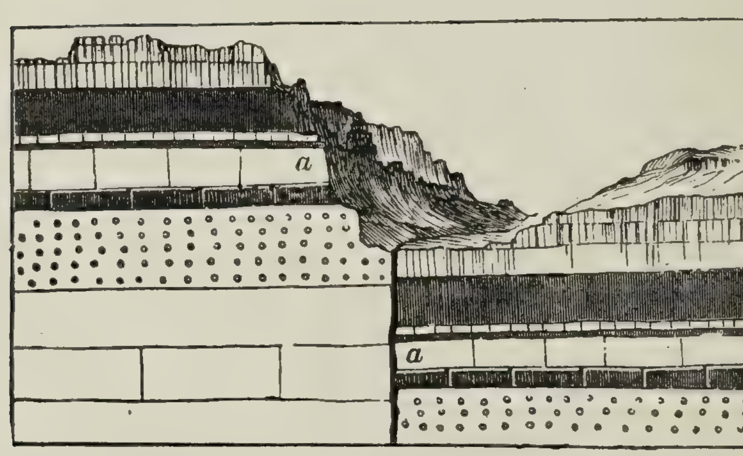

Fig. iv.—Section across a simple fault. (Powell).

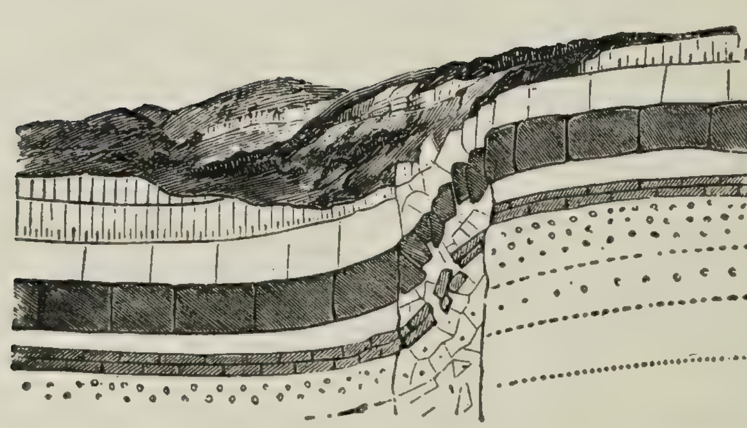

Fig. v.—Section across a monocline which is passing, by crushing of the strata, into a fault. (Powell). Compare Plate XVI.

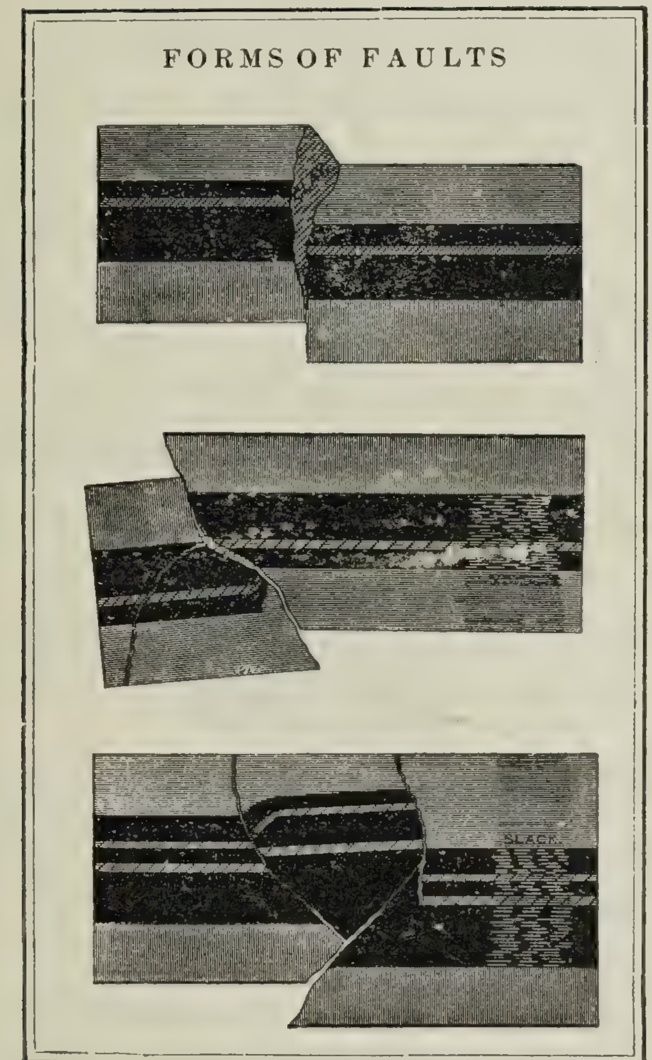

Fig. vi.—Gravity, and simple and compound thrust faults.

but more frequently it is inclined. The angle which the fault plane makes with the vertical in this latter case, is the angle of *hade*. The overlying portion of the strata, along an oblique fault plane, constitutes the *hanging wall* of the fault. The underlying portion constitutes the *foot wall*. If the hanging wall of the fault has slipped down, tension is indicated, for the strata now occupy more horizontal space than before, as can be easily tested by an experiment, with blocks to represent the strata. In such a case, the faulting was caused by the action of gravity, which pulled down the hanging wall. Therefore such a fault is called a "*gravity fault*," and in as much as most faults are gravity faults, they are commonly called "*normal faults*" (fig. vi., 1). If however, the hanging wall slips up, a compression is indicated, which shortens the beds, so that they occupy less horizontal space than before. A thrust force is required for the production of such faults, and they are therefore called "*thrust faults*." Being of less frequent occurrence than the other class, they are also called "*reversed faults*" (fig. vi., 2, 3). It is the latter kind which occurs in this vicinity.

Related to the disturbances which produced faults and folds, are those which produced *joint cracks*, *i. e.* those prominent fissures which traverse all the rocks of this region (see Plates III., XXVI. and XXVII.). One explanation of these is, that they originated through the action of earthquake shocks, which traversed the rocks, and produced a series of earth-waves, which in unconsolidated material would produce little effect, but in solid rock would produce these fissures at regular intervals (Crosby). The other well accepted explanation which accounts for these joints is, that by unequal elevation, the beds have become twisted and have been subjected to a torsion strain, and that this has produced the parallel and intersecting joints (Daubrée). Both causes undoubtedly co-öperate in the formation of these joints, as is well illustrated, when a sheet of glass is twisted and then a shock sent through it by a

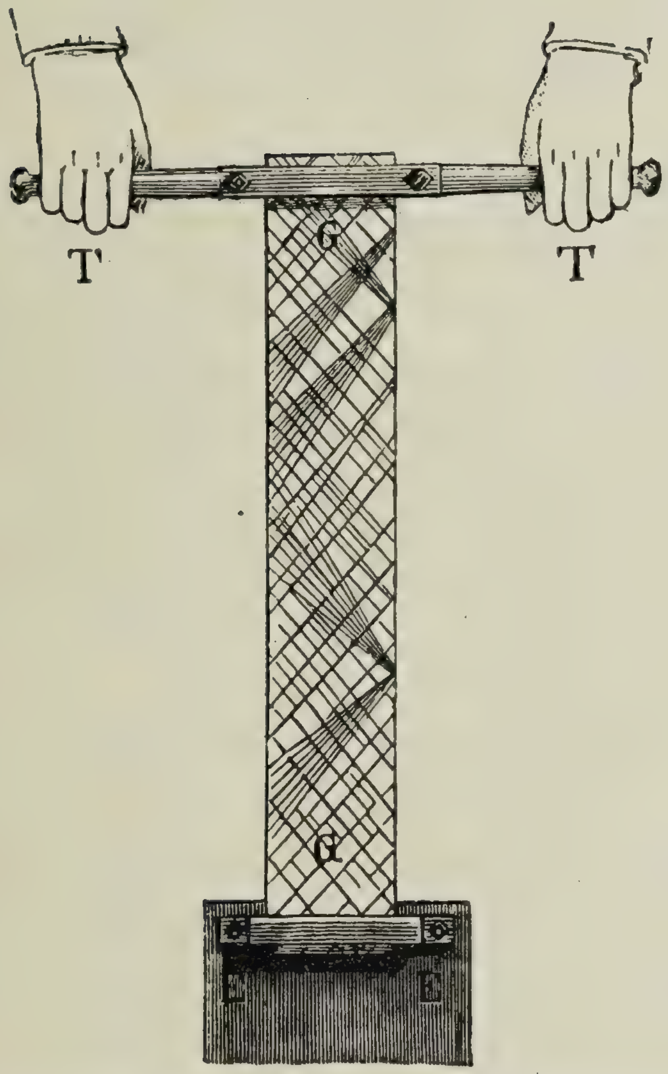

Fig. vii.—Apparatus for breaking plates of glass by torsion, with an example of the results produced. (Daubrée).

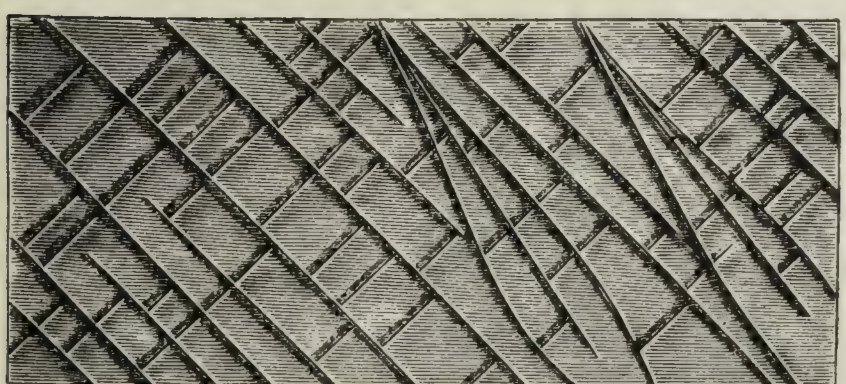

Fig. viii.—Arrangement of fractures in a large plate of glass which was broken by torsion. (Daubrée).

blow given in its vicinity. The glass will break, with the formation of two sets of parallel fractures, which intersect each other at a constant angle in a given piece (figs. vii. and viii.).

Nomenclature.—In the study of the geological formations of any region, it becomes necessary that a classification of the various beds should be made, and that a proper nomenclature should exist, so that each division and subdivision may be properly designated. Professor H. S. Williams has discussed the various systems of nomenclature which have been used for stratified rocks, and for a full account the reader is referred to his book.* A brief synopsis, and definitions of the various terms employed, are given here.

In the first place it must be remembered that we are dealing both with the rocks, and with the time occupied in their deposition. Consequently, a dual nomenclature and classification is necessary, and two kinds of scales must be adopted, namely: the "formation scale" and the "time scale."† The formation scale of classification takes account of the rock formations only, while the time scale is only concerned with geologic time and its subdivision. The time scale will be considered first.

The whole of geologic time is divided as follows:

CENOZOIC TIME—Time of "modern life."
MESOZOIC TIME—Time of "mediæval life."
PALÆOZOIC TIME—Time of "ancient life."
PROTEROZOIC TIME—Time of "first life."
AZOIC TIME—Time of "no life."

Each of these great "Time" divisions is characterized by the progress of life during its continuance, such progress being indicated by the names.

*Geological Biology, 1895.

†See H. S. Williams, Dual Nomenclature in Geological Classification. Journal of Geology, Vol. II., pp. 145–160.

The times are divided into eras, which have received locality names, as Devonic era from Devonshire, England, old historic names, as Siluric era, from the old tribe of Silures, or names derived from the lithological character of beds deposited during the era, as Carbonic era, from the coal beds deposited at that time. The division is chiefly based on biological changes.

The subdivision of eras is not a uniform one. The best is that proposed by H. S. Williams,* who would recognize in general an early, a middle and a later period in each era. The terms *Eo*, *Meso* and *Neo*, proposed by him, form suitable prefixes to which can be added the distinctive era name. Thus *Eodevonian*, *Mesodevonian* and *Neodevonian* are proper names to apply to the early, middle and later periods of the Devonic era.

Periods are divided into epochs, these latter marking the continuance of a characteristic species and its associates. The name applied to the epoch should be the specific name of the important species, a rule which as yet is not very generally followed. From the nature of the division it follows that it can not hold over very wide areas, and that its length may vary in different regions. The epoch during which the Hamilton shales of New York were deposited—here called the Spiriferoides epoch, from *Athyris spiriferoides*—can perhaps not be recognized outside of north-eastern United States and portions of Canada. The Stringocephalus epoch of Europe is, in part at least, its foreign equivalent. On the other hand, the Disjunctus and Intumescens epochs (Table B) are recognized in Europe, where they are marked by the same species. So too, the Acuminatus epoch, during which the Corniferous limestone of eastern North America was deposited, may be recognized in European geological history as the time during which *Spirifer cultrijugatus*, the European equivalent of *S. acuminatus*, existed.

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*Loc. cit.

The term "age" is frequently used in the succeeding pages. It is to be understood as capable of a general application in speaking of divisions of the time scale, whether large or small. The term age, is also used in designating the time occupied in the formation of a particular stratum, or substage, thus: Encrinal age, Moscow age and Styliolina age, or age of the Styliolina limestone.

The unit of classification in the formation scale is the *stratum*. Each *stratum* comprises a section of the formation, which consists throughout its thickness of the same rock material. Thus the Encrinal limestone is a stratum. Similarly the eight or nine feet of black uniform carbonaceous Genesee shales form one stratum. The stratum may be subdivided into *beds*, of which, in a thick stratum, there may be many. The bed may again be divided into *layers*, of which there may be several in one bed. A *rock formation* or *terrane* may consist of a single stratum, or of a number of strata, according to the magnitude of the division under consideration, but all the related strata of that particular division are included in the term *formation*. Thus the *Devonian formation* includes all the strata of the Devonian division, and the *Genesee formation* includes all the strata of the Genesee division.

The smallest division of the formation scale is the *stage*. This may comprise a number of strata, as in the case of the Hamilton stage. It may be subdivided into smaller formations, as is the case in the example here cited. The names applied to the stages are commonly locality names, but as in the Corniferous stage, the lithological character may furnish the name. The strata comprised within a stage are usually restricted in distribution, seldom covering more than a few hundred square miles of area, and they were all deposited during the continuance of the corresponding epoch. The stages are united into *groups*, the groups into *series*, and the series into *systems*. Groups are local in distribution, their formation depending on the physical conditions which existed during the corresponding period of time at the place where they occur. On this account rock groups commonly receive local names, such names being taken from the locality where the group is best developed, or where it was first studied. A number of local rock groups, known by various names, were deposited during each geological period, each group characterizing a different locality, and indicating different physical conditions during the time and at the place of its deposition. For purposes of correlation it is desirable to have one name to which the local groups can be referred, and such a name must be of general applicability. None of the local group names can be selected, no matter how much priority any one of them may have. For example: the Huamampampa sandstone of Bolivia was probably deposited while the Hamilton sediments were accumulating over New York, but the Huamampampa sandstones are not Hamilton. They are Middle Devonian just as the Hamilton sediments are Middle Devonian. It is therefore proposed to use the terms Lower, Middle and Upper to designate a threefold division of each rock *series* deposited during the corresponding geologic era. Thus the *Devonic series*, built up during the *Devonic era*, is divisible into three groups, the Lower, Middle and Upper Devonian groups, which were deposited respectively during the Eo, Meso and Neodevonian periods. This division may seem somewhat artificial, especially as some rock series are divisible into more or less than three groups in different localities. Thus in Tennessee the whole of the Devonic series is represented by the Chattanooga black shale, which in places is only twelve feet thick and shows no subdivisions. But in those twelve feet of shale are probably included the Lower, Middle and Upper Devonian groups. One division may be unrepresented, as is probably the case in the Devonic or Old Red Sandstones of Scotland, where only a Lower and an Upper group are recognized, the place of the Middle group being represented by an unconformity. Where a rock series is locally divisible into more or fewer than three groups, one of these local groups may correspond to a portion of a group in the general division, or to more than one of those groups. It remains for the student of the local group to adjust them to the general scheme, which is to serve as a basis for correlation and comparison.

The rock systems include those rocks which were formed during the corresponding great time division. Both series and system take the names of the corresponding eras and times.

In Table A, the subdivisions of the Palæozoic time and system are given, with the New York and other equivalents in common use. In Table B, the detailed subdivision of the New York Devonic is given.

NOTE.—*Tropidoleptus carinatus* is a much more widely distributed Hamilton species than *Athyris spiriferoides*. The former occurs in Middle Devonian beds throughout New York, at the Falls of the Ohio, and at various localities in Ohio, Pennsylvania and Illinois. It is also abundant in the Middle Devonian sandstones of the Rio Maecurú in the Amazonian district, S. A., and in the Erere, Province of Para, Brazil. It furthermore occurs in Devonian beds at Lake Titicaca; on the Rio Sicasica, Bolivia; in South Africa; in France, Germany and England. In many of these localities it is associated with *Vitulina pustulosa*. In some of the last mentioned localities however, the beds characterized by these species are regarded as of Eodevonian age. The wide distribution of *Tropidoleptus carinatus* would make the adoption of the name *Carinatus epoch* for a single epoch of the Mesodevonian period desirable (the Marcellus to be included in this epoch), were it not for the discrepancy in the ages of the beds characterized by this species at the various localities.

TABLE A.—Palæozoic Subdivisions.

TIME SCALE.	FORMATION SCALE.	PROMINENT NORTH AMERICAN EQUIVALENTS. (Chiefly New York State Equivalents).
PALÆOZOIC TIME.	**PALÆOZOIC SYSTEM.**	
5. CARBONIC ERA.	5. CARBONIC SERIES.	
c. Neocarbonian period	*c.* Upper Carbonian group	Upper Barren Measure Group. (Pennsylvania). (Permian).
b. Mesocarbonian period	*b.* Middle Carbonian group	Pennsylvanian* Group. (Pennsylvania). (Carboniferous—Equivalent to: Coal measures and Millstone grit of Mississippi Valley).
a. Eocarbonian period	*a.* Lower Carbonian group	Mississippian* Group. (Mississippi Valley). (Sub-carboniferous—Equivalent to: Mauch Chunk and Pocono of Pennsylvania).
4. DEVONIC ERA.	4. DEVONIC SERIES.	
c. Neodevonian period	*c.* Upper Devonian group	Chemung Group.
b. Mesodevonian period	*b.* Middle Devonian group	Hamilton Group.
a. Eodevonian period	*a.* Lower Devonian group	Upper Helderberg Group.
3. SILURIC ERA.	3. SILURIC SERIES.	
c. Neosilurian period	*c.* Upper Silurian group	Lower Helderberg Group.
b. Mesosilurian period	*b.* Middle Silurian group	Onondaga Group.
a. Eosilurian period	*a.* Lower Silurian group	Niagara Group.
2. ORDOVICIC ERA.	2. ORDOVICIC† SERIES.	
c. Neoördovician period	*c.* Upper Ordovician group	Trenton Group.
b. Mesoördovician period	*b.* Middle Ordovician group	
a. Eoördovician period	*a.* Lower Ordovician group	Canadian Group.
1. CAMBRIC ERA.	1. CAMBRIC SERIES.	
c. Neocambrian period	*c.* Upper Cambrian group	Potsdam Group.
b. Mesocambrian period	*b.* Middle Cambrian group	Acadian Group. (Eastern Provinces).
a. Eocambrian period	*a.* Lower Cambrian group	Georgian Group. (New England).

*H. S. Williams, Bull. 80, U. S. Geol. Survey, 1891.

†Lapworth's name is here used in place of the old "Lower Silurian." Only two groups are recognized in New York State, the Canadian and Trenton, but in the typical British locality, three groups are recognized: 1–Arenig, 2–Llandeilo, and 3–Bala and Caradoc Groups.

TABLE B.

SUB-DIVISIONS OF THE NEW YORK DEVONIC.

TIME SCALE.	FORMATION SCALE.
DEVONIC ERA.	DEVONIC SERIES.
c. Neodevonian period........	...*c*. Chemung group.
2. *Disjunctus* epoch........	........2. Chemung stage.
	(2). Chemung sandstones and shales.
	(1). Portage sandstone.
1. *Intumescens* epoch.....	........1. Genesee stage.
	(3). Naples shales.
	(2). Genesee shales, including Styliolina limestone.
	(1). Tully limestone.
b. Mesodevonian period.....	...*b*. Hamilton group.
2. *Spiriferoides* epoch.....	........2. Hamilton stage.
	(3). Upper or Moscow shales.
	(2). Encrinal limestone.
	(1). Lower or Hamilton shales.
1. *Minuta* epoch............	........1. Marcellus stage.
	(1). Marcellus shales.
a. Eodevonian period.........	...*a*. Upper Helderberg group.
3. *Acuminatus* epoch.....	........3. Corniferous stage.
	(2). Corniferous limestone.
	(1). Onondaga limestone.
2. *Caudagalli* epoch.......	........2. Schoharie stage.
	(1). Schoharie grit and Esopus shales.
1. *Hipparionyx* epoch....	........1. Oriskany stage.
	(1). Oriskany sandstone.

The name "*Disjunctus* epoch" (H. S. Williams) is derived from the characteristic fossil *Spirifer disjunctus*, while the name "*Intumescens* epoch" is derived from the characteristic fossil *Goniatites intumescens*.* "*Spiriferoides* epoch" and "*Minuta* epoch" are derived from the fossils *Athyris spiriferoides* and *Orbiculoidea minuta*, which are practically confined to their respective epochs. The names are of limited applicability.† In the Eodevonian period, the name "*Acuminatus* epoch" is used for the last epoch, it being derived from the characteristic fossil *Spirifer acuminatus* Conrad. This species is represented by *S. cultrijugatus* F. Roemer, in the upper (Coblenzian) part of the Rhenan or Lower Devonian

*See J. M. Clarke, Intumescens fauna, Am. Geol., Vol. VIII., p. 86 et seq.

†See note page xvi.

of the Eifel in western Germany, and in the Ardennes on the borders of France and Belgium. The same species is found in the Lower Devonian rocks of South Devonshire. If, as is held by many authors, the two species are identical, Roemer's name must give way to the earlier one of Conrad. The "*Caudagalli* epoch" is named from the peculiar sea-weed, the *Spirophyton* (*Taonurus*) *caudagalli*, which abounds in the rocks formed during that epoch, while the "*Hipparionyx* epoch" is so called after the brachiopod *Orthis hipparionyx* (*Hipparionyx proximus*).

The rock formations have, with few exceptions, received their names from typical localities in New York State. Thus Chemung is derived from Chemung Narrows; Portage from Portage on the Genesee River; Naples from Naples, Ontario County, (the two shales comprised under this name, *i. e.* the Gardeau and Cashaqua, having received their names from the Gardeau flats on the Genesee, and from Cashaqua Creek, respectively); Genesee from the Genesee River at Mt. Morris; Tully from Tully, Onondaga County, (this rock is absent in the Eighteen Mile Creek region); Moscow from Moscow, Livingston County; Hamilton from Hamilton, Madison County; Marcellus from Marcellus, Onondaga County; Helderberg (both upper and lower) from the Helderberg mountains; Onondaga from Onondaga County; Schoharie from Schoharie County, and Oriskany from Oriskany Falls, Oneida County. All of these localities exhibit typical exposures. The other names, viz, Encrinal (crinoid bearing) and Corniferous (chert or hornstone bearing), are names derived from the character of the rock.

When we study the rocks in greater detail, we find in them associations of fossils which do not occur above or below a certain level. This association is called a *fauna*. The Century Dictionary definition for fauna is: "the total of the animal life of a given region or period; the sum of the animals living in a given area or time." Thus the Lake Erie fauna includes the present animal life of that region. Similarly the Hamilton fauna is the sum of the animal life which existed during that period. We may speak of the fauna of a stratum, as for instance the "Encrinal limestone fauna," or the "Spirifer sculptilis fauna," or the fauna of a bed viz: the "Demissa fauna."

Methods of Study.—In beginning the study of the stratified rocks of this region, it is highly desirable that a stratum be selected which may be used as a datum plane, with reference to which the position of all the beds may be ascertained. There are two such reference strata in this region, both of which, on account of their great areal extent over Western New York, will also serve in the correlation of the strata of the Eighteen Mile Creek region with those of more eastern localities. These strata are the Styliolina limestone, which here forms the base of the Upper Devonian, and the Encrinal limestone, which separates the Moscow and Hamilton shales. The first of these is seen in seven of the eight sections in Eighteen Mile Creek, and again in the first of the South Shore Cliffs. The Encrinal limestone is first exposed in Section 5 in Eighteen Mile Creek, and appears in all the sections below that one, as well as in the cliffs on both sides of the mouth of Eighteen Mile Creek. While therefore, the Styliolina limestone forms a reference plane for the upper strata of this region, the Encrinal limestone becomes a convenient datum plane for the lower beds.

A third stratum which may be used as a reference plane in this region, is the Strophalosia bed, which lies fifty feet below the Encrinal limestone, and is considered the top bed of the Marcellus stage. This bed is exposed in Avery's Creek, and in Erie and Athol Springs Cliffs.

The study of the several cliffs is best undertaken in the order in which they are described in chapters one and two. The following itinary is suggested: Leave the train at North Evans station, and descend into the gorge by the steps of the abutment of the stone railroad bridge (see Plate IV.). The stream can usually be crossed near the bridge, where the Styliolina limestone forms the bed of the stream. Taking this stratum as the first datum plane, the overlying beds, exposed in the section can be studied with reference to it. The loose blocks in the bed of the stream will well repay attention, and the shale outcrops between Sections 1 and 2 should not be overlooked.

By following the map, the various sections can be examined, and the rocks studied in descending order. The Styliolina bed will always serve as a guide for the determination of the position of the various beds. Below Section 4, are numerous exposures of the Moscow shale in the bed of the stream, and these deserve attention. In Sections 5 to 7, the Styliolina limestone occurs only at a considerable elevation above the base of the section, but the Encrinal limestone can here be selected as the reference plane.

The first of the South Shore Cliffs is conveniently examined after the Eighteen Mile Creek sections, as it will afford a review, in ascending order, of the strata studied in the gorge, in descending order.

After reaching Pike Creek, leave the shore and return by the Lake-shore road or along the top of the cliffs, to the left or southern bank of Eighteen Mile Creek, and follow the road, which in many places skirts the bank, and affords good general views of the sections, all the way to North Evans village, and beyond.

The Lake Shore Cliffs south of Pike Creek are best approached from Derby or stations further south. A bicycle will be found convenient, as the cliffs are all approachable from the Lake-Shore road. A full day should be devoted to the examination of these cliffs, while weeks may be advantageously spent on them in detailed study.

The North Shore Cliffs can be approached from Lake View station or the Lake-shore road. The study of the Idlewood and Wanakah Cliffs will occupy the time of one excursion, the Erie and Athol Springs Cliffs, together with the ravine of Avery's Creek affording sufficient material for a second, and Bay View Cliff for a third, rather shorter excursion. All these can be approached from the Lake-Shore road. Erie and Athol Springs Cliffs are best approached from Hamburgh-on-the-Lake station (p. 60), while the Bay View Cliff may be easily approached from Woodlawn Beach.

After the sections have been studied in a general way, the details of the various beds will demand the attention of the student, and the longer the time occupied in their study, the more satisfactory will be the results. Attention should be given to the proper succession of the beds, and collections from the talus should not be made while engaged in the study of stratigraphy, unless it be from fragments of beds whose position is definitely known.

In Table C, the beds of this region, with the sub-divisions shown in the sections, are given.

TABLE C.

STRATIGRAPHY OF EIGHTEEN MILE CREEK AND THE LAKE SHORE SECTIONS IN ERIE COUNTY, NEW YORK.

THICKNESS OF BEDS.	RELATION OF BASE OF BEDS TO: TOP OF STYLIOLINA LIMESTONE.	TOP OF ENCRINAL LIMESTONE.	BASE OF ENCRINAL LIM'STN'E.	NAME OR DESCRIPTION OF BEDS.	CLASSIFICATION OF BEDS.		
	+48 to 50′	+66 to 68′	....	Gardeau shales (base)............................		Upper	Naples Shales.
8 inches.	+ 32′	+50′	....	Goniatite bed..		Lower	Naples Shales.
30 ft.	+ 18′	+36′	....	Cashaqua shales (base)..........................		Lower	Naples Shales.
9.5 "	+ 8.5′	+26.5′	....	Upper, black Genesee shales.....................		Genesee Shales.	
8.5 "	+ 0′	+18′	....	Lower, gray Genesee shales.....................		Genesee Shales.	
.5 "	— .5′	+17.5′	....	**Styliolina limestone**.............................		Genesee Shales.	
.25 "	— .75′	+17.25′	....	Conodont limestone.................................		Genesee Shales.	
.25 "	— 1′	+17′	....	Spore-bearing shales.................................		Genesee Shales.	
....	....	....	....	....			
12-14 inches.	— 2′	+16′	....	Transition beds with Schizobolus fauna, (*Schizobolus truncatus*, *Liorhynchus multicostus*, *Ambocoelia præumbona*).	Spirifer tullius fauna.	Upper	Upper Hamilton or Moscow Shales.
3 ft.	— 5′	+13′	....	Shales and concretionary beds.................	Spirifer tullius fauna.	Upper	Upper Hamilton or Moscow Shales.
8 "	— 13′	+ 5′	....	Barren shales, containing near the middle a thin band, with *Orbiculoidea media*, *Schizobolus truncatus*, and a few other species, all rare..........................		Middle	Upper Hamilton or Moscow Shales.
3.25 "	— 16.25′	+ 1.75′	....	Shale with *Spirifer consobrinus*, etc.........	Spirifer consobrinus fauna.	Lower	Upper Hamilton or Moscow Shales.
.25 "	— 16.5′	+ 1.5′	....	Coral layer, with *Heliophyllum halli*, *Cystiphyllum*, *Atrypa aspera*, etc.........	Spirifer consobrinus fauna.	Lower	Upper Hamilton or Moscow Shales.
1.5 "	— 18′	+ 0′	....	Shale with *Chonetes* and *Ambocoelia umbonata*..	Spirifer consobrinus fauna.	Lower	Upper Hamilton or Moscow Shales.

TABLE C.—Continued.

Thickness of beds.	Relation of base of beds to: Top of Styliolina limestone.	Top of Encrinal limestone.	Base of Encrinal lim'st'ne.	Name or description of beds.	Classification of beds.
1.5 ft.	— 19.5′	— 1.5′	0	**ENCRINAL LIMESTONE**	Spirifer sculptilis fauna.
1 inch.	— 20′	— 2′	— .5′	Stictopora bed, (*Stictopora incisurata*, *Nucleospira concinna*, crinoid joints)	Spirifer mucronatus fauna. Lower Shales or Hamilton Shales proper.
4 inches.	— 20.5′	— 2.5′	— 1′	Demissa bed, (*Stropheodonta demissa*, *Spirifer mucronatus*, and more than 70 other species)	
.5 ft.	— 23.5′	— 5.5′	— 4′	Tentaculite bed, with *T. gracilistriatus* and *Styliolina fissurella*	
.75 "	— 28.5′	— 10.5′	— 9′	Athyris spiriferoides bed	
.5 "	— 39.5′	— 21.5′	— 20′	Lower Athyris spiriferoides bed	
1 to 2 inches.	— 44.5′	— 26.5′	— 25′	Modiomorpha subalata bed	
1 ft.	— 53.1′	— 35′	— 33.5′	Calcareo argillaceous bed	
2.5 "	— 61.5′	— 43.5′	— 42′	Trilobite beds, with intercalated shales (base of Eighteen Mile Creek sections).	
2.25 "	— 63.75′	— 45.75′	— 44.25′	Fossiliferous shale, with Bryozoa bed at base (1 inch)	
1 inch.	— 66′	— 48′	— 46.5′	Hard bed, with *Spirifer granulosus*, etc.	
1.5 ft.	— 68.5′	— 50.5′	— 49′	Upper and Middle Pleurodictyum beds, with shales	
4 inches.	— 69.5′	— 51.5′	— 50′	Nautilus bed, base of Hamilton shales	
5 ft.	....	— 52′	— 50.5′	Strophalosia truncata bed, (*Strophalosia truncata* and Mollusca)	Transition beds. (Upper Marcellus Shales.)
29.5 "	....	— 81.5′	— 80′	Transition shales	
3 inches.	....	— 82′	— 80.5′	Pteropod bed	Upper Marcellus beds. (Upper Marcellus Shales.)
2 inches.	....	— 88′	— 86.5′	Ambocoelia bed	

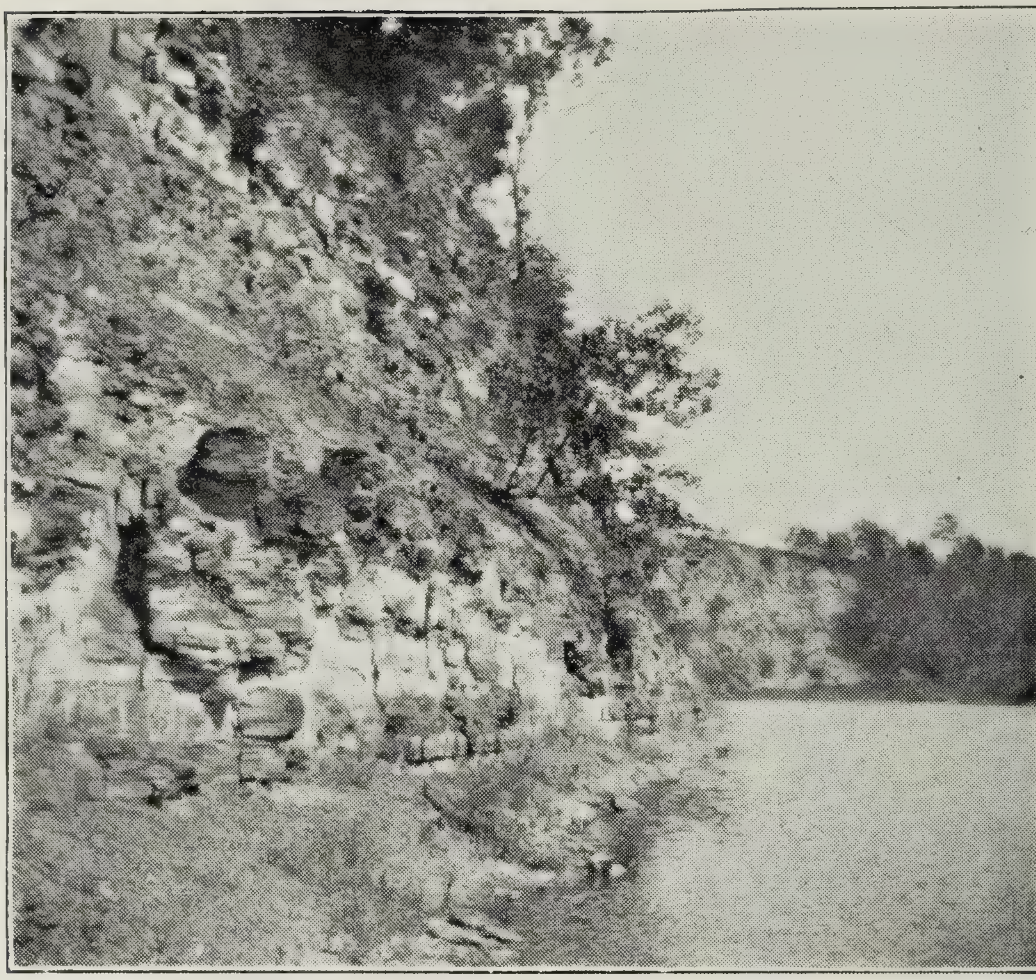

PLATE III. (*a*).—View of the cliffs in the gorge of Eighteen Mile Creek, above North Evans.

(*b*).—View of the joint structure in the Gardeau black shales, above North Evans.
—Photographed by A. W. GRABAU.

CHAPTER I.

THE GEOLOGY OF EIGHTEEN MILE CREEK.

General Description.—Eighteen Mile Creek belongs to the St. Lawrence drainage system, its waters being tributary to the basin of Lake Erie. The course of the stream lies wholly within the southern portion of Erie County, N. Y., its most important sections, from a stratigraphical point of view, lying within, or on the borders of the township of Hamburgh.

Taking its origin in the southern uplands of the county, it flows northward and westward, receiving numerous tributaries, until its united waters are poured into Lake Erie at a point just eighteen miles south-west, along the lake shore, from the former village of Black Rock, at the head of the Niagara River, a site now included within the limits of the city of Buffalo.

The general direction of the stream in the last two miles of its course is north-westerly, and for this distance it forms the boundary line between the townships of Evans and Hamburgh. For the greater part of its course the stream flows through a rocky gorge, the walls of which, in many places, rise to a perpendicular height of a hundred feet or more.

The strata exposed in the gorge of the main stream and its tributaries all belong to either the middle or upper part of the Devonian series. The lowest beds found in the gorge are exposed at the mouth of the main stream and belong near the base of the Hamilton stage. The highest beds exposed in the upper portions of the gorge probably belong to the lower Chemung, *i. e.* the Portage sandstone, but this is simply a matter of inference as the upper gorge and branches have not been examined.

The lower portion of the gorge is wider than other parts. This is to be accounted for by the presence of the softer Hamilton shales, which first become prominently exposed about a mile from the lake shore. The stream also makes a greater number of turns in this part of its course, thus furnishing sections which extend in different directions. The widening of the gorge in this portion is due to lateral planation or undercutting in the soft shales, which causes the upper shales and calcareous beds to fall down. This destruction of the banks is materially advanced by the very perfect development of joint fissures which traverse all these rocks and which allow the separation of the shale and limestone masses after they have been undermined by the stream. Such of the fallen material as comes within the transporting power of the current, is carried away, and only the larger rocks remain. (See Plate XI.). These may accumulate in such numbers at the foot of the cliff as to form an effectual protection against the current when the amount of undercutting will be reduced to a minimum. The foundations for a talus thus laid, rock fragments broken from the cliffs by frost and heat will slide down and accumulate, and finally the sloping bank is produced, which from the decomposition of the rock becomes soil covered and overgrown with vegetation. In this manner a talus may form even though the stream keeps close to the base of the cliff as in Section 7. (Plate XII.). In Section 6 a talus would probably be formed were it not for the fact that the blocks of Encrinal limestone are carried away for building purposes. Ordinarily, however, the cliff is kept free from such accumulations as long as the stream keeps close to its base. But if the deflection of the current transfers the cutting zone to another portion of the stream bed, the cliff will rapidly be degraded by atmospheric action, a heavy talus will accumulate, and vegetation growing upon this talus will completely hide the underlying rock.

As will be noted by reference to the map (Plate II.) the talus is best developed upon the inside of the bends, where deposition, rather than erosion takes place, while the banks on the outside of the bends are usually kept perpendicular by the current which continually undermines them.

Fronting the degraded banks, we usually find level terraces built up during seasons of high water from the material derived by the stream in the upper part of its course. These terraces rise from three to five or six feet—rarely more—above the stream bed and they are very level on top. The more extensive ones are utilized as farm and garden lands. Such is the case with the terrace below the Idlewood Camp Grounds opposite Section 8, with the Glen Flora terrace opposite Section 7, and with the extensive terrace opposite Section 5. The other terraces indicated upon the map are uncultivated. A few cultivated terraces of small extent exist in the gorge opposite North Evans village, but above this the terraces and flats along the river side are largely in a state of nature.

At the North Evans station, about a mile and a half above the mouth of the creek, the gorge is spanned by two railroad bridges—that of the Lake Shore and Michigan Southern Railroad, a stone bridge, and that of the Western New York and Pennsylvania and the Nickel Plate Railroads, an iron structure. At the stone bridge the gorge has a depth of eighty-eight feet, and it is between this point and the lake shore that the most interesting sections are exposed, these alone being considered in the following pages.

Age of the Gorge.—The gorge is wholly post-glacial in origin; there is, however, a pre-glacial valley which mouths about a mile to the north of the present gorge. This valley which is over a thousand feet wide, and a section of which is seen in the bank on the lake shore, is deeply filled with drift material, containing many Corniferous Limestone boulders. The valley of this old river, which may be called the pre-glacial Idlewood river, underlies the estate of Mr. Albert Myer, but it has not been traced inland beyond this. Mr.

P. L. Grabau, however, reports its existence near Water Valley and near North Boston.

Detailed Description of the Sections.—There are eight sections between the railroad bridges and the lake shore. These will be considered in descending order, beginning with the one at the stone railroad bridge on the right side of the stream, which will here be designated Section 1.* (Plate IV.).

Section 1 (H).

Plate IV.

This section has a total height of ninety and one-half feet, although at the bridge the height is only eighty-eight feet. The length of the section is about eight hundred feet, and it extends north 50 degrees west, by south 50 degrees east. The strata dip one degree to the south-east. Near the lower end of the section is a small lateral ravine ("Philip's ravine") which extends back three hundred feet or more, where a vertical wall of shale terminates it. This ravine affords a good opportunity for the examination of the upper beds of this section, especially the "Cashaqua" shales.

The following is the thickness of the various beds exposed in this section, taking them in descending order:

Black Naples or Gardeau	40	feet.
†Grey Naples or Cashaqua	30	"
‡Black Genesee	9.5	"
Gray Genesee	8.5	"
Styliolina bed	.5	"
Conodont Limestone	.25	"
Shale	.25	"
Moscow Limestone and Shale	1.50	"
Total	90.50	feet.

*This is the way in which these sections were designated in the field notes, but in my paper on the "Faunas of the Hamilton Group of Eighteen Mile Creek and Vicinity" they are lettered from the lake shore upwards, the present one being Section H.

†Prof. Hall assigns a thickness of thirty-three feet to this rock on the shore of Lake Erie.—Geol. Rept., 4th Dist., 1843, p. 227.

‡The whole thickness of the Genesee on the shore of Lake Erie is made by Hall twenty-three feet and seven inches.—Ibid, p. 221.

PLATE IV.—View of Section 1 at the stone railroad bridge. The rock in the foreground is the Styliolina limestone. The black Genesee shales project from the bank, and above them the gray Naples (Cashaqua) shales form a sloping bank. —Photographed by I. P. Bishop.

The Black Naples Shales (Gardeau shales).—These are highly bituminous, dark brown or black shales, with a chocolate colored streak. They split into thin layers, which often have iridescent surfaces. When struck with a hammer they emit a strong petroleum odor. The joint fissures are well developed, two sets usually being recognizable. These, together with the fissility of the shales, often give the cliff the appearance of having been cut up artificially, smooth walls, projecting prisms and parallelepipeds resulting, while deep fissures frequently penetrate into the rock. Fossils are rare and consist mainly of plant remains, commonly in an unidentifiable condition.

This rock forms the walls of the gorge for many miles above the bridges, the lower strata having entirely disappeared beneath the bed of the stream. The black shale is succeeded by olive shales, some of which are more sandy than others, but all are quite destitute of fossils as far as known at present. Without doubt, however, diligent search will reveal an interesting, though limited fauna, probably containing a number of fish remains.

Although the rock is generally deficient in calcareous material on account of the scarcity of fossils, such material does occur at intervals in the form of calcareous concretions. These are often of great size—sometimes eight or ten feet in diameter, but usually much smaller. They are commonly lense shaped, though gobular or loaf shaped forms are not uncommon. Imitative forms of grotesque appearance are frequent. The stratification is sometimes continuous through them, at other times the strata bend over and under them exhibiting a crowded appearance, as if the growing concretion had forced them apart. It is probable, however, that the concretion was fully formed before the lithification of the adjoining strata had taken place, and that on the contraction of the rock consequent upon lithification, the strata settled down, and produced this crowded and bent appearance. The source of the calcareous material is to be looked for in the scattered shells and other calcareous remains, which were dissolved by the percolating waters. The exterior of the concretion seldom shows any veining, but when broken, a series of calcite veins, usually branching and intercrossing, is seen. These veins are often beautifully banded, exhibiting white crystalline calcite in the center, and successive bands of darker impure calcite towards the margin. The veins are largest in the center and thin out towards the periphery of the concretion. When exposed to the mechanical wear of the stream, and to the solvent action of the water, the outer crust is removed, and as more and more of the claystone is worn away the veins begin to stand out in relief, because the pure crystalline calcite is much less soluble than the amorphous particles which cement the clay. The septate or divided appearance thus produced has given rise to the name "septaria," commonly applied to this class of concretions. Where a considerable portion of the concretion has been worn away, the calcite veins—usually stained yellow or brown by hydrous oxide of iron—appear very prominent, and by their intercrossing cause a resemblance of the concretion to the back of a turtle, on which account these rocks are often called "turtle stones," "turtle backs" or "petrified turtles."

Large numbers of these concretions, derived from the shale banks above the bridge, are carried down every spring by the floating ice, and strewn over the flats and the river bed in the lower portion of the gorge, where they form one of the curious attractions, exciting commonly more interest than the large numbers of finely preserved fossils occuring with them.

Regarding the mode of formation of these concretions little is known. They undoubtedly bear a genetic relation to the clay stones common in unconsolidated deposits in various portions of this and other countries. When lithification of the concretion begins, chiefly through the loss of the combined water, a radial contraction takes place, which must be towards the periphery of the concretion, since the weight of the superincumbent strata prevents the formation of cracks in the outer shell. Consequently the cracks are widest towards the center and disappear towards the periphery of the concretion. Whether the calcite and other mineral matter filling these cracks, is derived from without, by infiltration, or from the concretion itself by segregation, is still an open question. If the latter occurs, the processes of widening of the fissures by radial contraction of the rock mass, and of segregation of the mineral matter are probably simultaneous, so that at no stage are there any open fissures.

The Gray Naples Shales (Cashaqua shales).—These shales are greenish gray in color, much less fissile than the preceding, and prone to weather into a tenacious clay. They embrace numerous layers of concretions, but in general these do not exhibit the septarium structure. This is probably due to the fact that the calcareous matter is more abundant in these shales than in the black shales above, and hence the concretions partake more of the nature of concretionary limestone masses.

The upper fifteen feet of these shales, while rich in concretions, seem to be very poor in organic remains, no fossils having been noted in them. They form the lower part of the vertical wall which terminates Philip's ravine, but in the main section they face the stream in a sloping, more or less weathered and talus covered bank, supporting vegetation in some places. Below this, at the base of the terminal wall of Philip's ravine, and forming a prominent band in the main section, is a layer of calcareous concretions, or better a concretionary bed of impure limestone, eight inches in thickness. This probably corresponds to J. M. Clarke's "Goniatite concretionary layer,"* in as much as specimens of *Goniatites* are of common occurrence in it, usually forming the nucleus of the concretion. Several species of *Goniatites* occur, but they are seldom found in a good state of preservation. They are commonly found in a very much compressed condition, frequently perfectly flattened, and from having been replaced by iron pyrites which subsequently oxidized, much, if not all of the structure is obliterated. The external form and amount of involution therefore become the only characters

*J. M. Clarke: On the higher Devonian faunas of Ontario County, N. Y. Bull. 16, U. S. Geol. Survey, 1885, p. 38 et seq.

by which to identify the species, and this, at best, can be but an unsatisfactory identification. In a few cases, in the specimens collected, the septal sutures are shown, allowing a more precise determination. The most abundant and characteristic species of *Goniatites* in these concretions are *Goniatites intumescens* (Beyr.) and *G. lutheri* (Clarke). The non-umbilicated species are rare, a single doubtful specimen having been noted. Besides the *Goniatites* a few other fossils occur in this rock. Those found are:

Coleolus aciculum (Hall).
Styliolina fissurella (Hall).
Cardiola retrostriata (von Buch).
Lingula spatulata (Vanux.).
Chonetes lepida (Hall).

Cardiola retrostriata (von Buch) is the only other common fossil, and although most of the specimens are small, they show all the characteristic features. *Lingula spatulata* (Vanux.) is represented by small specimens only. This and the other species are rare.

In the shale below the Goniatite bearing layer, fossils are rare. Occasionally in the immediate neighborhood of the layer, Goniatites occur, but these are usually so poorly preserved that specific determination is out of the question. *Cardiola retrostriata* (von Buch) also occurs, though much less commonly than in the concretionary layer. *Lunulicardium fragile* (Hall) is sparingly represented, and with it occurs usually the minute pteropod *Styliolina fissurella* (Hall). *Coleolus aciculum* (Hall) is another sparingly represented species, and a few Orthoceratites occasionally occur. One well-preserved specimen of *Orthoceras* allied to *O. mephisto* (Clarke) was found.

On the whole, the fauna of these beds is a very meagre one, and were it not for the *Goniatites*, which are frequently found, lying at the foot of the cliff, it might be entirely overlooked.

In Ontario County and the Genesee Valley, this shale has a much greater thickness, amounting, according to Hall* to about 150 feet in Ontario County. Correspondingly we find a richer fauna, sixty-six species having been recorded by Clarke in 1885.† The fauna is rich in *Goniatites*; and as Clarke has shown, recalls the characteristic association of fossils found in the "Intumescens" beds of the lower Upper Devonian of the continent of Europe. It is therefore regarded as representing the transatlantic development of the European "Intumescens fauna." (See J. M. Clarke—"The fauna with *Goniatites intumescens* (Beyr.) in Western New York." Am. Geol., Vol. VIII, p. 86.)

The Black Genesee Shales.—These shales recall the bituminous Naples shales, the latter representing a recurrence of the conditions under which the bituminous Genesee shales were deposited. These shales are fissile when weathered, but appear heavy bedded in the fresh mass. Pyrite in minute disseminated grains, and in larger concretionary masses is very common, and from its oxidation, the surfaces of the weathered shale laminae are covered with a coating of red and brown iron rust. There are, however, no large calcareous concretions, such as are common in the black shales above. The jointing is very perfect, and frequently blocks produced by the intersection of the joints, project from the wall, ready to fall. The joint faces are often thickly covered with an efflorescence of alumn.

The oxidation of the pyrite furnishes free sulphuric acid, which, if in excess, will attack the shale and form aluminium sulphate and silica. The reactions may be written:

a. $2\ Fe\ S_2 + 7\ O_2 + 2\ H_2O = 2\ Fe\ SO_4 + 2H_2\ SO_4.$

b. $6\ H_2SO_4 + Al_2(Si\ O_3)_3\ Al_2O_5H_4$‡$= 2\ Al_2(Si\ O_4)_3 + 3\ Si\ O_2 + 8\ H_2O.$

The aluminium sulphate will crystallize in dry places.

Fossils are rare in these beds and consist mainly of the characteristic Genesee species, viz: *Lunulicardium fragile* (Hall) and *Styliolina fissurella* (Hall).

The Gray Genesee Shales.—These consist in descending order of:

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*Geol. N. Y. Rep't, 4th Geol. Dist., 1843, p. 221.

†Bull, 16 U. S. Geol. Survey. The number of species has been added to since then.

‡The approximate formula for clay slate.

a. Seven feet of grayish and purplish shales with bands of bituminous shales. Towards the top these shales weather considerably, but farther down they are more resistant, and large thin slabs may be obtained.

b. Eighteen inches of bituminous black shales, with two bands of limestone, each an inch in thickness, and made up of the exuviae of the minute pteropod *Styliolina fissurella* (Hall).

This latter mass contains an interesting association of fossils, representing a commingling of Hamilton and Genesee species, but with a preponderance of the latter. *Lunulicardium fragile* (Hall) is the most abundant fossil in the black shale, and with it occurs *Styliolina fissurella* (Hall), though not very commonly, except in certain places. *Lingula spatulata* (Vanuxem) is a fairly common and well preserved shell, passing through several variations. *Orthoceras* and *Bactrites* are represented by small species, and these with *Coleolus aciculum* (Hall) are frequently replaced by iron pyrites. *Goniatites* are rare, a few small specimens having been found, including *G. lutheri* (Clarke). *Spirifer tullius* (Hall) is fairly well represented for a normal Hamilton species. Of crustacean remains, a small ostracod—*Entomis* (?) has alone been found. Plant remains in an unidentifiable condition occur frequently. The included limestone bands represent accumulations of enormous numbers of the small tapering pterepod tubes known as *Styliolina fissurella* (Hall). To the unaided eye the limestone has a compact appearance, with indications of a finely crystalline texture on the broken surfaces. Viewed under a magnifier, the rock appears finely crystalline, and if sufficiently magnified, is seen to be made up of the very fine delicate needle-like shells. Occasionally these are large enough to be clearly visible under an ordinary magnifier, or even to the naked eye. Most commonly, however, a considerable magnification is needed to show the shells clearly.

The only other fossil observed in these beds is *Lingula spatulata* (Vanuxem), which is not uncommon, and of average size.

The Styliolina Limestone.—This is a continuous stratum from four to six inches thick, and of a somewhat concretionary character. It forms the bed of the stream under the bridge, and for the greater part of the distance fronting the section. (Plate IV.). Its concretionary character is brought out by the differential solution which it has undergone, an irregular undulating surface resulting. A part of this is, however, original structure, as shown by the overlying shales which conform to it. Near the lower end of this section the stream has cut down through this rock, exposing it in its full thickness, together with the "Conodont" limestone and a part of the underlying Moscow shales.

The Styliolina limestone is usually very compact, without any appearance of crystalline structure. It is highly argillaceous, giving off a strong clay odor when breathed upon. This fact accounts for the great amount of solution which the rock has suffered on the exposed surfaces. These surfaces invariably present a dissolved appearance, which is not unlike an artificially smoothened mass of moulding clay, which still shows the finger marks upon it. This solution has brought out in relief the contained organic remains other than *Styliolina* and the otherwise smooth surface frequently exhibits small projecting fragments and joints of crinoid stems, black shining "conodonts" and other minute organisms. This is especially true of the under side of the bed, which thus exhibits a close relation to the next underlying bed. The whole of the limestone is made up of the exuviae of *Styliolina fissurella* (Hall) which frequently are visible to the unaided eye. The shells lie in all positions, a fact prominently brought out by thin sections. (Fig. i).

The Styliolina (Styliola) layer was first described by Clarke* from Ontario county and adjoining districts. It there lies about twenty feet above the base of the Genesee formation and varies in petrographical character in its different outcrops. Clarke has estimated that the rock contains at least 40,000 individuals of the *Styliolina* to a cubic inch, which, when the whole extent of this limestone bed is taken into consideration, indicates an almost incredible numerical development of these shells. According to Clarke's investigations† the shells have been filled by calcic carbonate, deposited in even concentric layers on the inside of the shell, a longitudinal section of a shell thus having the appearance of vein infiltration. Many shells also have an external coating of calcic carbonate, which like the internal filling, has a crystalline structure.‡

Plant remains are not uncommon in the Styliolina stratum, these being usually the trunks and other woody parts of coniferous trees, most of which may probably be referred to the genus *Dadoxylon* (Unger). These tree trunks are supposed by Sir William Dawson to have been carried by river floods into the sea, like modern drift wood, and there buried in the growing lime stones and shales, and finally to have been replaced by mineral matter.

The genus *Dadoxylon* (Unger) is referred by Dawson to the yews,§ while Shenk‖ classes it with *Cordaites*. Speaking of these trees Dawson says¶: "It" (the wood) "often shows its structure in the most perfect manner in specimens penetrated by calcite or silica, or by pyrite, and in which the original woody matter has been resolved into anthracite or even into graphite. These trees have true woody tissues, presenting that beautiful arrangement of pores or thin parts enclosed in cup like discs, which is characteristic of the coniferous trees, and which is a great improvement on the barred tissue" (of lycopodiaceous trees) ". . . . . . . affording a far more strong, tough and durable wood, such as we have in our modern pines and yews." A remarkable fossil wood was described by Dawson under the name *Syringoxylon mirabile*°, from a small fragment collected by Prof. Hall—"from a limestone in the upper part of the Hamilton group" at Eighteen Mile Creek. The limestone referred to is probably the Styliolina, or perhaps the "Conodont." The wood is that of an angiospermous exogen, the

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*J. M. Clarke, Bull. 16, U. S. Geol. Surv., p. 14.

†Loc. cit., p. 15.

‡For a detailed description of the interesting optical phenomena exhibited in sections of these shells, see Clarke, Bull. 16, U. S. Geol. Surv., p. 16.

§Geol. Hist. of Plants, 1888, p. 78.

‖Zittel Handb., d. Pal. 2te Abth., p. 870.

¶Loc. cit., pp. 79 and 80.

°Quart. Journ. Geol. Soc., Vol. XVIII., p. 305, 1862.

specimen constituting, according to Dawson, the sole representative of this class of trees in the Palaeozoic, implying "the existence in the Devonian Period of trees of a higher grade than any that are known in the Carboniferous system."*

The fossil wood, as it occurs in the limestone, is always much compressed, and its determination is attended with considerable difficulty. Nevertheless the specimens are interesting as examples of "petrified woods" related to, and in a sense ancestral to, the fossil woods of the Tertiary and Post-tertiary forests of the west, which have furnished so many beautiful and often brilliantly colored specimens for our cabinets.

The Conodont Bed.—This limestone is from two to two and one-half inches thick, and full of fossils, which on the weathered surfaces stand out in relief. The rock is concretionary, with thin masses of shale occupying the deeper hollows. In some places masses of bituminous shale lie between it and the overlying Styliolina limestone, while in others again the two are in contact. The rock is more coarsely crystalline than the Styliolina limestone, and is always readily distinguished from the latter.

The Conodont bed is interesting on account of the numerous fish remains which it contains, these being usually the plates and jaws of Placoderms, the spines of Sharks and more rarely the scales of Ganoids. Most of the remains are fragmentary, though small perfect plates and scales are occasionally found. When weathered in relief they have a highly dissolved appearance. These fish remains are not confined to the Conodont bed, but frequently pass upward into the lower portion of the Styliolina limestone.

Another characteristic class of fossils in this rock and the one which has given in it's name, is that of the so-called "Conodonts." These are minute jaw-like bodies, black and lustrous, covering the weathered surfaces of the rock in great

*Loc. cit.

numbers. In form they are very variable, no two probably being exactly alike. A number of species have been described by Hinde from this bed, and they are all illustrated in Part II. They are composed of carbonate and phosphate of lime, and were regarded by Pander and others as the teeth of Myxinoid fishes. According to Zittel and Rohen*, however, they must be regarded as jaws of Annelids.

The Conodont bed was described and named by Hinde†, who discovered its position in this and the adjoining sections of Eighteen Mile Creek. He referred it to the Upper Hamilton, which was clearly erroneous, as all its affinities, lithological and palaeontological are with the Styliolina of the Genesee. This is well shown by the fact that in places the rock loses its distinctive character and is made up of local accumulations of *Styliolina fissurella* (Hall).

Normally the rock is composed of the fragments of crinoid stems, and probably some other calcareous remains, mingled with those of fish plates and corneous conodonts. Grains of a green mineral, probably glauconite, are common, and pyrite likewise occurs in considerable abundance. In a thin section, fine quartz grains appear at intervals. Altogether the limestone may be regarded as a fragmental rock, composed of the broken remains of organisms, with a very small admixture of transported material.‡

Besides the fossils already mentioned, imperfect specimens of (?) *Ambocoelia umbonata* (Conrad) have been noticed in the rock, but in general, the shells, if they occur, are so poorly preserved as to be unidentifiable.

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*Zittel and Rohen, "Ueber Conodonten." Sitzungsber. Bay. Akad. Wissensch. Bd. XVI., 1886.

†Quart. Journ. Geol. Soc. Vol. 35, p. 352, et seq.

‡Since the above has gone to press, my friend, Dr. Theodore G. White of Columbia College has examined, at my request, thin sections of the Conodont limestone. He has kindly furnished me with the following note concerning the petrographic character of this rock: "The sections strongly resemble in appearance the silicate bunches occurring in the Archaean or Algonkian limestones at Port Henry, N. Y., near the contact with the crystalline rocks and ore bodies. The texture of the rock is distinctly crystalline and the mineral fragments do not seem to be water rounded. *Magnetite* is very abundant through the sections, accompanied by *pyrite*. *Biotite* ranks next in abundance and forms a large proportion of the mass of the rock. Scattered throughout the sections are long shreads of a fibrous mineral, white in color, scarcely polarizing and giving no interference figure. The extinction angle is 25° to 28°, which would indicate that the mineral was probably *cyanite*. It contains grains of the magnetite, as does also the biotite. *Quartz*, *calcite* and *hornblende* are present in lesser amounts. One distinct and very perfect spherulite was observed."

In addition to the above, the rock contains the organic remains already noted.

The Conodont, the Styliolina, and the overlying eighteen inches of bituminous shale and limestone (b) may be designated collectively as the *Styliolina band.*

The fauna of this band appeared again under more favorable conditions during the deposition of the Naples shales, when the Goniatites were much more abundant. It did not, however, reach such a luxuriant development in this region, either in its first or its second appearance, as was the case in the Genesee Valley. Clarke has noticed over fifty species from the Styliolina band of that region, besides numerous Conodonts and fish remains*. Careful exploration of these beds in the region about Eighteen Mile Creek will undoubtedly reveal a richer fauna than is now known, though the number of species and individuals will probably always be much smaller than that characterizing the fauna in the Genesee Valley.

The Conodont limestone is seen in this section only near the lower end, where the stream has cut through the Styliolina limestone. Large blocks of the rock are scattered about in the bed of the stream near the lower end of the section, and for some distance below. With them are blocks of the Styliolina limestone, of Corniferous limestone, and occasionally of Encrinal limestone, these latter two having been carried by floating ice from the bridge, where they were brought for purposes of construction.

Underlying the Conodont bed are about two inches of shale, which are divisible into an upper chocolate colored band, frequently bearing *Styliolina fissurella* (Hall) and occasionally *Conodonts*, and a lower, almost unfossiliferous gray band, which splits into thin laminae, with smooth surfaces, having a talcose feel. Besides the *Styliolina*, the chocolate colored slate contains numerous small, flattened disclike bodies, of a black carbonaceous appearance, the spores of plants allied to modern rhizocarps. These spores, (macrospores) when viewed under the microscope, present thick, rounded rims, and a more or less irregularly depressed centre. They are frequently thickly scattered through the shales, giving to them, in part at least, their bituminous

*Am. Geol., Vol. VIII., p. 86 et seq.

character.* Similar spores occur in vast numbers in Devonian shales and limestones of various parts of the United States and Canada, and to them the name *Sporangites* (*Protosalvinia*) *huronensis* was given by Dawson. Allied spores have been discovered in widely separated localities all over the world, and they are not infrequently found in such quantities as to suggest that they may play a not unimportant role in the accumulation of vegetable carbon. In the Devonian shales of this country they probably constitute one of the sources of petroleum and natural gas. Spores are occasionally found in the gray portion of the shale, but they are very rare.

The spores are, as a rule, readily separated from the shale, and may be mounted either in balsam or dry. When viewed under the microscope by transmitted light, the discs appear of an amber or orange hue, translucent and structureless, except for minute spots, which are regarded as pores in the thick walls. The size varies; the ordinary specimens having a diameter of from one seventy-fifths to one one-hundreds of an inch (one-third to one-fourth of a millimeter). Some of the spores, however, are larger. Flocculent carbonaceous matter often occurs, associated with these macropores, probably representing the more or less decomposed microspores.

These shales mark the base of the Genesee stage, and, since the Tully limestone is absent, the base of the Upper Devonian.

The Moscow Shales. These, the upper shales of the Middle Devonian, are exposed near the lower end of Section 1, where about a foot is visible. The top of the series is formed by a gray concretionary limestone band, four inches thick and highly argillaceous. It is a very refractory rock, and of a uniform texture throughout. Fossils are common, but they are chiefly of three species which characterize this horizon. These are:

Liorhynchus multicostus (Hall).
Schizobolus truncatus (Hall).
Ambocoelia praeumbona (Hall).

*According to Newberry, the carbonaceous matter of the bituminous shales is mainly derived from the broken down and carbonized tissues of algae and other low plants. See his paper on this subject in the Annals of the New York Academy of Sciences, Vol. II., No. 12, 1883.

The first of these is a form common at various levels in the Hamilton group. Nowhere, however, does it occur so abundantly and so well preserved as at this level, and it is especially in the concretionary limestone bed that this fossil shows its characteristic outline and convexity of valves. It is a form eminently characteristic of the Hamilton stage, giving way in the Genesee to a form with few, almost obsolete plications, the *L. quadricostatus* (Vanuxem), which however, apparently did not flourish in this vicinity. *Schizobolus truncatus* (Hall) (Fig. 85, Pt. II.) is a characteristic Genesee fossil, not commonly occurring below that formation. In fact, this appears to be the first locality from which this fossil has been recorded as occurring in the Hamilton beds, and its occurrence here is in direct accord with the slow change from Hamilton to Genesee conditions which took place in this portion of the Interior Devonian Sea.* It is a noteworthy fact that this species has not been found in the Genesee shales of this region, though it seems to be a characteristic fossil of that formation in the Genesee Valley and eastward. It usually occurs in the limestone bed as separate valves; not infrequently showing the interior of the valves. Where the true surfaces of the valves are exposed, either internal or external, these commonly have a bluish-gray color, which seems to be characteristic, and due to the corneous character of the shell.

Ambocoelia praeumbona (Hall) (Fig. 127, Pt. II.) while a characteristic Hamilton fossil, is, in this region entirely restricted to the upper part of the Moscow shales. It is an abundant and well-preserved form in the concretionary limestone bed, retaining its normal convexity in both valves. The specimens vary considerably in size, and occur usually as separate valves, their surface characters commonly obliterated through the exfoliation of the outer layers of the shell. Brachial valves are quite as common as pedicle

*See Chapter III.

valves, and are at once recognized by their semi-elliptical outline, slight convexity and straight hinge line.

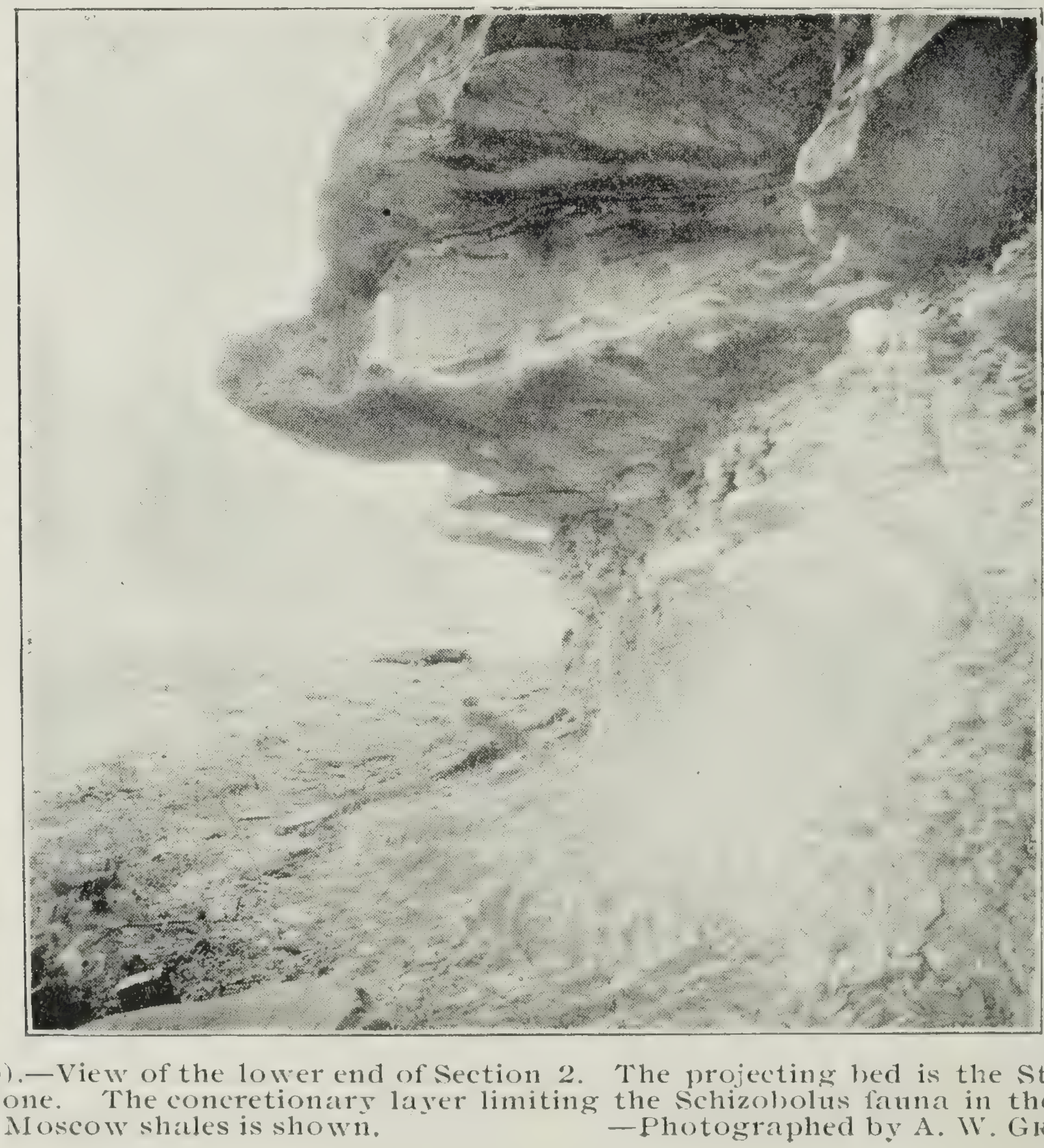
These three species occupy the rock almost to the exclusion of every other form, and constitute a distinct association of fossils, which is characteristic of the upper part of the Moscow shale of this region. The fauna thus produced constitutes the "Schizobolus fauna," named so after its most characteristic member, and, inasmuch as it contains typical Hamilton and typical Genesee fossils, it is a true *transition fauna* from the Middle to the Upper Devonian of this region.

The most fossiliferous portion of the rock is that portion having the character of individual concretions. The more continuous portion of the bed, while containing these fossils, is nevertheless comparatively barren.

The limestone rests on gray calcareous shale, readily splitting into thin layers, and moderately fossiliferous. On the surfaces to which air and water have access whitish or yellowish granules can usually be observed scattered thickly over the shale and the fossils. Sometimes these are so closely crowded as to give the rock an oolitic appearance. Under a lens these granules appear dull, rounded or disclike, but under a microscope they appear to be bunches or aggregates of small crystals. Analysis shows them to be crystals of gypsum (hydrous sulphate of calcium). The origin of these crystals is explained by the occurrence of pyrite grains and nodules in considerable number in the shale. These by oxidation form sulphate of iron, which reacts with the calcium carbonate in the shale and produces calcium sulphate. Free sulphuric acid is likewise formed, which reacts with the calcium carbonate to form calcium sulphate, water and carbon dioxide. The calcium sulphate, from the presence of water during its formation will be hydrated. The formation of the gypsum is probably going on constantly, just as the alum is constantly forming on the exposed laminae of the Genesee and other bituminous shales.*

*See the reactions given in Chapter II.

PLATE V. (*a*).—View of a part of Section 1, showing the Styliolina limestone at the base, the Genesee shales and the Naples shales.



(*b*).—View of the lower end of Section 2. The projecting bed is the Styliolina limestone. The concretionary layer limiting the Schizobolus fauna in the underlying Moscow shales is shown. —Photographed by A. W. GRABAU.

This shale well repays careful study, for in it occur a large number of those minute problematical bodies, the "Conodonts." They are readily detected by the use of a lens, and from the nature of the rock in which they are imbedded, they are in an excellent state of preservation, and afford interesting objects for microscopic study.

Ambocoelia praeumbona (Hall) occurs in considerable numbers in some portions of this shale, but the specimens are smaller on the average than those found in the calcareous bed above. *Liorhynchus multicostus* (Hall) also occurs, the specimens occasionally attaining great size. Some of the specimens of this species from these shales, approach much more closely to the typical *L. quadricostatus* (Vanuxem) of the Genesee than any of those found either above or below. Besides these, the minute pteropod *Styliolina fissurella* (Hall) occurs, often in considerable numbers, on the laminae of the shale.

Section 2 (G).

Plate V.

This section is a very short one, being scarcely more than three hundred and fifty feet in length. It is cut in the left bank of the stream, and extends in the same general direction as the preceding one. The dip of the strata is greater than that of Section 1, being about 2.5 degrees to the southeast. A large portion of this section is covered by the decomposed shale which the rains have carried down from above, and on which a strong growth of vegetation has become established, obscuring the rocks underneath. In consequence of this, the upper strata are well exposed only near the up-stream end of the section, but from the steepness of the bank at this point the study of these strata is attended with considerable difficulty.

The Black Naples Shales appear at the top of this section, and they are again exposed in a "dug way" which leads from the terrace, just beyond the section, to the top of the bank. The whole of the Gray Naples or Cashaqua shales is exposed in this section and the concretions are numerous. Those of the Goniatite stratum are frequently found at the foot of the section, where they have fallen on being loosened by frost action and the disintegration of the bank. The specimens of *Goniatites* in these concretions, as in those of Section 1, are much compressed, and only the outline and the degree of involution of the respective species are as a rule discernable.

The Genesee shales show the same characteristic as in Section 1. The upper bituminous portion projects in masses bounded by joint planes, and where these masses have fallen after the removal of the support, smooth walls remain, on which frequently may be observed an efflorescens of alum. The shales usually present the rusty surfaces on their laminae which result from the oxidation of the pyrite. The lower portion of the Genesee is, as everywhere in this region, represented by about eight feet of grayish shale with a few bituminous bands, and grades below into the Styliolina band. This has much the character noticed at Section 1, except that the Styliolina limestone is about ten inches thick. In the black shale of the "band" spores are not uncommon, while *Lunulicardium fragile* (Hall) and *Styliolina fissurella* (Hall) are the only other abundant fossils. The Conodont limestone is chiefly represented in the upstream end of the section. Here it is about three inches thick, less compact than at Section 1, and rich in crinoid joints, which on the weathered surfaces stand out in relief. This causes the rock to contrast strongly with the overlying Styliolina limestone, which always has a dissolved appearance, owing to the uniformity of its texture. Near the middle of the section, the Conodont bed dwindles in thickness to less than an inch, and finally appears only as a thin coating on the under side of the Styliolina limestone.

From the erosion of the soft Moscow shales the Conodont and Styliolina limestones together project for some distance beyond the bank, frequently forming an overhanging shelf, which in the course of time will break down, carrying with it large masses of the overlying shale. (See Fig. b, Pt. V.).

About four feet of the Moscow shales are exposed near the lower end of the section. The concretionary limestone bed which capped the shale at Section 1, is here represented by a layer of scattered concretions which contain a few fossils, principally *Liorhynchus multicostus* (Hall). About a foot below this is a second layer of concretions, double in many places, and more continuous than the upper one. The shale between these two layers of concretions contains the Schizobolus fauna, *i. e. Schizobolus truncatus* (Hall), *Liorhynchus multicostus* (Hall) and *Ambocoelia praeumbona* (Hall). The first of these is quite common and well preserved. Large individuals of the other two are common, but the shells exfoliate so strongly that the original surface characters are seldom preserved in the specimens obtained.

About four inches below the lower bed of concretions, or from fourteen to sixteen inches below the top of the Moscow shales, occurs a band of pyrite concretions, some of which are of considerable size.* They are highly impure, and when oxidized show as a brown band in the cliff. *L. multicostus* (Hall) occurs abundantly down to the pyrite layer, after which it becomes rare. *Ambocoelia praeumbona* (Hall) is common, however, throughout the exposed portion of the shale in this section.

In the lower beds of this section a dwarfed form of *Spirifer tullius* (Hall) occurs, a species which, in this region, appears to be wholly restricted to the upper Moscow shales. *Schizobolus truncatus* (Hall) occurs occasionally, but fossils on the whole, are rather uncommon. The characteristic association, however, of three species restricted to the upper Moscow shale, namely: *Spirifer tullius* (Hall), *Ambocoelia praeumbona* (Hall) and *Schizobolus truncatus* (Hall),

*My attention was first called to this band and its persistence in the other sections by Prof. I. P. Bishop.

establish a distinct fauna—the *Spirifer tullius fauna*—which occupies the upper four feet of the Moscow shales of this region.* The Schizobolus fauna (or faunule) is merely the last phase of this fauna, where *Spirifer tullius* (Hall) has disappeared, while *Schizobolus truncatus* (Hall) and *Liorhynchus multicostus* (Hall) have reached a great numerical development.

Between Sections 1 and 2, the Moscow shale is exposed in various portions of the stream bed.

Section 3 (F).

Plate VI.

This section extends almost due north and south, and it forms a projecting point, the termination of a semi-circular wooded rock wall, which itself is an extension of Section 1. In front of this cliff is an extensive "flat" or terrace, rising four feet or more above the river bed. The portion of the cliff showing the rocks is only about five hundred feet long. It is kept clear of talus by the stream, which washes its base. The most prominent rock of the cliff is the black fissile and much jointed upper Genesee shale, which here as everywhere, projects from the bank. The Gray Naples or Cashaqua shales appear above it, and in some parts of the section, a portion of the Black Naples (Gardeau) shales can be seen. The lower Genesee shales form the greater portion of the remainder of the cliff, while only a slight thickness of the Moscow shales appears. The Styliolina projects as a shelf from the bank, and on its under side frequently patches of the crystalline Conodont limestone appear, never, however, exceeding a fraction of an inch in thickness. The beds dip about one degree to the south.

Of the Moscow shales, eighteen inches are exposed at the lower (southern) end of the section, and three feet at the upper (northern) end. The shale embraces a very con-

*For a complete list of the species of this fauna see "Faunas of the Hamilton Group of Eighteen Mile Creek and Vicinity."

PLATE VI.—View of the lower end of Section 3. The upper portion of the Moscow shales is exposed at the foot of the section. The projecting Styliolina band, the gray and much-jointed black Genesee shales, and a portion of the Cashaqua shales appear above it. —Photographed by A. W. GRABAU.

tinuous layer of calcareous concretions, one-half foot below the top at the upper end and one foot below the top at the southern end. This layer, therefore, dips to the south at a higher angle than does the Styliolina bed. It corresponds to the lower of the two layers of concretions noticed in Section 2, the shale over it containing the Schizobolus fauna. In the shale beneath the concretions, a considerable variety of fossils occur, most of which, however, are but sparingly represented. The characteristic Hamilton trilobite *Phacops rana* (Green) is not uncommon, while a minute pteropod, the *Tentaculites gracilistriatus* (Hall) occurs in great abundance in a layer less than half an inch think. This species occurs by the hundreds on the shale laminae, closely resembling the *Styliolina fissurella* (Hall), and showing a similar longitudinal line of compression. The concentric rings or annulations, however, which are characteristic of the genus, serve to distinguish it at once. *Spirifer tullius* (Hall) is also a frequent and characteristic fossil.

Just beyond the lower end of the section, in the bed of the stream, appears a small anticlinal fold, the axis of which extends nearly north and south. The fold indicates a lateral compression of the strata, as a result of which they were crushed and uplifted. The line of weakness thus produced probably determined the course of erosion, which has removed the overlying rock. In the shale thus crushed occur a large number of the spiny brachiopod *Productella spinulicosta* (Hall), none of which, however, retain their original outline. The long slender curved spines appear, however, in great numbers on the shale, an occurrence nowhere else observed. (Fig. 112, Pt. II.).

Section 4 (E).

Plate VII.

This section is cut into the left bank of the stream, beginning opposite the southern end of Section 3, and extending in a general north-west direction. Opposite it is the deepest portion of the creek, and when the water is high, it is practically impossible to pass along the foot of the cliff. The greatest height of the section is seventy-seven feet, but it becomes much lower towards its down-stream end. The dip of the strata, as determined from the Styliolina limestone, is about four degrees to the south-east, giving an average rise of one foot in one hundred and fifty. The section has a length of about six hundred feet.

At the upper end of the section, between twenty-five and thirty feet of the Black Naples (Gardeau) shales are exposed, the line of demarkation between them and the underlying Cashaqua shales being very distinct. (See Fig. a, Pl. VII.). The whole of the latter shales are exposed, including seven distinct courses of concretions. The line of separation between the Cashaqua and the Genesee shales is not so strongly defined, the latter, however, exhibiting their characteristic jointing and fissility. (Fig. b, Pl. VII.). The Styliolina limestone has a thickness of ten inches, its upper portion having a shaly character. At the upper end of the section it forms the basal layer, projecting as an extensive shelf beyond the bank. Its surface here is very uneven, showing the same semi-concretionary character exhibited under the bridge at Section 1, and wherever a large area of its surface is exposed. At the lower end of the section the Styliolina limestone is about four feet higher, and frequently projects from the bank when the shale beneath has been worn away. The disintegration and falling of the shales above furnish material for the accumulation of a talus on this shelf, which may remain in this position long enough for vegetation to grow. Sooner or later, however, the undermining is carried so far that the projecting limestone blocks break off, and with their loads of debris, tumble into the stream. The Conodont limestone is not represented in this section.

The whole four feet of the upper Moscow shales, which contain the Spirifer tullius fauna, are exposed at the lower

PLATE VII. (*a*).—View of the upper end of Section 4. The base of the section is formed by the Styliolina limestone, above which are visible the gray and black Genesee, and the Cashaqua and Gardeau shales.

(*b*).—View of the Genesee shales of Section 4, showing the characteristic jointage of the black shales. —Photographed by A. W. GRABAU.

end of the section. The lowest portion of this mass of shale contains chiefly *Ambocoelia praeumbona* (Hall), which for the first time made its appearance in this region, and continued to the close of the Hamilton or Mesodevonian period. The characteristic species of this fauna all occur in these shales, the type species *Spirifer tullius* (Hall) having its best development near the middle of the series. The layer of concretions which marks the downward limit of the Schizobolus sub-fauna (faunule), appears again in this section. It is usually double, and very continuous. At the upper end of the section it is twelve inches below the Styliolina limestone, while at the lower end it is only four inches below that rock. The point of first appearance of this layer in Section 4 is just opposite the southern end of Section 3. In both places the layer is a foot below the Styliolina band, and approaches it as we go northward.

The shale between this layer and the Styliolina limestone is especially rich in *Liorhynchus multicostus* (Hall), which occurs by the hundreds between certain of the shale laminae. Many of the specimens are of great size, but the shell commonly breaks away, while the specimens usually present a compressed, semi-crushed appearance. The other members of the Schizobolus sub-fauna are by no means rare. The layer of pyrite nodules noticed in Section 2 is sparingly represented here, occuring in a similar position.

At the lower end of the section the Genesee shales form the top of the bank, which is here much lower than elsewhere. Beyond the end of the section, where a roadway leads to the top of the bank, is the mouth of "Fern brook" ravine, which is cut back nearly to the main road, and terminates in a vertical wall, over which, in wet weather, the drainage of a considerable portion of country descends as a fall. In this ravine only the Upper Devonian shales are exposed, and it is a place more frequented by the botanist than by the geologist.

Between this section and the next, there is a long reach of the stream, banked by no well cut sections. There are numerous exposures in the bed of the stream, however, and these allow an examination of the shale underlying that which bears the Spirifer tullius fauna. The greater portion of these "middle Moscow" shales is barren, and one may search for hours without finding a single specimen. Near the middle of the mass, however, about eight or nine feet below the Styliolina band, occurs a thin layer containing an abundance of the nearly circular brachiopod *Orbiculoidea media* (Hall). Associated with this species are specimens of *Schizobolus truncatus* (Hall), this being the lowest position in the Hamilton strata, in which this species has been found.

As we approach the bottom of the Moscow shale, fossils become abundant again, the first to do so being the trilobite *Phacops rana* (Green), of which very good and large specimens may be obtained. These lower Moscow beds should be explored when the water in the stream is low, the shale in the stream *bed* being much more accessible than that in the *bank* at Section 5. Just before reaching this latter section, the stream descends over the hard Encrinal limestone bed, which separates the Moscow shales from the Hamilton shales proper.

It is above this fall, in the bed of the stream, that the lower Moscow shales are best exposed. The fossiliferous portion comprises about five feet of the shale, which is characterized by an association of species, differing from that at other levels. The robust, short winged, sparingly plicated *Spirifer* called in the old reports *S. zigzag* (Hall) from the zigzag surface striae, but the correct name for which is *S. consobrinus* (D'Orb.) is entirely restricted to these shales, and gives its name to the fauna. Besides the type species, the *Spirifer consobrinus fauna* comprises a large number of species which are common only at this level, while a few are entirely restricted to it.* In the shale

*For a complete list of the fossils of this fauna see the author's paper on the "Faunas of the Hamilton Group, etc."

immediately above the Encrinal limestone occur vast numbers of the small *Ambocoelia umbonata* (Conrad), with the sinus or depression in the centre of the convex valve. (Fig. 125, Pt. II.). This fossil in some places almost makes up the rock, and for a few inches in thickness scarcely any other fossils occur. Occasionally crushed specimens of *Athyris spiriferoides* (Eaton) occur with it, this fossil when first exposed having a white or calcined appearance. A little higher up, the large flat *Stropheodonta perplana* (Conr.) occurs in considerable numbers, and with it a small patella-like brachiopod—the *Pholidops hamiltoniæ* (Hall). The small conical coral *Streptelasma rectum* (Hall) is also found. Other corals occur, making up the "coral layer," which is so well exposed in Section 5, under which it will be described. The shale from two to three feet above the Encrinal limestone is rich in two small species of *Chonetes*, which are very similar to each other, and both of which are characterized by the possession of laterally projecting spines. These are *C. deflecta* (Hall) and *C. mucronata* (Hall). The type species, *Spirifer consobrinus* (D'Orb.) is likewise abundant in this portion of the rock. Above this *Ambocoelia umbonata* (Conr.) gradually disappears, while the coarser brachiopod *Atrypa reticularis* (Linn.) and the corals *Streptelasma rectum* (Hall) and several species of *Cystiphyllum* become quite abundant. A few crinoids also occur. The trilobite *Phacops rana* (Green) occurs throughout the five feet of shale containing this fauna, and it is the last to disappear. Finally, it too, is no longer represented, and the shale is barren to the base of the Spirifer tullius fauna, except for the thin band with *Orbiculoidea media* (Hall) already noticed.

Section 5 (D).

Plates VIII and IX.

This is by far the longest and most interesting section in the gorge. It lies on the right side of the stream, and begins some little distance above the, fall formed by the outcrop of the Encrinal limestone. The length of the section below the fall is about 2200 feet, and the chord of the crescent described by it, extends approximately, east 20 degrees north, by west 20 degrees south, which is about the direction of the strike of the strata in this region. This accounts for the fact that the strata appear horizontal in the section. The dip may be observed at the fall near the head of the section. On the right side of the fall the limestone commonly projects above the water, while on the left side it is a foot or more below the ordinary water level.

In the section appear representatives of the strata from the black Naples (Gardeau) shales to the Hamilton shales. The former are represented by their lower five or ten feet only, which form a vertical face under the influence of the perfect jointing developed in them. The gray Naples or Cashaqua shales are represented in their entirety, and form a more or less sloping bank under the vertical cliff of Gardeau shales. Beneath the gray Naples shales, another vertical cliff is formed by the black Genesee shales, which in many places overhang the rock below, presenting smooth joint faces, and projecting prisms and parallelepipedons, nearly separated from the main wall and dangerously insecure. Frequent falls of rock from a height of about thirty feet, furnish abundant material for examination, at the same time making the collecting of the fossils from the extremely rich Hamilton fauna at the base of the cliff, a hazardous undertaking.

The Genesee shales in their fresh condition, are heavy bedded, and large blocks will hold together quite firmly. On weathering, however, probably by the oxidation of the pyrite grains which are plentifully scattered through the rock, they become more fissile, so that ultimately large slabs of excessive thinness can be readily separated. It is probable that the pyrite grains are spread more thickly on the bedding planes, or at any rate that they are most prone to

PLATE VIII.—View of the upper end of Section 5, showing the falls caused by the outcropping of the Encrinal limestone.
—Photographed by I. P. Bishop.

oxidize along these, where water and oxygen find a ready access. Nodules of pyrite, often of quite large size, are common in this shale.

The gray Genesee shales, being calcareous, weather more readily than the black, which, from the absence of soluble material offer peculiar resistance to the chemical action of the atmosphere. Hence the portion of the cliff formed by the lower Genesee shales recedes rapidly through weathering, while that portion formed by the upper black Genesee shales recedes only by the fall of the undermined portions.

The Styliolina limestone appears in the bank seventeen feet above the top of the falls. It has an average thickness of six or seven inches, and in character does not vary much from the outcrops in other sections. It frequently projects beyond the underlying shales, while blocks which have fallen to the base of the cliff are not uncommon.

The whole of the Moscow shales are exposed in this section, lying between the Styliolina limestone above, and the Encrinal limestone below. Their thickness is nearly seventeen feet, and they usually form an almost perpendicular wall. A smooth face occasionally appears where a joint crack has cut the rock in the direction of the face of the section. This feature, however, is not characteristic, the calcareous shales, probably from their more tenacious nature, being much less fissured than the bituminous shales.

Five inches below the Styliolina limestone is a layer of concretionary limestone, gray, compact and practically non fossiliferous. This apparently corresponds to the layer of concretions noted in a similar position in the preceding sections. A few layers of scattered concretions appear in the shale below this concretionary limestone.

The most interesting portion ot these shales is the "coral layer" of the Spirifer consobrinus fauna. This layer appears in the bank eighteen or twenty inches above the Encrinal limestone, and can be traced the whole length of the section.

It is about three inches thick, and in most places consists entirely of an accumulation of cyathophylloid or cup corals. These are mostly of the genera *Heliophyllum* (*H. halli* E. & H.) *Cystiphyllum* and *Zaphrentis*, and nearly all lie prostrate. Frequently three or four lie above each other, as if they had been carried in by a strong flood and spread over the sea bottom. They show, however, no signs of wear, the delicate bryozoans and small corals which encrust many of them, showing that little, if any disturbance has occurred here since the growth of the corals. They therefore indicate a flourishing coral reef or forest, which was suddenly overwhelmed, probably by the influx of muddy waters, and was completely destroyed, without, however, undergoing any mechanical abrasion. The appearance of these large corals seems to have driven out the small *Streptelasma*, for this coral, adapted probably to muddy waters, occurs above and below the coral layer, but not in it.

Associated with the corals, and becoming the sole occupants of the bed in the absence of the corals, are a number of brachiopods, usually of robust character. These are *Spirifer audaculus* var. *eatoni* (Hall), *Atrypa reticularis* (Linn.) and *A. aspera* (Dalman). The latter form is restricted to this bed, and is abundant in all its outcrops. A curious feature, however, is, that nearly every specimen has lost its spines, while the same species in the Genesee Valley, where it is associated with the same species of corals, nearly always retains its spines. That the loss of the spines in this region is due to protracted maceration before final burial seems likely, and would be in direct accord with the slight thickness of the Moscow shales in this region.*

The Encrinal Limestone. This rock appears for the first time near the upper end of Section 5, where it causes the fall in the stream. Above this point it quickly dips below the Moscow shales, and is not seen in any of the upper sections.

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*See Chapter III.

The thickness of the stratum is one and one-half feet, varying but little in different parts of the section. Its upper portion is of a somewhat shaly character, and highly fossiliferous. More than fifty species of fossils have been obtained from this portion of the stratum, many of them being either rare or unrepresented outside of it. One of the most striking species is a large pelecypod, which is found in considerable numbers in the upper part of the limestone, near the lower end of the section. This is the *Mytilarca oviformis* (Conrad), a large mussel shell which is not found outside of this bed. The shell is commonly removed, the "mould" of the interior alone remaining. The rock is composed chiefly of the finely comminuted remains of calcareous organisms, among which crinoid stems and joints predominate. Weathering brings the coarser of these out in relief, a character often observable on the moulds of such shells as the *Mytilarca*.

Although fossils are numerous, perfect specimens are difficult to obtain. This is due to the fact that the outer layer of the shells tends to adhere to the rock on being split out. This exfoliation is not restricted to shells alone, but occurs in the trilobites and other organisms as well. It is only where weathering has removed the surrounding matrix that the perfect surface characters become visible. The lower, more solid and more crystalline portion of the bed contains chiefly corals, among which the honeycomb coral—*Favosites hamiltoniæ* (Hall) predominates. It usually forms rounded heads six inches to a foot in diameter, sometimes containing petroleum, probably the result of the decomposition of the original animal matter.

The rock is pyritiferous in places, sometimes so to a considerable degree. On its under side occurs a coating of iron sulphide, probably in the form of the mineral marcasite, which occasionally has a thickness of an inch. From the oxidation of this mineral, the rock is stained a reddish brown color. This feature diminishes the value of the rock as a building stone, for structures built of it will invariably show the characteristic but undesirable iron stain. This can be seen in various buildings in the vicinity of the creek on the lake shore road. The rock of this section was formerly quarried and used for constructive purposes, in part at least, on the railroad bridges at North Evans. That the rock had a tendency towards the formation of concretionary masses is indicated by the occurrence of one of these on the under side of the bed, about half way down the section. This mass is cylindrical, three inches in diameter, and lies just below the limestone bed. It is of similar composition, and lies approximately parallel to a joint plain.

Among the more important fossils of the rock *Spirifer sculptilis* (Hall) should be mentioned, a form readily recognized by its few angular plications and the zigzag concentric lamellæ. This species is entirely restricted in this region to the Encrinal limestone, and may be regarded as the typical fossil of the fauna, which is named after it, the Spirifer sculptilis fauna.*

The fauna contains a number of gasteropods not found outside of it, as well as a number of others, (*Platyostoma* (*Diaphorostoma*) *lineata* (Conrad), various species of *Platyceras*, etc.,) which occur both above and below. Trilobites are common and of large size, the predominating form being *Phacops rana* (Green). The pelecypods are few and poorly preserved, but the brachipods are well represented. *Orthis* (*Rhipidomella*) is very common, and so are the *Stropheodontas*. One of the important fossils almost entirely restricted to the bed is *Tropidoleptus carinatus* (Conrad), of which large specimens may be obtained. The little *Vitulina pustulosa* (Hall) and the equally neat *Centronella impressa* (Hall) occur side by side in the upper part of the rock, and have not been noticed outside of it. Another characteristic Terebratuloid is the *Cryptonella planirostra* (Hall), which however is not wholly confined to this rock.

*For a list of the fossils of this fauna see my paper on the "Fauna of the Hamilton Group," etc.

PLATE IX.—View of Section 5, showing the Hamilton shales, with the Demissa bed at the base. Above this appear the Encrinal limestone, the Moscow shales, the projecting Styliolina limestone, the jointed Genesee shales, and in the upper, sloping portion of the bank, the lower Naples (Cashaqua) shales. —Photographed by I. P. Bishop.

The Lower Shales, or the Hamilton Shales Proper. Only about a foot of these is exposed at the base of Section 5, but this foot of shale contains a large number of interesting fossils. Immediately below the Encrinal limestone the shale is practically barren for a thickness of three or four inches. Even calcareous matter seems to be absent from it, and the shale is soft, light colored and easily cut with a knife. If it is exposed to the atmosphere and the heat of the sun, it hardens, by the evaporation of the water which it contains, but on soaking, it becomes a tenacious mud. This character is due to the leaching out of the calcareous matter by the waters which carried sulphuric acid, derived from the oxidation of the iron sulphide on the under side of the Encrinal limestone. Below this decalcified mass of shale is a bed an inch or less in thickness, which is made up mainly of three classes of fossils, viz: A small, flat, branching bryozoan, *Stictopora incisurata* Hall, a small brachiopod with matted spines all over its exterior, *Nucleospira concinna* Hall and a large number of the joints of crinoid stems. These three forms occur in such numbers, and they are usually so firmly cemented, that the bed becomes a solid limestone. Where it has been exposed for a considerable length of time, the fossils have weathered out completely, so that they may be picked up in a perfect state of preservation. This bed has been called the Stictopora bed. It is the highest true Hamilton bed which has a distinct association of fossils. Throughout it, and in almost every bed below, the typical Hamilton brachiopod *Spirifer mucronatus* (Conrad) occurs. This is frequently furnished with long mucronate points or lateral extensions, and in the Stictopora bed it is represented mainly by the separated valves. The species is practically restricted to the Hamilton shales*, where it is abundant, only a few fragmentary specimens having been obtained from the higher beds. It therefore constitutes the index species of this lower fauna—the Spirifer mucronatus

*It occurs however, in the transition shales of the Marcellus.

fauna, which is by far the richest of any of the faunas of this region.

The most fossiliferous bed in this fauna is the one exposed at the very base of Section 5, about a foot below the Encrinal limestone. This bed has been called the Demissa bed, from the fact that the brachiopod *Stropheodonta demissa* (Conrad) occurs in it in great numbers and is practically restricted to it. It has furnished more than sixty species of fossils, though its total thickness is not over four inches. It may be explored at low water continuously along the base of the cliff, as well as in the shallower portions of the stream below the fall. The occurrence of *Stropheodonta*, especially *S. demissa* (Conrad) and the large *S. concava* Hall, as well as large numbers of *Spirifers*, including the large and robust *S. granulosus* (Conrad), make it conspicuous. This latter species occurs also in considerable numbers in the Encrinal limestone, but it has not been observed in the Moscow shales. It does not occur, at Eighteen Mile Creek, in the shales below the Demissa bed.*

Near the lower end of the section occurs an oblique thrust fault, which has brought up about a foot of the shale underlying the Demissa bed. The shearing plane passes obliquely upwards from left to right,(as seen from the opposite bank). The inclination from the horizontal is 24°, thus giving the fault a hade of 66°. The fault is of interest as indicating a compressive force, the same probably which caused the anticlinal fold at Section 3, and the other thrust faults to be noted later.

Section 6 (C).

Plate XI.

This section is cut in the left bank of the stream and extends in a general north and south direction. Its height is about sixty-two feet above the stream bed, and its total

*For a list of the fossils in the Demissa bed, see "Faunas of the Hamilton Group," etc. They are all included in the descriptions in Part II.

PLATE X.—View of the "corry" in Section 7, showing an example of gorge cutting in an early stage. The backward cutting of the falls produces the gorge, and the downward cutting of the stream the V-shaped trench seen above. The Encrinal limestone is seen near the middle of the cliff.

—Photographed by A. W. GRABAU.

PLATE XI. (*a*).—View of Section 6, showing four feet of Hamilton shales at the base; the Encrinal limestone, the Moscow shales, the Styliolina band, the Genesee shales and a portion of the Cashaqua shales.

(*b*).—View of the Encrinal limestone of Section 6, showing the undermining of the bed, and the recently fallen blocks. —Photographed by A. W. GRABAU.

length about seven hundred feet. The highest beds exposed are the gray Naples (Cashaqua) shales, which, as usual, contain many concretions. The shale has crumbled under the action of the atmosphere until the whole upper portion of the cliff is soil-covered and overgrown with vegetation. The Genesee shales appear much less prominently in this section than in any of the preceding, nevertheless the characteristic jointed structure of the upper shales appears half way up the bank. The Styliolina limestone projects from the bank, and as usual, forms a prominent line of demarcation between the Middle and Upper Devonian strata of this region. The Moscow shales, seventeen feet thick, form a vertical cliff in some portions of the section. In the main, however, they are more or less covered up by the talus which has accumulated on the shelf formed by the projecting Encrinal limestone. This latter stratum has a thickness of twenty-two inches in this section, and exhibits the same coating of oxidized iron sulphide on the under side, which characterizes its other exposures. The many fallen blocks at the base of the cliff, as well as the dangerously far-projecting portions of the bed in the cliff, testify to the continued activity of the stream in the wearing away of the softer shales beneath. (Plate XI, fig. b). These blocks are collected from this section and used for purposes of construction. Fossils are not so numerous in the bed at this section, as they are at Section 5, nevertheless some very fine specimens of *Actinopteria decussata* Hall have been obtained from it. Corals are common, especially the honeycomb—*Favosites hamiltoniæ* Hall. The average northward rise of the limestone in this section is one foot in forty-seven, giving an approximate southward dip of five degrees. This allows nine feet of the Hamilton shales to be exposed at the lower end of the section, while at the upper end the exposure is only three feet.

Here is the first good opportunity to examine the Hamilton shales in their relation to the overlying limestone, and it becomes at once apparent that the most fossiliferous beds are those near the top of the series, namely the Demissa and Stictopora beds. As the water became purer towards the close of the deposition of the Hamilton shales, the brachiopods, which occurred sparingly during the greater part of the time, underwent a luxuriant development, all the important and characteristic species growing in great profusion. The change of conditions, however, which succeeded, drove out most of them, and when the water became pure enough for the growth of the limestone-building corals and crinoids, a quite distinct assemblage of species appeared. (See further, Chapter III.).

In the lower beds the fossils are scattered, from some, they appear to be entirely absent. Down to about three feet below the Encrinal limestone, the shale contains species such as are found in greater abundance in the Demissa bed. Associated with these is *Athyris spiriferoides* (Eaton), which here reached its last abundant development. Below this, down to about four feet below the Encrinal limestone, fossils are very rare, with the exception of the two species of minute needle-like pteropods, *Styliolina fissurella* (Hall) and *Tentaculites gracilistriatus* Hall, both of which occur in vast numbers on some of the shale laminæ. With them occur several species of minute ostracod crustaceans, among which the *Primitiopsis punctulifera* (Hall) predominates.

Still descending, we find the fossils somewhat more abundant, but in no case do they approach the numerical development found in the Demissa bed. The only constant and abundant species throughout these shales is the type species of the fauna, the broad-winged *Spirifer mucronatus* (Conrad).

Nine feet below the Encrinal limestone, or at the base of the section at its lower end, and forming a portion of the stream bed, is a layer of large, flat calcareous concretions, occasionally united into a continuous bed; but chiefly composed of separate masses. These contain a large number of

PLATE XII.—View of the upper part of Section 7, looking up-stream. The talus covered Hamilton shales appear in the lower part of the cliff. The Encrinal limestone projects above them, and blocks of this have fallen to the foot of the cliff. Near the middle of the bank are seen the Moscow shales, and the Styliolina limestone projecting above. The top of the cliff is formed of the Genesee shales.

—Photographed by I. P. Bishop.

Athyris spiriferoides (Eaton), all in a perfect state of preservation. The same fossil occurs in the shale between the concretions, and when thus found, it presents its original gibbous character. Above or below this layer, however, this fossil usually occurs in a compressed condition from the settling down of the shale masses on lithifying, thus showing well, how the presence of such concretions in a bed, may protect the fossils from the compression incident upon the lithification of the containing rock. This layer furnishes most of the specimens of this brachiopod, which is nowhere else so characteristic as at Eighteen Mile Creek.

Section 7 (B).

Plates XII and XIII.

This section extends north-west from a point directly north of the northern end of Section 6, to the bridge on which the Lake Shore road crosses the creek. It is cut into the right bank of the stream, and has a total length of about twelve hundred feet. Near the middle of the section a small lateral stream has cut a V-shaped gully down to the Styliolina limestone, over which the water falls in wet weather. Below this is a larger V-shaped recession, a diminutive "corry," which here marks the beginning of a lateral gorge. (Plate X.).

The lower portion of the section is covered by a talus of fine shale particles, derived from both Moscow and Hamilton beds. At the foot of the cliff are large fragments of limestone and shale, with fossils, as well as a debris of foreign material. The difference in the steepness of the bank, between this section and the preceding one, forms an interesting study, the small amount of undercutting in Section 7 being due, as already noted, to the shallowness and width of the stream, which two features combine to dissipate the force of the current, and also to the presence of the large rocks at the foot of the cliff, which act as a barrier to the inroads of the current.

The Upper Devonian strata of this section include several feet of the black Genesee shales, the gray Genesee shales, and the Styliolina band. The Genesee shales are usually talus-covered and overgrown with vegetation. The Styliolina limestone is somewhat more shaly in this section than in the preceding ones, but as usual, projects some distance from the bank. No good opportunity for the study of the Moscow shales is afforded, for they are practically inaccessible. The large cup corals which are common in the talus at the foot of the section are all derived from the coral layer in the lower Moscow shale. They may be seen in place by climbing the bank in the little "corry" near the centre of the section. The Encrinal limestone appears near the middle of the section, forming a prominent band. It rises north-westward at the average amount of one foot in sixty-three, giving an approximate south-easterly dip of less than one degree to the strata.

On the Lake Shore road, at the descent to the bridge from the north, the Encrinal limestone formerly caused a distinct shelf or ridge, which extended across the road. The earlier visitors to the Eighteen Mile Creek sections will remember the distinct bump which the carriage or omnibus, which brought them, experienced in passing over this rock. At the present time the rock has either been taken out or covered over, so that the characteristic bump is no longer experienced.

Where the rocks first become exposed at the upper end of the section, about sixteen feet of the Hamilton shales appear. At the bridge, thirty to thirty-five feet of these shales are exposed, but the lower portion of the cliff is covered by talus. The layer of concretions bearing the *Athyris spiriferoides* (Eaton), first noted in Section 6, appears throughout in this section, remaining at the average distance of nine feet below the Encrinal limestone. From its disintegration, the talus at the foot of the cliff is rich in this fossil, this being the best locality for collecting it. Many specimens will be found

PLATE XIII.—View of Section 7, looking down stream, showing the "corry" on the right. The same strata are seen as in Plate XII. —Photographed by I. P. BISHOP.

overgrown with delicate Bryozoa and *Aulopora* corals, which furnish an additional incentive for collecting them.

A large number of concretions occur in this lower shale, among which the horn-shaped forms with smooth slicken-sided exterior are characteristic. These are often mistaken for organic remains, chiefly cup corals, and are prized as such by the inexperienced collector. An axis or core of iron pyrites will usually be found as the nucleus of these concre-cretions. Frequently the strata above and below, as well as on the sides, appear crowded out of position, as if by the growth of the concretion. As before noted, however, this crowded appearance is probably due to the settling down of the strata around the resistant body.

A few feet below the layer bearing the *Athyris spiriferoides* (Eaton), pelecypods occur plentifully. A large number of species have been obtained, many of which have not been noticed elsewhere in this region. At the base of the cliff, near the mouth of the "corry" *Liorhynchus multicostus* Hall again occurs in abundance in some concretion bearing beds. Another concretionary layer containing *A. spiriferoides* (Eaton) occurs twenty feet below the Encrinal limestone. Throughout the exposed portion of the shales, fossils occur in considerable number and variety. Brachiopods always predominate, the most abundant being *Spirifer mucronatus* (Conrad). Good specimens of the trilobite *Phacops rana* (Green) are occasionally found; but on the whole, only the smaller species of organisms are abundant. Thus, *Chonetes lepida* Hall, and *Ambocoelia umbonata* (Conrad), as well as the little *Pholidops hamiltoniæ* Hall, are abundantly scattered through the shales. *Liorhynchus multicostus* Hall is common in the lower ten or fifteen feet.

About twenty-five feet below the Encrinal limestone occurs a thin argillo-calcareous bed, less than two inches thick. This contains large numbers of *Modiomorpha subalata* (Conrad), a characteristic Hamilton pelecypod, and one which occurs throughout the lower shales. In this bed, however, it occurs in great abundance, almost to the exclusion of every other form. The bed is not well exposed in this section owing to the talus, but in the east branch of Idlewood Ravine, which mouths in the main gorge below the bridge, it appears both in the bed and banks of the ravine.

Section 8 (A).

Plate XIV.

This is the lowest section in the gorge, occurring in the left bank and extending from near the mouth of the creek halfway to the bridge. Its total length is not over one thousand feet, and it extends north forty degrees west, by south forty degrees east. Its height is about fifty-six feet above the normal lake level.

Only middle Devonian strata are exposed in this section, the Moscow shales forming the top member. The greater portion of these are exposed near the upper end of the section, but owing to the rise of the strata north-westward, only a few feet occur at the lower end of the section. The Encrinal limestone occurs throughout, and large blocks of it are found at the foot of the section. The lowest bed exposed at the upper end of the section is an argillaceous limestone, which in places becomes shaly, and the total thickness of which is about a foot. This contains very few fossils, *Spirifer mucronatus* (Conrad) and a few pelecypods being the only ones observed. Underlying it are about six feet of shale, which become exposed at the lower end of the section. These contain few fossils, principally *Spirifer mucronatus* (Conrad) and *Phacops rana* (Green). Below them, and exposed only near the lower end of the section are the "Trilobite beds." These are three in number. The upper one is a foot thick, shaly and often fissile, yet sufficiently calcareous to be distinct from the overlying shale. It is very rich in trilobites, though usually the heads and tails alone

PLATE XIV.—View of Section 8, looking down stream. The Trilobite beds appear at the base of the section, near its lower end. The Encrinal limestone projects from the bank near the top. Blocks of Encrinal limestone lie at the foot of the section.
—Photographed by I. P. Bishop.

are common. The thorax, from its jointed condition, is subject to greater destruction, and hence is not commonly preserved. Nevertheless, complete and perfect specimens are occasionally obtained. The trilobite most common in this bed is the ordinary Hamilton species *Phacops rana* (Green), though *Cryphaeus boothi* Green, the form with long spines on both sides of the head, and with fringed tail, also occurs. Other fossils are rare in this bed. Below it, is a somewhat more compact calcareous layer three to four inches thick and rather concretionary. In this layer fossils are rare. Under it occurs the second trilobite layer, eight inches thick and, like the upper one, it is a calcareo-argillaceous, and somewhat arenaceous bed, sometimes becoming quite gritty. This contains more fossils than the upper bed, but the trilobites of both species are the only abundant forms. Below this, and separating it from the lowest trilobite bed—which latter is only exposed at low water at the extreme lower end of the section—are two or three inches of fissile shale, in which *Athyris spiriferoides* (Eaton) is especially abundant. With it occurs a large number of the small cup coral *Streptelasma rectum* Hall, these two, with an occasional specimen of *Spirifer mucronatus* (Conrad), forming the only important fossils of the bed.

Only about six inches of the lowest trilobite bed are exposed, the total thickness of that bed being about a foot. Both species of trilobites are abundant, and good specimens may be easily obtained.

Nowhere in the entire Hamilton group of this region are trilobite remains so abundant. The conditions of the sea must have been particularly favorable for their development at that period, so that their remains became entombed by the thousands. That they were but slowly buried seems to be indicated by the separated portions of the body, a condition probably brought about by long continued maceration before burial. Trilobites probably never lived in very deep water, and both the nature of the rock and the scattered position of the remains indicate shallow water with a distinct current, though with probably a small amount of mechanical sediment.

Several small thrust or reversed faults may be noted in this section. They have mostly affected the trilobite beds, and the calcareous bed six feet above them. The vertical displacement is never more than a few inches, yet the occurrence of these faults in connection with that of Section 5, and another one on the lake shore, present a problem of extreme interest.

GENERAL REMARKS.

At several places in the gorge, gas bubbles up through fissures in the rock. Near the upper end of Section 5, above the falls, bubbles of gas constantly escape from the water. In the gorge above the railroad bridges, opposite the village of North Evans, gas escapes from a fissure in the rock in such quantity as to give a steady flame when lighted. The occurrence of such gas springs has led to the sinking of a well in the gorge near the head of Section 6. The supply of gas thus received has diminished but little during a number of years of steady flow.

The origin of the gas is probably to be sought for in the bituminous shales, some of the springs undoubtedly deriving their supply from the deeply-buried black Marcellus beds. The gas well, however, draws its main supply from Silurian strata, which are tapped several hundred feet below the surface.

The Mouth of the Stream. An interesting problem in the shifting of the mouth of a stream by current and wave action is presented by Eighteen Mile Creek. Running out from the left bank is a long sand bar, which effectually closes the mouth of the gorge, and compels the stream to find its outlet at another point. The bar formerly extended

PLATE XXI.—View of the mouth of Eighteen Mile Creek, the Idlewood Cliff on the right, and the sand bar on the left. (Compare Plate XXII.). —Photographed by I. P. Bishop.

nearly 2000 feet northward, and the mouth of the stream was shifted to that point. Since then, the stream has broken through the bar at several places, shifting its mouth every season, and leaving partially closed outlets to be filled in subsequently by the waves. The map (Plate II.) represents the temporary conditions which existed in August, 1895. (See also Plate XXI.).

CHAPTER II.

THE GEOLOGY OF THE LAKE SHORE SECTIONS.

All along the lake shore from Eighteen Mile Creek, north to Bay View, and south to the county line, there are numerous exposures of the strata described in the preceding chapter, as well as others which lie above and below these. The exposures are in the cliffs, which, with few exceptions, front the lake, rising sometimes to a height of nearly a hundred feet. The cliffs commonly rise with a vertical face from the beach. Many of them are washed by the waves the year round, and consequently kept in a perpendicular or even overhanging condition, while others experience the cutting of the waves only during storms or in seasons of unusually high water. In this latter case a talus of shale fragments usually accumulates at the foot of the section, and this not infrequently becomes a rich collecting ground for the palaeontologist, for here the weathered out fossils may be found in great numbers, and usually in a perfect state of preservation. The stratigraphist, however, avoids collecting from these natural "dump-heaps," or at least does not attach much stratigraphic value to his collections, for he finds in them a commingling of the fossils of the various beds exposed in the section, a condition which is unfavorable to the proper discrimination between successive faunas.

The sections are by no means of uniform height. This can be best appreciated by the diagrammatic representation of these sections given on Plate V. of the Geological Report of the Fourth District of New York. In this plate Professor Hall gives a semi-pictorial representation of the shore of Lake Erie from Black Rock to Sturgeon Point, with the omission of the eight miles of beach and low swamp-land between Buffalo and Bay View (Comstock's tavern). By reference to this plate it will be seen that the highest cliff is just south of Eighteen Mile Creek, in the first section of the "South Shore Cliffs."

This irregularity in the height of the cliffs, is, of course, produced by erosion, which has swept away the rocks in some places, and left them in others. In general terms, the sections as seen on the lake shore represent a profile of the topography, which was impressed upon the country during long cycles of preglacial erosion. The low drift-filled portions, where no rock is exposed, probably in all cases represent broad valleys cut out by some preglacial stream. Some of the irregularities in height, however, are only apparent, and due to the varying directions in which the sections are cut. To this latter cause must also be attributed the varying dips observed in different parts of the sections, as these sections sometimes extend in the direction of the strike of the strata, or again obliquely across it. In no portion of the sections is the true dip exposed, which, as was noted in Chapter I., is to the south-east.

The shore of Lake Erie presents a succession of crescents, the projecting points usually being headlands of rock, which frequently extend into the water, and so form an obstacle to walking on the beach. Excepting such instances however, the beach is of a character, which allows easy travelling on it. Wherever it is sandy, it is usually much compacted and firm, and will even permit the advantageous use of a bicycle. But when the beach is composed of shingle, as on the more exposed portions of the shore, the case is different, for the pebbles are usually smooth flat shale fragments, which slip over each other, and make walking a rather tiresome undertaking, while the use of a bicycle is impossible.

In the following descriptions of the sections on the Lake Shore, the names applied to them are those by which they are designated in the paper on the "Faunas of the Hamilton Group" of this region, to which the student is referred for many points not here discussed. If access to the volume on the Geology of the Fourth District can be had, a thorough study of the sections as given on Plate V., should be made.

A. The South Shore Cliffs.

Plates XV to XX.

The first of these cliffs extends from the mouth of Eighteen Mile Creek south-westward for a distance of about three miles, beyond which a low and sandy stretch separates it from the next cliff. The northern half of this section, or that portion between Eighteen Mile Creek and Pike Creek, is of the greatest interest to the student, as it includes, besides all the beds found in the lower gorge of Eighteen Mile Creek, a number of interesting structural and dynamic phenomena, which will be described below. This portion of the section comprises several crescents, and as the strata dip at about forty feet to the mile, or approximately one foot in one hundred and thirty,* the appearance of faults is produced, wherever the central portion of the farther crescent is seen directly behind the projecting salient between the two adjacent crescents.

About forty feet of the Hamilton shales are exposed in this section near the mouth of Eighteen Mile Creek. The Trilobite beds would probably be exposed at the base of the section, if the talus were removed. The other beds noted in the Eighteen Mile Creek sections, can be seen in the northern half of this section, when not covered by talus. The shale is full of fossils, mainly brachiopods, among which *Spirifer mucronatus* (Conrad) predominates. The shells may be picked out of the weathered bank with ease, and usually occur with the valves separated, so that specimens showing the muscular impressions and other internal features are among the frequent treasures to be met with in collections from these banks. The talus is especially rich in *Athyris spiriferoides* (Eaton). These are furnished by the disintegrating concretionary layer, nine feet below the

*This estimate is based on the fact, that at the mouth of Eighteen Mile Creek, the Encrinal limestone is about forty feet above water level, while at the "uplift," a little over a mile to the south, in a straight line, this rock has reached the level of the lake. The inaccuracy comes from the greater actual length of the section when the curves of the crescents are considered. The dip thus obtained is only the apparent, and not the true dip.

PLATE XV.—View of the first section of the South Shore Cliffs, looking southward from the mouth of Eighteen Mile Creek. The Encrinal limestone appears as a prominent southward dipping band in the cliff. —Photographed by I. P. BISHOP.

Encrinal limestone. Specimens of *Spirifer granulosus* (Conrad) are also common. They are derived from the Demissa bed, which also furnishes the specimens of *Stropheodonta demissa* (Conrad), though these are of less frequent occurrence.

The Encrinal limestone is the most prominent stratum in the bank. It appears for the first time a few hundred feet south of the northern end of the cliff, and gradually descends, until near the middle of the section, at Pike Creek, it passes below the level of the lake. It has the same thickness and character as in the Eighteen Mile Creek sections, and also has the coating of iron sulphide on the under side, which is characteristic of all its outcrops. Professor Hall states that this coating was formerly "wrought to some extent on the supposition that it was silver."*

From the constant wearing away of the soft Hamilton shales, the Encrinal limestone becomes undermined, so that large blocks break off annually and fall to the beach, where they accumulate in considerable numbers. Not infrequently, these blocks of limestone are full of fossils, chiefly corals, some of which stand out in relief through differential solution. They tempt the collector with visions of choice specimens for the cabinet, but he is apt to be disappointed in his attempt to obtain them, unless he has a good hammer, a number of well-tempered chisels, and plenty of time and patience. A sledge hammer is the most desirable tool in such cases. Unless the collector is properly equipped, he had better not attempt the working of this refractory rock, for he is sure to end in spoiling his tools, his temper, and worse than all, the specimens, which he should leave for some one better prepared.

The Moscow shales have much the same character which they exhibit in the Eighteen Mile Creek sections. Their thickness hardly diminishes, and they usually contain a fair proportion of concretions. The coral layer appears in the

*Geol. Rep't, 4th Dist. N. Y., 1843, p. 472.

lower portion of the mass in the same position, and with the same fossils as at Section 5. It alone furnishes the specimens of large *Cyathophylloids* and *Atrypa aspera* Dalman, which are so common in some portions of the talus. The specimens of *Streptelasma rectum* Hall are likewise furnished by beds of the lower Moscow shale.

The Styliolina limestone rapidly thins out towards the south, so that, at the middle of the section, it is scarcely an inch in thickness, being at the same time very shaly. The Genesee shales, in this section, appear in their full thickness, which, according to Professor Hall, is twenty-three feet and seven inches, including the Styliolina band.* The lower portion of this shale is more homogeneous in this section, partaking in color and texture more of the character of the upper beds. The bituminous character of the shale as a whole is strongly marked, plant remains and even coal seams being of not infrequent occurrence. Large masses of the rock are usually found on the beach, and in them the characteristic fossil *Lunulicardium fragile*† Hall, is often found in great numbers. Pyrite grains are scattered throughout the shale in large quantities, and these on oxidizing produce the usual result of thin, iron-stained shale laminae, which frequently have iridescent surfaces.

One of the interesting products of the oxidation of the pyrite, is found in the sulphuretted water, which trickles from the bank at various places. On exposure to the air, the sulphuretted hydrogen, with which the water is charged, is commonly decomposed, (see below) and sulphur is deposited. This is well seen in a small cavernous indentation in the bank, midway between Eighteen Mile and Pike Creeks, where the shale walls are covered with a thin coating of sulphur.

*Rep't 4th Geol. Dist. N. Y., 1843, p. 221.

†This is the *Avicula fragilis* Hall of the Geol. Rep't of the 4th Dist., 1843.

Mr. S. H. Emmens has tabulated the following steps in the oxidation of pyrite.* Part of the sulphur of the pyrite is converted by the oxygen and the moisture of the atmosphere into sulphuric acid, leaving a residue of iron monosulphide. This is then attacked by the sulphuric acid and ferrous sulphate results, while at the same time sulphuretted hydrogen is evolved. The reactions are as follows:†

(*1.*) $Fe\,S_2 + O_3 + H_2O = Fe\,S + H_2S\,O_4.$
(*2.*) $Fe\,S + H_2\,S\,O_4 = Fe\,S\,O_4 + H_2S.$

If the sulphuretted hydrogen comes in contact—as it naturally must in passing through the rock—with oxydizing pyrite, and if, as Emmens holds, sulphurous anhydrite ($S\,O_2$) is formed, together with the sulphuric acid, the hydrogen sulphide will react with the sulphurous anhydrite and form water and free sulphur. The reactions would be tabulated thus:

a. $Fe\,S_2 + O_2 = Fe\,S + S\,O_2.$
b. $S\,O_2 + 2\,H_2S = 2\,H_2O + 3\,S.$

or, as given by Emmens:

(*3.*) $Fe\,S_2 + O_2 + 2\,H_2S = Fe\,S + 2\,H_2O + 3\,S.$

This sulphur may be in part deposited, and in part again oxidized to sulphuric acid, thus:‡

(*4.*) $S + O_3 + H_2O = H_2S\,O_4$

this latter again attacking the monosulphide (Fe S).

The third and fourth reactions probably do not take place in these shales, the hydrogen sulphide being directly decomposed by the atmosphere, with the formation of sulphur and water, the former being deposited where the oxidation takes place. Thus:

$2\,H_2S + O_2 = 2\,H_2O + S_2.$

The ferrous sulphate will absorb oxygen, and sulphuric acid, if the latter is in excess, and form ferric sulphate, according to the following reactions:§

(*5.*) $2\,Fe\,S\,O_4 + O + H_2S\,O_4 = Fe_2\,(S\,O_4)\,3 + H_2O$

which would be the final result of the oxydation. But if the amount of sulphuric acid is insufficient, or if the ferrous sulphate is carried in solution and spread over the surface of the shales, it will oxidize in part to ferric hydrate or limonite, which stains the shales. The reaction, according to Emmens, is:

$Fe\,S\,O_4 + 6\,O. + H_2O = 4\,Fe_2(S\,O_4)_3 + 2\,Fe_2O_3\,.\,H_2O.$

*Stephen H. Emmens: "The Chemistry of Gossan," Engineering and Mining Journal, Dec. 17, 1892, p. 582.

†‡Emmens, loc. cit.

§Loc. cit.

If lime is present in the shales, this will react with the ferric sulphate to form calcium sulphate and ferric oxide; the latter being insoluble, will be deposited where formed.* The reaction is:

$$Fe_2(SO_4)_3 + 3\ CaCO_3 = 3\ CaSO_4 + Fe_2O_3 + 3\ CO_2.$$

The calcium sulphide will be hydrated and deposited as gypsum, as was noted in some portions of the upper Moscow shales.

The ferrous sulphate may react directly with the calcium carbonate of the shales, giving calcium sulphate and ferric carbonate. The former is hydrated and deposited as gypsum, while the ferrous carbonate is carried off in solution. This may account for the absence of much iron stain on the shales in which the gypsum crystals are formed. Eventually on exposure to the atmosphere, the ferrous carbonate will oxidize to insoluble ferric hydrate, which will be deposited.

Concretions are not uncommon in this shale. They are usually of iron pyrite, or at least have a pyrite nucleus. Occasionally they have a septarian structure, with veins of crystalline calcite, siderite, or more rarely, barite. The gray Naples or Cashaqua shales, appear between the Genesee below, and the black Naples or Gardeau shales above. They are readily recognized by their gray color, the numerous rows of concretions, and the sloping, more or less weathered face which they present. The rocks above and below form perpendicular banks, and consequently whatever vegetation grows on the face of the cliff, is chiefly confined to the portion formed by the Cashaqua shales. The upper (Gardeau) shales, are exposed in the first half mile of the cliff, after which they are absent for a greater distance, the banks decreasing to less than half their original height.

This decrease in height begins at the "uplift," a thrust fault of considerable magnitude, when the general undisturbed character of the strata of this region is taken into consideration. The fault appears in a recession of the bank, which is due to the weakening of the strata by the fault, and consequently the greater readiness with which they succumb to the attack of the waves. The vertical displacement of the

*In this manner shells are often entirely replaced by limonite.

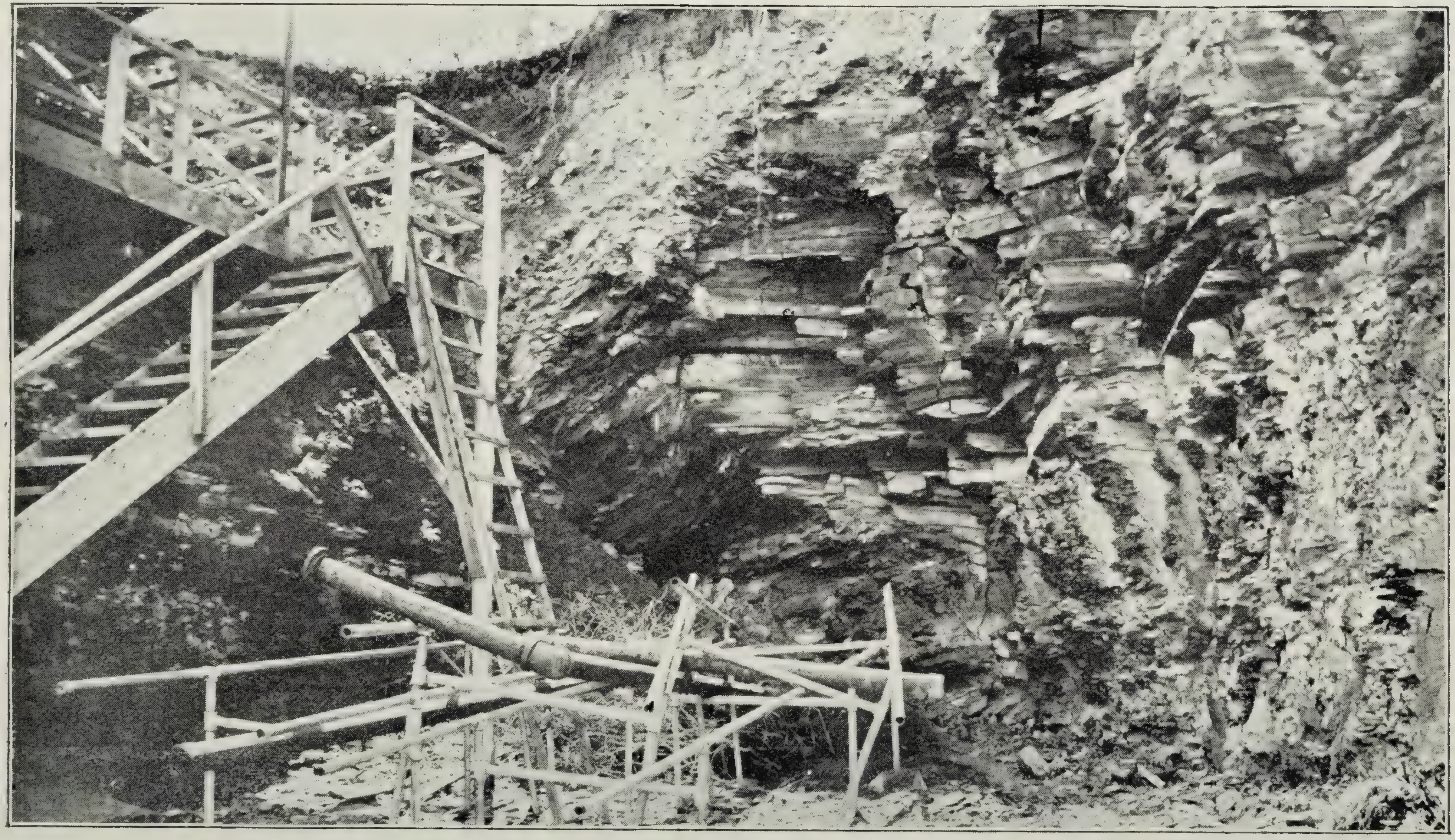

PLATE XVI.—View of the "uplift" in the South Shore Cliffs, a mile and a half south of the mouth of Eighteen Mile Creek. The flexure passes into a fault in the rigid strata. The Moscow shales are shown below, and the much-jointed Genesee shales appear above.
—Photographed by I. P. Bishop.

strata in this fault, is about four feet*, and the thrust plane passes obliquely upward from right to left. The upper strata, *i. e.* the Genesee, which, with the Hamilton beds are alone involved, are flexed and broken, some portions standing on end, the whole having the appearance of a monoclinal fold. The Moscow shales are much fractured along the shearing plane, and present the characteristic features of the "crushed zone" of such displacements. The Encrinal limestone is completely broken, the right hand portion being raised four feet above the left hand portion. Professor Hall who described and figured this fault†, found striæ on the faces of one of the oblique fissures, a feature not unusual in such displacements. (See Plate XVI.).

The crushed zone has afforded a suitable avenue of escape for the sulphuretted waters from the Genesee shale, and the odor of the sulphuretted hydrogen is very strong near the fault, while deposits of sulphur are not uncommon on the face of the cliff.

Just before reaching the "uplift" the Encrinal limestone descends almost to water level. Beyond the uplift it quickly returns to this level, forming a floor of rock for some distance along the shore, and finally dipping below the water. The coral layer of the lower Moscow shale appears to advantage in this portion of the cliff, numerous large cyathophylloids characterizing it.

From the uplift, to Pike Creek, the bank is low, scarcely rising above thirty feet, and is made up of the Moscow and Genesee shales. At Pike Creek less than half of the Moscow shales is exposed, their final disappearance below the lake level occurring about a quarter of a mile beyond the mouth of that creek.

The mouth of Pike Creek presents an interesting feature, due to the combined wave and stream erosion. The opening

*Hall, Rep't 4th Geol. Dist., 1893, p. 295.
†Loc. cit., p. 295, fig. 141.

in the rock wall is very broad, and in the centre is a mass of shale completely separated from the main bank, and rising like the sea-stacks of the English and Scottish coast from the general platform of rock, which forms the bed of both the stream and the lake. The illustration given below—(Plate XVII.), represents the stack as it appeared in 1888. The dead tree at its further end has long since fallen, through the continued crumbling of the rock, as will be noticed in the photograph reproduced in Plate XVIII. A reference to Plate V. of the Report on the Geology of the 4th District will show that these conditions did not exist in 1843. Only a single mouth is indicated for Pike Creek, which is the opening shown in the right of the illustration (Plate XVII.). The other and smaller one between the stack and the main bank was cut, according to the testimony of the residents, within the last thirty or forty years.

In the ravine of Pike Creek, the Genesee shales alone are exposed, the bed of the stream furnishing a good opportunity for the exploration of these strata. For some distance beyond Pike Creek, the Genesee shales form the top of the cliff. Farther on, the gray Naples (Cashaqua) shales appear again in the cliff, rising to a height of about fifty feet. The Genesee shales disappear below water level about two miles south of the mouth of Eighteen Mile Creek. Before the section comes to an end, the black Naples (Gardeau) shales again make their appearance, the Cashaqua shales dipping below the water near the end of the section.

Several of the projecting points of this portion of the cliff can not be rounded by the pedestrian on the beach, unless he is willing to wade in water sometimes waist-deep. These projecting headlands afford interesting examples of the carving and undercutting action of the waves, which, during storms, hurl pebbles against the foot of the cliff. The smooth, cavernous indentations are excellent illustrations of phenomena frequently noted on a larger scale, on

PLATE XVII.—View of the mouth of Pike Creek in the Spring of 1888. The stack has been separated from the main bank on the left by the stream and wave cutting within very recent times.

—Photographed by H. C. Gram, Jr.

PLATE XVIII.—View of the mouth of Pike Creek in the autumn of 1897, showing the changes produced by sub-ærial denudation. (This view is not taken from the same point as the preceding one). The lower part of the stack consists of the Moscow shales and the upper of the Genesee shales.
—Photographed by I. P. BISHOP.

the rocky shore of New England, and the rock bound coasts of other regions.

Beyond the first of these projecting points, another thrust fault of similar character to the "uplift," appears in the bank. As in the case of the latter, this fault passes upward into a monoclinal fold, while the lower strata alone are fractured, portions of them being turned on end.

From the point where the shale appears again in the bank, something over three miles below the mouth of Eighteen Mile Creek, as far as Sturgeon Point, the cliffs are comparatively low, and composed wholly of the black Naples or Gardeau shales. Septaria are common in these shales, and they often reach a large size. One of these which, I observed in the bank some years ago, was perfectly elliptical in outline, its length and thickness being twelve and ten inches respectively. It had been split in two by a joint crack, and the septarian structure was clearly visible. The shale above and below curved around the concretion, this being caused by the settling of the whole mass upon the shrinking of the clay beds during the process of lithification.

Before reaching Sturgeon Point, the shale disappears, and the banks for some distance are composed of sand and clay, with occasional outcrops of the shale near the water's edge. Septaria of great size are common on the beach. At Sturgeon Point the shale appears again in the bank, and is visible for some distance. It is black, highly bituminous, and contains plant and fish remains. The latter are of great interest, and are occasionally found in a very good state of preservation.

The following notes on the fish-remains found up to date at Sturgeon Point, were kindly furnished by Mr. F. K. Mixer, who has for many years studied the fish horizons of this vicinity:

"The first of the remains described from the shales at Sturgeon Point, was the dorso-median plate of a new species of *Dinichthys*, which by its discoverer and describer, Dr. E. N. S. Ringueberg, was named *D. minor*.* This name being pre-occupied, *D. ringuebergi* was substituted for it by Newberry.† In 1886, Dr. Herbert Upham Williams described and figured two new species, both of the genus *Palæoniscus* De Blainville.‡ These were *P. riticulatus* H. U. Williams and *P. antiquus* H. U. Williams. With these were found remains of, probably, *Dinichthys ringuebergi* Newberry (*D. minor* Ringueberg). Since that time a number of remains have come to light from these shales,§ among which the following may be mentioned: 1.—A specimen showing both rami of the mandible of a *Dinichthys*, which may be referred to *D. minor* Newberry with a good deal of reservation, since the terminal portion is completely crushed, and beyond the recognition of the characteristic features. Its size is intermediate between that of *D. minor* Newb. and that of *D. newberryi* Clarke. 2.—A specimen of an undescribed *Dinichthys*, considerably weathered. 3.—A specimen which appears to be the terminal tooth of *D. minor* Newb., but smaller than the usual form. Besides these there are specimens referable to *Mylostoma variabilis* Newberry, *Callognathus serratus* Newberry, and a large scale which appears to belong to a species of *Holoptychius*, but further examination may result in placing it in a new genus. These remains of fishes are not found in any great abundance. They have to be carefully looked for over a considerable area at Sturgeon Point, and they are found most frequently associated with two species of *Lingula*—*L. concentrica* Conr., (probably a variety of *Schizobolus truncatus* Hall) and *L. spatulata* Vanux., with *Goniatites*, *Lepidodendra*, *Calamites* and Conodonts. The larger specimens of fish remains are usually so much weathered, that their identification becomes, if not impossible, yet a matter of extreme difficulty."

Beyond Sturgeon Point the shale disappears again, and unconsolidated material takes its place. In many places the bank is low, and largely composed of sand dunes, in others it is a sand and clay cliff, which bears evidence of being constantly eroded by the waves. Trees and shrubs have slid down the bank, and are now growing from it at all angles.

At "Dibble Point," beyond the mouths of the Sister Creeks, the shales appear again in a low cliff. They vary in color from dark gray to black, and are full of septaria, most of

*Am. Journ. Science, Vol. 27, p. 476, 1884. With figures.

†The Palæozoic Fishes of North America by J. S. Newberry. Mon. XVI., U. S. Geol. Surv., p. 60.

‡Bull. Buff. Soc. Nat. Sciences, Vol. V., No. 2, pp. 81-84; one plate.

§Mainly through the labors of Mr. Mixer himself.

PLATE XIX.—View of the stack at Pike Creek and the cliff beyond. The beach in the foreground consists of "flat gravel," derived from the shale cliffs.
—Photographed by I. P. BISHOP.

PLATE XX.—View of the cliff south of the mouth of Pike Creek. A few feet of the Upper Moscow shales are exposed at the base of the cliff, where they are cut into by the waves. The Genesec and Gray Naples shales form the main portion of the cliff. The beach consists largely of transported material from the drift.
—Photographed by I. P. BISHOP.

which are of gigantic size, individuals six, eight, or even ten feet in diameter being common. Many of them exhibit grotesque imitative forms, and are often taken for prehistoric monsters, which some freak of nature has preserved in all their grotesqueness. These concretions are of similar size to those found in the gorge of Eighteen Mile Creek near the forks, and it is possible that the same bed is represented in both localities. Another small fault occurs in this cliff.

The septarium-strewn beach finally gives way once more to a sandy and pebbly beach, behind which the banks again consist of unconsolidated material, which completely conceals the underlying shale beds.

Beyond Muddy Creek the shales appear again. The bank is at first only eight feet high, but soon rises to the height of thirty feet or more. This is at Harrison's Point, a rocky headland, the base of which is washed by the waves the year round. The cliff beyond, descends perpendicularly to the water, and ordinarily passage along its base is impossible. These conditions continue for some distance, after which the cliffs are again fronted by sand and gravel beaches. Several of the points beyond this, however, project far out into the water, so that ordinarily travel on the beach is impracticable. Near Cattaraugus Creek the banks are low, and for the most part composed of unconsolidated material.

It will be observed that the highest members of the Genesee stage, *i. e.* the Naples (Gardeau) flags, are not exposed in the section along the lake shore. This is due to the fact that the sections extend in a general south-west direction, which does not vary much from the direction of the strike of the strata in this region. Consequently most of the sections exhibit strata having a very low dip, and therefore no great stratigraphic ascent has been made by the time the county line is reached. The flagstones of this stage, as well as the sandstones of the lower Chemung stage (the Portage sandstones) are however, found in the higher south-eastern portions of the county, where they are exposed in ravines and water courses, and uncovered in quarries.

B. The North Shore Cliffs.

North of the mouth of Eighteen Mile Creek, there are five sections, which are of sufficient importance to require separate and detailed descriptions.

THE IDLEWOOD CLIFF.

Plate XXII.

This section extends from the mouth of Eighteen Mile Creek northward to the old drift-filled gorge noted above. The cliff is usually steep, but much weathered, and many places are thickly overgrown by vegetation. The beach at the foot of the cliff is very broad, and the waves ordinarily do not reach the cliff. In consequence, a strong talus has accumulated at the foot of the cliff, thus obscuring many of the lower strata.

At Idlewood, the cliff has a total height of something over sixty feet. At the top, six feet of the Moscow shales are exposed, these therefore, including the whole of the shale bearing the Spirifer consobrinus fauna. If care is taken to collect all the fossils when excavations are made, preparatory to the erection of new cottages, a most complete series of specimens of this fauna may be obtained. The natural exposures in this cliff are such, that the Moscow shales can not be readily examined. The Encrinal limestone is exposed in the cliff at Idlewood, its average thickness being one foot and a half. It may be traced for some distance northward, after which it is not seen again until near the northern end of the next section. The calcareo-argillaceous layer first noticed at the upper end of Section 8 in Eighteen Mile Creek, forms a prominent band on the face of the cliff, ten or twelve feet above the base. About seven feet above it, the Modiomorpha subalata bed is seen, forming a distinct band one inch wide, on the cliff. At the base of the cliff the three

PLATE XXII.—View of Idlewood Cliff and the mouth of the gorge of Eighteen Mile Creek. The Trilobite layers, and the hard bed seven feet above them, are prominent in the cliff. The south shore cliff is shown in the distance, and the sand bar, stretching from it across the mouth of Eighteen Mile Creek, is seen on the right. A foot bridge connects the bar with the Idlewood Cliff. —Photographed by I. P. BISHOP.

PLATE XXIII.—View of Wanakah Cliff, looking north. About forty feet of the Hamilton shales are shown at the base, succeeded by the Encrinal limestone, which projects from the bank. The Moscow shales, Styliolina limestone and Genesee shales appear above these. Encrinal limestone blocks occur on the beach.

—Photographed by I. P. BISHOP.

Trilobite beds appear, having all the characters, and the same species of fossils, as those noted in their exposures in the gorge of Eighteen Mile Creek. The lowest bed, not fully exposed there, exhibits its full thickness of one foot in this section. In some places the shale underlying the lowest Trilobite bed is seen, bearing *Athyris spiriferoides* (Eaton), and *Spirifer mucronatus* (Conrad). At the lower end of this section the Trilobite layers appear on the beach, where they form a distinct shelf or platform, at the water's edge.

Altogether this section is not a good one at the present time, though some years ago, when a cutting was made into it for a roadway, it afforded an excellent opportunity for collecting fossils.

WANAKAH CLIFF.

PLATES XXIII AND XXIV.

This cliff begins north of the drift-filled gorge, on the land of Mr. Albert Meyer. It extends northward for about a mile and a half, and terminates in a bluff seventy-five feet high. The northern end of the bluff drops off quite suddenly, and a long stretch of low clay banks, with occasional outcrops of shale on the beach, succeeds this section, and separates it from the next one.

The cliff at the southern end is very low, and much broken. There is considerable accumulation of debris at the base, which has to be removed if the lowest strata are to be examined. The Trilobite beds appear prominently in the bank, the base of the lowest being some eight or ten feet above normal water level. In their total thickness these beds do not differ much from the Eighteen Mile Creek outcrops, but in the subdivisions into shaly and calcareous beds, some variations are observable. The most important strata, however, occur again, *i. e.* the lower bed (one foot thick), and the shale next above, (with *Athyris spiriferoides* (Eaton), and *Streptelasma rectum* Hall). Half way up the bank appears the calcareous layer noted in other sections as lying about six feet above the upper Trilobite bed. This contains many robust specimens of *Spirifer mucronatus* (Conrad), but few other fossils are found. Mr. Albert Meyer has, however, obtained some interesting fish remains from a fragment of rock which probably came from this bed.

About five feet of the shales below the Trilobite beds are exposed. The upper two feet of these are highly fossiliferous. The fossils are mainly brachiopods, of the genera *Spirifer, Stropheodonta, Rhipidomella, Athyris, Chonetes,* etc. Below this the shale is less fossiliferous, down to about five feet below the lowest Trilobite bed. Here a hard calcareous layer occurs, an inch or two in thickness, in which fossils are very abundant. The large *Spirifer granulosus* (Conrad), which was found to be characteristic of the Demissa bed, and of the Encrinal limestone, occurs here in considerable numbers. Many other fossils occur with it, among which may be mentioned *Tropidoleptus carinatus* (Conrad), which is almost absent from the shale between this bed and the Encrinal limestone, but is abundant in the latter rock. Less than a foot below this bed is another of similar character, which however, is usually covered by the debris on the beach. In this bed the little Favositoid coral, *Pleurodictyum stylopora* (Eaton) is met with for the first time, this being the highest bed in which the fossil occurs in this region. *Spirifer granulosus* (Conrad) is also common in this bed, and besides these, twenty other species of fossils have been obtained from it. Among them should be mentioned a specimen of *Goniatites uniangularis* Conrad, completely replaced by iron pyrites, as well as a number of specimens of *Orthoceras* similarly replaced. This bed is the upper one of three, in all of which *Pleurodictyum stylopora* (Eaton) is common, and to these beds it is restricted in this region. These strata have, therefore, been named the Pleurodictyum beds,* and will later be described more at length.

*Faunas of the Hamilton Group, etc.

PLATE XXIV.—View of the northern end of Wanakah Cliff. The Hamilton shales, Encrinal limestone, and Moscow shales are shown. The beach on the left is underlain by the Trilobite beds. Erie Cliff appears in the distance. —Photographed by I. P. Bishop.

In a little ravine near the center of the section, a good opportunity is afforded for the exploration of the Modiomorpha subalata bed, which is twenty-five feet below the Encrinal limestone. This bed appears near the center of the cliff as a well-marked band one inch wide, whence it can be traced in the bank of the ravine, to a little beyond a foot bridge, where the layer produces a small fall or rapid in the bed of the stream. *Modiomorpha subalata* (Conrad) is extremely abundant, while the other fossils in this bed are rare. *M. subalata* occurs in the beds above and below, but nowhere in these shales is it so abundant, or so well preserved. The floor of the old Devonian sea must have been thickly covered with these ancient mussels, which formed a bed similar to those near our modern shores. The Trilobite beds, and the calcareous layer above them, likewise appear in the floor and banks of the little ravine.

Beyond this ravine, the cliff rapidly increases in height, until in its last third, it has a height of seventy-five feet or more. It there forms one of the finest sections anywhere to be seen in this region. The perpendicular face of the cliff, the projecting Encrinal limestone half way up, and the overhanging prismatic blocks of black Genesee shale on top, are the most striking features, and all combine to make the height of the cliff seem greater than it actually is. At the northern end of the section the Trilobite layers appear on the beach, forming a shelf at the water's edge. The middle bed is highly fossiliferous, while the shale just below is full of *Streptelasma rectum* Hall. The apparent northward dip of the Trilobite beds is due to the direction in which the section is cut, which in its lower part is more east and west than north and south.

Large slabs of Encrinal limestone occur on the beach, containing *Heliophyllum confluens* Hall, several species of *Zaphrentis*, and a large number of crinoid stems. *Stropheodonta concava* Hall is also common in the limestone.

ERIE CLIFF.

PLATE XXV.

This section is best approached from Hamburgh-on-the-lake station. To the right of the road which leads from the station to the shore, is Avery's Creek,* a small stream, which has cut several sections in the rock. Near the rail-road crossing, the hard layer, six feet above the Trilobite beds, appears in the bank, included by shale above and below. Farther down the stream, the Trilobite layers are exposed in the bed of the stream, where they are the cause of rapids. They contain essentially the same fauna as at Eighteen Mile Creek and the sections on the Lake Shore, except that the trilobites are somewhat less abundant. The beds here are subdivided as follows in descending order:

Argillo-arenaceous limestone	3 inches
Shale with few fossils	3 "
Limestone similar to above	4 "
Fissile shale	8 "
Arenaceous limestone, somewhat shaly and very fossiliferous	12 "
Total	30 inches

In the middle bed the rare trilobite *Homalonotus dekayi* (Green) was found. The two feet of shale next below the Trilobite beds contain a rich fauna, which recalls the fauna of the Demissa bed in the upper Hamilton shales. *Spirifer mucronatus* (Conrad) is very common, and *Athyris spiriferoides* (Eaton), and *Streptelasma rectum* Hall are likewise abundant. *Rhipidomella penelope* Hall is one of the rarer forms found here, *Tropidoleptus carinatus* (Conrad) being another. *Rhipidomella leucosia* Hall and *R. cyclas* Hall are among the forms seldom found above this shale. Altogether more than thirty species of fossils occur, most of which are brachiopods.†

*The stream is named after Mr. Truman G. Avery, the proprietor of the land through which it runs.

†For a list of the fossils obtained from these and the lower beds see the author's paper on the Faunas of the Hamilton Group of Eighteen Mile Creek and vicinity. —Ann. Rept. State Geol. N. Y. 1896.

PLATE XXV.—View of the mouth of Avery's Creek, and a part of Erie Cliff. Only the Transition shales of the Upper Marcellus are shown.
—Photographed by I. P. BISHOP.

Below this shale occurs a hard calcareous layer less than an inch in thickness. This is especially rich in bryozoans, which sometimes make up the bed. The shale below this bed is less fossiliferous and fissile than that above. About a dozen species of fossils occur, but all of them are rare. Among them is *Homalonotus dekayi* (Green).

About four feet below the Trilobite layers is another hard calcareous layer, something over an inch in thickness. This is full of fossils, among which *Spirifer granulosus* (Conr.) predominates. It corresponds to the layer noted in a similar position at the upper end of Wannakah Cliff.

Less than a foot below this calcareous layer, or about five feet below the Trilobite beds, appears the first or upper Pleurodictyum bed. The second and third are immediately below it, all of them being exposed in the bed of the stream, beyond the last bend, or not very far from Mr. Avery's barn. None of the beds have a very great thickness, the lowest and thickest not exceeding four inches. As already noted, the little coral *Pleurodictyum stylopora* (Eaton) is wholly restricted to them, and occurs in great numbers, being especially common in the middle one of the three beds. With it occurs *Spirifer granulosus* (Conrad), which is frequently overgrown with bryozoa and corals.

Altogether these are the richest beds in the lower Hamilton shales, holding the relation to the lower portion of these shales which the Demissa bed holds to the upper portion. Their chief interest lies in the presence of *Pleurodictyum stylopora* (Eaton), which is thus seen to be entirely restricted to the lower portion of the Hamilton shales of this region. The lowest of the three beds is of further interest, as it contains besides the *Pleurodictyum*, two other fossils, which are not found outside of it.* These are *Nautilus magister* Hall and *Ambocoelia umbonata* var.

*It should be noted, however, that the second of these, *Ambocoelia umbonata* var. *nana* Grabau, has been noticed in the bed just below, the few specimens found, however, differed considerably from the normal characters of the variety.

nana Grabau (var.). The *Nautilus* is of especial interest from the large size of the specimens obtained, which often measure six or eight inches in greatest diameter. The specimens occur in the concretionary masses of which this bed is composed, and from the nature of the rock and the brittleness of the fossils, great care is needed in freeing them from the matrix. This is by far the largest and finest fossil found in the region, and its restriction to this, the lowest bed of the Hamilton shales proper, is of great interest. This bed has therefore been named the Nautilus bed.* It was from this bed that the original specimens described and figured in Volume V. of the Palaeontology of New York, were obtained, and so far as known, this species has not been found elsewhere.

Ambocoelia umbonata var. *nana* is a small representative of the species, the brachial valve differing in its greater convexity and its general resemblance to that of *Spirifer subumbonus* Hall. The proportions differ from the normal for the species, and the surface is marked by numerous elongated pits, as in *A. spinosa* Clarke. This variety occurs in great numbers, and characterizes the rock whereever found.

Another fossil which is practically restricted to this bed, and which occurs in great numbers, associated with the preceding, is *Camarotoechia dotis* Hall. These shells are usually found in an excellent state of preservation, and where differential weathering has left them in relief, details of structure appear clearly. Sometimes the rock is made up of these shells and the little *Ambocoelia*, and in such instances it is a comparatively pure limestone, though ordinarily it partakes more of the nature of a calcareous claystone. Other fossils are extremely rare, and occur mainly in the shaly portions of the bed.

*Faunas of the Hamilton Group, etc.

The position of this bed is about seven feet below the base of the lowest Trilobite bed, and its outcrop in the ravine is almost opposite Mr. Avery's barn.

The Transition Beds. With the Nautilus bed the base of the Hamilton shales is reached. Underlying it are thirty feet of shales which contain a mixed Hamilton and Marcellus fauna, and they are therefore regarded as transition beds between the Marcellus and Hamilton. The shales are capped by a bed of somewhat arenaceous limestone, six inches in thickness and very fossiliferous. This bed lies immediately below the lower Pleurodictyum or Nautilus bed, its position being about fifty feet below the base of the Encrinal limestone. It forms the top of the fall in the ravine just below the bridge on which the Lake-shore turnpike crosses. Here the bed is full of *Orthoceras* (*O. exile* Hall) and of gastropods (*Bellerophon leda* Hall, *Loxonema hamiltoniæ* Hall and *L. delphicola* Hall). The small productoid brachiopod with the truncated beak—*Strophalosia truncata* Hall—is the most abundant fossil in this bed, and as it seldom occurs outside it in this region, it becomes a convenient form from which to name the bed. The name Strophalosia bed has been adopted for it,* this name at the same time indicating the geological position of the bed, since the *Strophalosia truncata* Hall is a characteristic Marcellus fossil.† The Strophalosia bed appears in the cliff both above and below the mouth of Avery's Creek. Passing southward, we find, after crossing the mouth of a second small ravine, which opens near Avery's Creek, that the cliff has a height of only twenty feet or thereabouts, and is entirely made up of the transition shales, which also form the walls of the ravine of Avery's Creek below the falls. Several layers of concretions occur in these shales, but fossils

*Faunas of the Hamilton Group, etc.

†This is the bed lettered (a) on Plate V. of the Report on the Fourth Geological District by Professor James Hall. The position of Avery's Creek is there indicated by the depression marked "13 miles from Black Rock." The bed is referred to on pp. 190 and 191 of that report, where it is spoken of as the westward extension of the "thick mass of sandy shale, so abounding in conchiferous molluska in the eastern part of the State, ... which in the central part is still in great force."

as a rule are rare. *Spirifer mucronatus* (Conr.) occurs in the upper portion, and with it a number of other Hamilton fossils, all of which, however, have been found in true Marcellus shales. Lower down, the characteristic Marcellus and Genesee pelecypod *Lunulicardium fragile* Hall appears, and with it its constant associate, the minute pteropod *Styliolina fissurella* (Hall). The eminently characteristic Marcellus fossil *Liorhynchus limitaris* (Conr.) is sparingly represented in the lowest beds. Some little distance below the mouth of Avery's Creek, the Strophalosia bed appears in the bank again, and with it the overlying lower Pleurodictyum or Nautilus bed. Both beds gently descend towards the south, until near the end of the section, they pass below the lake level.

This portion of the cliff affords a good opportunity for collecting the fossils from these beds, especially the *Nautilus magister* Hall. Specimens of the latter were formerly obtained in numbers on the beach at the foot of the cliff, and the supply is probably still a fairly good one.

North of the mouth of Avery's Creek the cliff rises to a height of something over thirty feet, a portion of it projecting out into the water, so that one can not pass along the beach for any distance. At the northern end of the section, however, one can descend in a dry ravine* to the beach, and walk southward along the beach to the projecting point. The Strophalosia and Nautilus beds are seen everywhere in the section near the top of the cliff, forming together a band about a foot in thickness. The beach is strewn with the fragments of these beds which have fallen from above, and a good collection of the specimens may be obtained with little labor. *Pleurodictyum* is especially abundant, the specimens usually being free from the matrix. The cliffs are very picturesque, and present good examples of wave and frost erosion. All the lower portion of the cliff consist

*Marked "Davis" on Plate V. of the Geol. Rep't 4th District, 1843.

PLATE XXVI.—View of the north end of Athol Springs Cliff, showing the Transition and the Upper Marcellus shales, traversed by two sets of parallel joints.
—Photographed by I. P. Bishop.

of the Transition shales, in the upper part of which, Hamilton species predominate, while the lower portion contains mainly Marcellus species.

ATHOL SPRINGS CLIFF.

PLATE XXVI.

This cliff extends from the dry ravine, which runs to the lake-shore from Lake-side Cemetery Station, to the Fresh-Air-Mission Hospital at Athol Springs. In the ravine few exposures are found, but some outcrops of the Trilobite and Pleurodictyum beds occur. In the cliff, for some distance above the ravine, the Strophalosia bed appears near the top of the section; but the overlying beds are too much obscured by talus and vegetation, to be visible. The whole of the Transition shales appear below the Strophalosia bed.

The Upper Marcellus Shales.—The Transition shales are limited below by a hard layer, containing an enormous number of pteropods, chiefly of the two species *Styliolina fissurella* (Hall) and *Tentaculites gracilistriatus* Hall. The two species appear very much alike on the rock, owing to the fact that both exhibit the longitudinal "fissure" due to compression. *Tentaculites* however, as noted before, is readily distinguished on close inspection, from *Styliolina* by the raised annulations. Where the surface of the rock has weathered, the pteropods appear in vast numbers, and in great perfection. This layer appears for the first time on the beach about the center of the section. It rises northward, until near the Hospital it forms the top of the cliff, which here has a height of from fifteen to twenty feet. At this point the cliff projects into the water, and in climbing over it, an opportunity is afforded for the examination of the pteropod-bearing bed. This bed marks the top of the Marcellus shales in this cliff. The shales below it contain only characteristic Marcellus fossils. The predominating species are: *Tentaculites gracilistriatus* Hall, *Styliolina fissurella* (Hall), *Lunulicardium fragile* Hall, and *Liorhyn-*

chus limitaris (Conrad). Several other species occur, but on the whole fossils are rare, and a day's search may furnish only a very meagre collection. A small specimen of *Nautilus marcellensis* (Vanux.) was found in the Pteropod bed. This fossil has heretofore been known only from the Goniatite limestone, between the lower and upper Marcellus of Central New York.

About six feet below the top of the Marcellus, occurs a hard layer, about two inches thick, containing *Ambocoelia umbonata* (Conrad) in considerable numbers. This bed appears about ten feet above the water in the cliff behind the Hospital. In the shale below it, carbonized plant remains occur occasionally. The cliff is succeeded by a long stretch of low, sandy shore, with no rock outcrops.

BAY VIEW CLIFF.

PLATE XXVII.

This cliff extends southward for about two thousand feet from the Bay View House (formerly Comstock's tavern). The cliff, where highest, does not exceed fifteen feet in height, while the greater portion is much lower. The outline of the cliff is a zigzag one, this being due to the two sets of joint cracks, which traverse the rock, and intersect at nearly right angles. The Marcellus shales alone are exposed in this cliff, and fossils are few, consisting chiefly of the pteropods *Styliolina fissurella* (Hall) and *Tentaculites gracilistriatus* Hall. *Lunulicardium fragile* Hall and *Chonetes lepida* Hall, are occasionally found. *Chonetes mucronata* Hall, and a few other Marcellus species also occur.

At the southern end of the section, the hard layer with *Ambocoelia umbonata* (Conrad) appears about ten feet above the water. It is here two inches thick. Six inches above, is a similar layer one inch thick, the two appearing as prominent bands wherever the section is fresh.

A little to the north of the Bay View House, the shale disappears, and the beach from this point to the Niagara

PLATE XXVII.—View of Bay View Cliff, showing the jointed Marcellus shales, overlain by glacial detrilus.
—Photographed by I. P. Bishop.

River, a distance of about eight miles, is low and sandy. The country for some distance back from the lake, is low, level farm or swamp land. The shale appears in the bed of Smoke's Creek, near West Seneca, containing *Liorhynchus limitaris* (Conr.). The exposure is about a mile and a half from the shore, and its consideration does not properly belong here.

General Summary of the Lake Shore Sections.—Taking a general view of the lake shore cliffs, we notice that they furnish a continuous section from the Marcellus to the upper Naples shales. Of the former, less than twenty feet are exposed, these representing the upper olive shales of the formation. The greatest thickness of the Marcellus in Western New York, according to Professor Hall, is not over fifty feet.* The thickness of the rock in Erie County is probably somewhat less.

Resting on the Marcellus shales, are the thirty feet of Transition rock, terminated by the Strophalosia bed. These are by some included in the Hamilton stage, but their relation is probably more with the Marcellus, and they are here placed with the latter. The whole thickness of the Lower or Hamilton shales—about fifty feet—is exposed, beginning with the Nautilus bed.

The noteworthy beds included in the Hamilton shales are as follows: First, at the base, the three Pleurodictyum beds, (the lowest of which is the Nautilus bed). Second, the three Trilobite beds, beginning between nine and ten feet from the base. Third, the lithologically similar bed, six feet above these, or eighteen feet from the base, (noteworthy mainly on account of its persistence). Fourth, the Modiomorpha subalata bed, twenty-five feet from the base. Fifth, the Athyris spiriferoides layer forty-one feet from the base. Sixth and seventh, the Demissa and Stictopora beds, between four inches and a foot from the top.

*Rep't 4th Geol. Dist. 1843, p. 179.

The Encrinal limestone, eighteen inches to two feet thick, is well exposed. The whole of the Upper or Moscow shales (seventeen feet) are exposed. The divisions into lower Moscow (shales bearing the Spirifer consobrinus fauna), middle Moscow (barren shales), and upper Moscow (shales bearing the Spirifer tullius fauna), are retained throughout.

The whole of the Genesee shales—twenty-three feet and seven inches thick (Hall), are exposed, beginning at the base with the Styliolina layer. The subdivision into lower gray and upper black shales is not as marked, as in the gorge of Eighteen Mile Creek. The whole thickness of the gray Naples or Cashaqua shales is exposed, this, according to Hall being thirty-three feet. Probably less than one hundred feet of the upper Naples or Gardeau shales are exposed in these sections, the lower half of which consist of black and fissile shales, while the upper, remaining exposed portion, consists of alternations of olive and gray or black shales, with septaria in the lighter colored beds.

This may be tabulated as follows:

UPPER DEVONIAN (CHEMUNG GROUP).	CHEMUNG STAGE.	Not exposed.		
	GENESEE STAGE.	Naples shales { Gardeau.......	100	ft. (estimated).
		Naples shales { Cashaqua	33	" (Hall).
		Genesee shales and Styliolina limestone......	23.5	" (Hall).
MIDDLE DEVONIAN (HAMILTON GROUP).	HAMILTON STAGE.	Moscow shales....................	17	ft.
		Encrinal limestone..............	1.5	"
		Hamilton shales..................	50	"
	MARCELLUS STAGE.	Transition shales................	30	ft.
		Upper Marcellus shales.......	20	" (exposed.)
		Lower Marcellus, (not exposed).		
		Total, . . .	275	feet.

CHAPTER III.

SEQUENCE OF GEOLOGICAL EVENTS.

Let us picture to ourselves the succession of the geological events which occurred in this region since Lower Devonian times.

The Lower Devonian in this part of the country was a limestone making age, when the pure, and presumably warm waters of the great interior Palæozoic sea, which stretched from the Adirondacks to the Rocky Mountains, was inhabited by corals, crinoids, and other pure water animals. Miles upon miles of coral reefs stretched across what is now the State of New York, and westward to the Mississippi River, and beyond. All that portion of the "vast American Mediterranean Sea," as Dana has called it, was inhabited by myriads of coral-building polyps, which constructed a reef, comparable to the Great Barrier Reef of Australia. This ancient reef was a barrier reef for the Devonian continent of North America, which lay to the north, and which consisted of the old Archæan lands, with the additions made during Cambrian, Ordovician and Silurian times.

This ancient coral reef now constitutes the Corniferous limestone, which can be traced from Buffalo eastward nearly to the Hudson River, and westward into Missouri and Iowa, with a northern spur running up into the peninsula of Michigan. Northern Illinois and Wisconsin, at that time, seem to have been above water. (Dana). Similar coral reefs were forming in the seas which covered portions of New England and Canada.

Dull-colored and unattractive as these ancient coral reefs may seem to-day to the ordinary observer, they nevertheless had beauty once, beauty comparable, if not superior, to that seen in existing coral reefs.* The visitor to the Bahamas, who looks through his water-glass at these marine flower-gardens, can form some conception of the beauty which once existed in the coral reefs of the Devonian Sea. He sees to-day the large coral masses, consisting of huge brain corals, multicolored Astræans and branching Madrepores, whose surfaces are covered with myriads of tiny polyps; and, waving over all, the graceful Gorgonias, the sea-whips and sea-fans, as they are so aptly called. Then let him be transported back, in imagination, some millions of years, to the coral reefs which then grew where now are some of the most important states of the Union. The Mæandrinas and Astræans were then represented by large heads of *Favosites*, which grew sometimes in such abundance that their remains constitute a large portion of the reef. The Madrepores and other branching corals were not represented, but in their stead grew multitudes of cup-corals, chiefly single, horn-like or funnel-like structures, not infrequently a foot in length, and supporting at their growing ends, polyps, which rivalled in size the modern sea-anemones of our coast. And beauty of color there probably was, as well as beauty of form, though only the latter is suggested in the remains. Waving over the bottom in place of the modern Gorgonia fronds, were those graceful and remarkable creatures, the crinoids, whose modern representatives, dredged principally in tropical seas, are objects of exquisite beauty. Swaying on their stems, with their much-divided arms outspread, flower-like, they must have presented a striking spectacle. In modern tropical waters, the multicolored fishes swimming in and out among the gorgeous coral masses, quickly attract the attention of the observer. There were fishes in the Devonian seas, but they were strange, uncouth creatures, predaceous

*Some conception of the luxurience of life and wealth of form in coral reefs can be obtained from an inspection of Mr. W. Saville Kent's photographs of living corals, reproduced in his book on the "Great Barrier Reef of Australia." The coloring is absent from these plates, but as far as the character of the corals and their association in the reefs are concerned, the plates are superb, and next to seeing the reef itself, the student can do no better than to study these photographs carefully. The coloring is reproduced in the chromo-lithographs appended to the volume. The student will also be surprised to find how universally the corals are exposed at low tide, a condition which one would ordinarily regard as fatal to the animals.

sharks and plate-covered ganoids, which probably had no great beauty of color. Their strange forms, however, and their frequently formidable size, made up for their lack of coloration, and they probably were among the most striking tenants of those waters. Shells were by no means uncommon, and though many of the modern brachiopods are dull-colored, it is highly probable that some, at least, of the many Corniferous species, showed tints approximating those of tropical gastropods and lamellibranches of the present day.

Thus, shut off from the destructive forces of the outer ocean by the Devonian land, which then existed to the east and south-east, this great interior sea was peopled with a multitude of organic forms, and the luxuriance of the life can only be imagined from the results which have been left behind. It is an interesting fact that this great Devonian coral reef seems to have been absent from Pennsylvania and the Southern States, and it is possible that this is due to the fact, that the water at that time was deeper over this area. For it is now generally recognized that corals flourish best in comparatively shallow water, and limestones are no longer regarded as necessarily of deep water origin. It is highly probable that the great Corniferous coral reef was built in shallow water, far enough away from land to be out of reach of the sediment carried down by streams. The reef probably grew southward, where the breakers, rolling in from the open ocean on the south-west, supplied pure water and ample nourishment for the polyps and other organisms.

How long these conditions continued, is difficult to say. That the time occupied for the growth and accumulation of the Corniferous coral reef was equal in length to that occupied in the accumulation of the much thicker shales succeeding it, will appear, when it is remembered that five to ten feet of fragmental rocks will accumulate during the time required for the formation of one foot of limestone.* We

*Dana, Man. Geol.

may place the time anywhere from a few hundred thousand to a million years or more. Eventually, however, the period came to an end, and the crinoids, corals, and other evidences of pure water disappeared. The limestone areas were invaded by mud-bearing currents, which apparently caused the local extinction of the reef-building corals. Thus we find, at the opening of the Hamilton period, that in place of the former wealth and beauty of the coral reef, organic life presents a more sombre tone.

The cause of this change in sedimentation was the shoaling of the water, so that extensive areas, formerly covered by the sea, became dry land, while other areas were converted into great mud-flats, laid bare at low tide. With the shoaling of the water, the influx of abundant fresh water from the land was probably combined, so that these shallower portions of the sea became fresh or brackish, rather than salt. We have here an approximation to the conditions which later gave rise to the extensive coal-swamps, and the black shales may be regarded as partial attempts at coal-making. As Professor William B. Rogers once said: "Nature tried her hand at coal-making during these epochs."

If we wish to gain a conception of these regions as they appeared after the beginning of the Middle Devonian period, we need only look at the extensive mud flats, which are laid bare at low tide on our shores, and notice the black carbonaceous mud, in which mussels and periwinkles lie buried by the thousands, waiting for the returning tide to restore them to activity. Some such conditions prevailed at the opening of the Mesodevonian period over all this region. Coarse sediment was absent, suggesting feeble currents in the shallow waters. Only fine silt and mud was spread out by the tidal currents, and the vegetation on these mud flats was slowly buried, and underwent a partial decay. Occasionally somewhat more gritty sediments were carried in, and at such times the pelecypods (*Lunulicardium fragile*, *Actinopteria muricata*, etc.) seem to have flourished in great numbers. The black carbonaceous muds hardened to form the black, bituminous, Marcellus shales, which immediately overlie the Corniferous limestone.* These shales, in many places, are full of fossils, chiefly brachiopods and pelecypods, indicating that these ancient mud-flats had their tenants similar to the mud-flats on the modern sea-coast. Streaks of coaly matter show how abundant was the vegetation, which, by its incomplete decay, gave rise to the bituminous matter in these shales.

During the Marcellus (Minuta) epoch, there were several minor oscillations, which, however, as their record is not revealed in any of the sections discussed in the preceding chapters, will be passed over. It may simply be remarked that after the accumulation of a number of feet of the black shale, more calcareous shales were formed, indicating the deepening of the water. Deeper water conditions were finally established towards the close of the Marcellus (Minuta) epoch, as recorded in the first sections on the lake shore. The pure water of the Corniferous (Acuminatus) epoch, however, was not re-established until very much later, and then only over limited areas.

In our own region, as the waters became deeper and purer, new forms of life appeared, probably through immigration from other regions where they originated. In the gradual appearance of these species in the Transition shales, we have recorded the long struggle to which the new-comers were subjected before they finally became established. By the time that the thirty feet of Transition shales had accumulated above the Marcellus beds, the water had become pure enough for the sudden development or immigration of the fauna of the Strophalosia bed. Silt and gritty material were still carried in, and constitute a large proportion of the material in the bed, but there was no longer any paucity of living forms. *Strophalosia*, *Bellerophon*, *Loxonema* and *Orthoceras* flourished in great numbers, and their shells

*These can be well seen in the beds of Cayuga and other creeks.

constituted a large proportion of the accumulation formed. These conditions, however, did not continue very long, for this fauna was soon driven out and replaced by the first of the true Hamilton faunas, which began with the development of corals, brachiopods, and large Nautili. It thus appears that the change from the Marcellus to the Hamilton conditions was a slow and gradual one, consisting in the deepening and purification of the water. Hamilton species gradually appeared, and although the change from the Strophalosia bed to the Nautilus bed is an abrupt one, the way for this change was being prepared during the long preceding ages. Not so, however, at the beginning of the Mesodevonian period, for the change from the Corniferous coral reef to the Marcellus mud-flats was sudden, resulting in the extinction of numerous forms of life, many of which disappeared forever. What became of the fauna of the Strophalosia bed at the opening of the Hamilton (Spiriferoides) epoch, is not known. The survivors probably migrated eastward, where the conditions continued more favorable.

At the commencement of the Middle Devonian period, the character of the sea-bottom, and the relative depth of the ocean, became more varied. In the west, owing probably to the absence of coincident subsidence and deposition, the conditions continued to remain uniform into the Upper Devonian. In the extreme east, however, subsidence went on at a uniform and continuous rate. This accounts for the fact that the beds are much thicker in the eastern portion of the State of New York than they are on Lake Erie or westward. For thick beds of fragmental material can not accumulate unless there is coincident subsidence, the sea floor sinking at a uniform rate, and thus making room for the material constantly brought in by the streams. While, however, the subsidence was greater in its totality and more continuous in the east, than in the west, it was more sudden in the Erie County region, so that, at the opening of the Hamilton period, the water over the present Erie County was deeper and purer than it was in the region of the present Genesee valley, where the Marcellus conditions continued into, and through the Lower Hamilton time. Farther east, *i. e.* nearer to the source of supply of the fragmental material, the water was still shallower and sands accumulated, the increase in the coarseness of which, was proportionate to their nearness to the old shore-line. It is an interesting fact, that in these near-shore formations we have a littoral fauna, consisting mainly of gastropods and pelecypods, brachiopods, which are the predominating forms in the deeper western waters, being almost entirely absent.

When we compare the fauna of the Hamilton shales in the region about Eighteen Mile Creek with that of the corresponding shales in the Genesee Valley, we will be impressed by the numerical preponderance, in species and individuals, of the life in the more western area. This indicates more favorable conditions in the Eighteen Mile Creek region, and consequently a greater luxuriance of life. The subsidence of fifty feet which occurred in this region during the deposition of the Hamilton shales was not uniform throughout, as is indicated by the alternations of coarser and finer material, and to some extent also by the variation of the faunas, and the fluctuation in the number of fossils in the various beds. That these local topographic faunas were influenced by local topographic changes, will be conceded, even though the precise changes can not be determined, just as the changes on modern shores can not always be determined, though their effects in the disappearance or reappearance of faunas may be quite marked. It is certain that many species, which flourished at the beginning of the Hamilton epoch, soon disappeared, and did not again occupy this region. An example is the great *Nautilus magister*, which flourished at the opening of the Hamilton epoch, but the remains of which are only found in the lowest true Hamilton bed, showing that the species disappeared at the end of the time occupied in the formation of that bed. The species associated with *Nautilus magister*, practically shared its fate, none of the characteristic forms of the Nautilus bed appearing in any higher horizon, with the exception of *Pleurodictyum stylopora*, and perhaps a few straggling individuals of *Camarotoechia dotis*. *Pleurodictyum stylopora* is another example of a species which became extinct in this region shortly after the opening of the Hamilton conditions, in the early times of which it flourished in great numbers.* Many of the species which lived at the beginning of the Hamilton epoch in this region, (many of which had undoubtedly immigrated from other localities) disappeared after the cessation of conditions favorable to their existence. While the mature individuals died, their more adaptable offspring migrated by successive stages, and finally became established in other localities. Towards the close of the Hamilton epoch, however, when the conditions favorable to the existence of the species again appeared, the species slowly returned. We find, therefore, the upper beds of the Hamilton shales, *i. e.* the Demissa and Stictopora beds, filled with species which are common in the Pleurodictyum beds and the shales just above.

It is not to be presumed, that during the time-interval which elapsed between the deposition of the lower and upper Hamilton beds, the migrated faunas made no attempt to return. The fact that such attempts were actually made seems to be indicated by the few straggling representatives of these faunas, such as *Tropidoleptus carinatus* and others, which occur at intervals in the beds overlying those in which they make their first appearance. But while a few individuals may have existed, the species never multiplied, until the time when the associated species which existed side by side with it during the earlier ages, returned. The causes for this may have been manifold, such as lack of proper food,

*It must be noted, however, that this species occurs in higher horizons farther east, and this may indicate an eastward migration after the conditions had become unfavorable in the west. On the other hand the eastern representatives of this species in the Moscow shale may have come from the same favorable locality from which the western forms had migrated at the opening of the Hamilton epoch, the species becoming entirely extinct in this region at the end of that time.

insufficiency of calcareous material in the water, increased or diminished depth or temperature, unfavorable currents, or other injurious physical conditions. The existence of other creatures, which preyed upon the species, may also have been the cause of the paucity of individuals. In this latter case the reappearance of the species in great numbers in the later beds, may have been due to reinforcement of the survivors from without, by the immigration of numerous individuals, so that by sheer force of number they survived the wholesale destruction, which formerly kept them down.

The sequence of changes during the continuance of the early Hamilton epoch was something as follows: The epoch opened with the formation of the Nautilus bed, the water being comparatively pure and free from coarse sediment. On the floor of the shallow ocean, grew millions of tiny brachiopods, which in places were closely packed, growing over and on each other and making clusters, in appearance recalling those of our modern mussel beds. Over these beds crawled the great Nautili, with their coiled and probably highly-colored shells. Brachiopods probably formed the food of these creatures, though many soft-bodied and shellless animals undoubtedly existed, of which no trace has been preserved. Here and there may have appeared a Nautilus floating on the surface or swimming vigorously to escape some hungry shark, which had wandered into the region. Scattered over the sea floor among the brachiopods were the tiny coral heads of the *Pleurodictyum*, the polyps probably with brilliant colors. Trilobites crawled about, but they were not very common. Gastropods likewise occurred, as well as a few pteropods, but pelecypods seem to have been absent altogether. With the beginning of the second Pleurodictyum bed the conditions changed. The Nautilus became extinct, the waters probably shoaled somewhat, and brachiopods continued to increase in number and variety, the earlier species, however, having disappeared. Bryozoa began to grow, and often formed large fronds, while gastropods and pelecypods became common. The *Pleurodictyum* still continued to exist in great numbers for some time, but finally it too disappeared. After that, the sea was peopled chiefly by brachiopods and bryozoa, while trilobites continued to increase in number. Before long, a rich brachiopod fauna had developed, and the deposition of the sediment went on at a somewhat accelerated pace. Another change occurred, and the rich brachiopod fauna disappeared. With this was brought to a close the deposition of the fossiliferous shales underlying the Trilobite beds. Then came a time of more shallow water, when gritty sediments were deposited along with the lime and mud. Here trilobites found conditions more favorable to their existence, and for a long time they continued to people the waters in great numbers. Occasionally they were kept down for a time, by unfavorable changes, and in their stead, other forms, such as *Athyris* and *Streptelasma* flourished. Eventually, however, they regained their vitality and again increased rapidly.

Then there came a time when the muddy waters allowed but little development of life, so that the shales succeeding the Trilobite beds are comparatively barren. When, however, the conditions recurred which favored the great development of the trilobites, these latter did not return. Probably by this time the great Placoderms had found their way into these waters in considerable numbers, and to them may be due the destruction of the trilobites. It is known from the specimen (before referred to) discovered by Mr. Myer, that these fishes were present at that time, and as they were ground feeders, the supposition lies near that they preyed upon the crawling trilobites and other bottom forms, and thus kept the water comparatively free from invertebrate life.

For a long time after this, animal life was scarce in the Hamilton sea of this region, brachiopods alone occurring in anything like abundance. Then came the arrival of numberless mussels (*Modiomorpha*), which at once began to settle down and appropriate the ground for themselves. These new-comers may have appeared from without, or they may indicate the sudden increase in numbers of the few forms which existed during the preceding ages. In any case, their development was rapid and complete, and so was their extermination. Thus was formed the mussel-bed which now appears in the sections twenty-five feet below the Encrinal limestone. After the mussels had virtually disappeared, except for a few stragglers, which remained on the scene of their former occupancy, brachiopods once more appeared in numbers, and continued thus for a very long period of time. At one time numberless individuals of *Athyris spiriferoides* appeared on the scene, and their appearance seems to have driven out most of the other forms of life, as recorded in the Athyris spiriferoides bed. Later, however, these returned again, but before they finally re-established themselves, some unexplained changes took place, which temporarily established conditions similar to those which prevailed during the later Marcellus epoch. The two pteropods, *Styliolina fissurella* and *Tentaculites gracilistriatus*, became the sole occupants of the water, and as they probably were pelagic animals, their occurrence in these shales may be explained by the assumption of the existence of currents, which carried them in from the open sea.

At last, when the Hamilton age was near its end, the rich fauna of the Demissa bed appeared. This sudden development of forms, many of them appearing for the first time, can only be explained by supposing immigration to have taken place. An interesting feature of this bed is the occurrence of two brachiopods, *Stropheodonta plicata* and *Spirifer asper*, both of which belong normally to the Hamilton fauna of Iowa. This fact would indicate, that at some time during the later Hamilton age, fairly uniform conditions extended westward from this region to Iowa, and perhaps beyond.

Before the close of the age, the water had become pure enough for the growth of crinoids, the remains of which, together with the fronds of the branching bryozoan *Stictopora incisurata*, and the shells of the small brachiopod *Nucleospira concinna*, make up the greater portion of the "Stictopora" bed. The age closed with the deposition of a few inches of mud, in which few remains were buried.

The conditions, however, were now favorable for the re-establishment of a coral reef, which began by the growth of large heads of *Favosites hamiltoniæ*. Cup corals soon made their appearance again, though they were of different species from those found in the Corniferous reef. This was to be expected, for the many vicissitudes which the old Corniferous corals passed through, would undoubtedly effect specific if not generic modification. Crinoids, too, reappeared, though the genera and species were widely different from those which grew on the Lower Devonian coral reef. The Encrinal limestone is this much modified coral reef, which by its slight thickness indicates a comparatively short period of duration.

This reef was also of less areal extent than its predecessor in early Devonian times. The Encrinal limestone is not recognized in the eastern portion of the State of New York, and it has not been traced westward. In Illinois, Iowa, Michigan, Ohio, Indiana and other central states, however, the Hamilton is chiefly represented by limestones, often of considerable thickness, and in these, corals of various kinds abound, thus showing that the Encrinal limestone represents only a temporary eastward extension of the coral reefs which were forming in the clearer waters of the Central Interior Sea.

With the close of the short Encrinal limestone age, the corals did not become suddenly overwhelmed as was the case with the Corniferous reef. In fact, we find that after an interval, a number of corals appeared which did not grow on the coral reef proper in this immediate region.* They did not flourish long however, but were soon overwhelmed and disappeared. Some of them, such as *Cystiphyllum* and the adaptable *Streptelasma* continued at intervals for some considerable length of time. Aside from these, however, the Hamilton fossils are not common in the Moscow shales of this region. True, there are some adaptable species, such as *Phacops rana*, which are to be met with everywhere, but the great majority of species had left this region, migrating, during the uniform conditions of the Encrinal limestone age, probably to the eastward. At any rate, most of them re-appeared in the Upper or Moscow shales in the Genesee valley. In this latter region the shales are also much thicker, aggregating nearly three hundred feet, while in our own vicinity seventeen feet constitute the whole thickness of these shales.† The cause of the slight development of these shales in the region under consideration, was the comparatively stationary character of the sea bottom, in other words, the absence of subsidence. The water more-over, was shallow over Erie County, the evidence for which is found in the character of the fossils and in the shale itself, in the plant remains which occur in it, and in a fragment of a water-worn shell and a similarly worn pebble which were found.‡

Throughout the Moscow time, the water probably continued shallow, and life was scarce. The mud flats were probably never exposed at low tide, but their component material was worked over and over by the tidal currents, so that no perfect lamination was developed. On a sandy sea floor, such conditions would have formed oscillation ripples, but the fine mud did not admit of such impressions, or if they were formed, their preservation in the shale was an improbability.

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*At Morse Creek, near Athol Springs, *Heliophyllum*, which among others is here referred to, occurs in the Encrinal limestone.

†For a comparison of the Hamilton faunas of Eighteen Mile Creek with those of the Genesee Valley, see "Faunas of the Hamilton Group, etc."

‡The shell was a *Spirifer granulosus*, which does not normally occur in the Moscow shales of this region, but is common in the Encrinal limestone.

Life finally disappeared almost completely from this region, and for a long period the waters were practically uninhabited. The Upper Devonian conditions were ushered in slowly, some of the Genesee species appearing early during the Moscow age. This indicates that the change from the upper Middle to the lower Upper Devonian was a gradual one, and that abrupt changes did not occur, either in physical conditions or in life.

Meanwhile, during the whole progress of the Hamilton period in the east, there were regions in the west and south-west, where neither the limestone nor the shale-forming conditions of this period existed. In these regions, bituminous shales were deposited from the close of the Lower Devonian, far into the Upper Devonian. The changes in physical geography which allowed the development of the Hamilton beds in New York State after the deposition of the Marcellus beds, did not occur in the south-west, and with the continuance of the same physical conditions, the material deposited as well as the life continued very uniform throughout. The "black shale" of Ohio and other states represents these deposits, which continued uniformly, during all the time that the Hamilton beds were being laid down over New York. This enables us to understand why the species of fossils which flourished in the Marcellus epoch, should return during the Genesee epoch, while during the intervening Hamilton epoch they were absent.

If the centre of distribution of these animals, which found their natural habitat under conditions necessary for the formation of the fine black shales, was in the southwest, and there continued undisturbed during the whole of the Middle and later Devonian periods, new emigrants could travel eastward when the favorable conditions were, in part at least, restored. In Central New York a limestone making age, that of the Tully limestone, preceded the Genesee age, and while it continued, deposition was almost at a standstill in the west. The Tully limestone at some places in

Central New York has a thickness of nearly twenty feet, but its average thickness is only about half that. Towards the west it becomes thinner, until at Canandaigua Lake it is represented by a calcareous band three or four inches thick.* This limestone contains an association of fossils, which cause it to be referred to the Genesee stage, of which it forms the basal member. It is succeeded by the black Genesee shales, containing a number of fossils which had been characteristic of the black Marcellus shales. Twenty feet of these shales occur in the Genesee Valley, while at Eighteen Mile Creek there is scarcely a trace of them. At Section 1, the thin bed of spore-bearing shale is the only representative of this series, and even this does not occur everywhere. It is very possible, however, that during the time that the Tully limestone and the black shale above it, were forming in central New York, the transition beds of the upper Moscow shale were deposited in the Eighteen Mile Creek region, and that the Schizobolus fauna of these shales (if not the whole Spirifer tullius fauna) was, in a limited sense, contemporaneous with the Tully and lower Genesee faunæ of Central New York.

After the close of the Moscow age, when the transition beds had been deposited in this region, and the few inches of spore-bearing shale were laid down upon them, a subsidence, somewhat widely spread through Western New York, occurred, which brought with it the purification of the waters, which had hitherto been laden with fine carbonaceous silt. In the region about Eighteen Mile Creek, the beginning of this purification of the water is marked by the appearance, in a circumscribed favored spot, of a colony of crinoids, which seem to have flourished there for a considerable period, so that their remains accumulated to a depth of from two to three inches, as indicated by the thickness of the "Conodont" limestone. That the water was not very deep at this time, is shown by the highly comminuted condition

*Hall, Rep't 4th Geol. Dist., p. 214.

of the remains, which indicate a considerable amount of wave action, as well as by the grains of sand which occur in the rock.

While the crinoids flourished in this spot, and while similar conditions probably existed elsewhere, there came, perhaps from Ohio and the south-west, representatives of the great Placoderms which had ruled for many generations in those waters. These fishes seem to have found the area where the crinoids flourished, an exceptionally good feeding ground if we are to judge from the frequency of their remains in the rock. Living among the crinoids was a vast number of marine worms, the record of whose existence is now found in the "Conodonts," so plentiful in the rock. These bodies, as already noted, probably represent the œsophageal teeth of animals similar to our modern Annelida and Gephyrea.

As the subsidence continued, and the water became purer over larger areas, there began the deposition of the countless millions of shells of the minute pteropod *Styliolina fissurella*, which as noted above, in many places completely make up the Styliolina limestone. The conditions which favored the deposition of this limestone, were quite uniform over the greater portion of what is now Western New York. The character of the rock indicates that it was deposited at a distance from shore, where comparatively little sediment was carried, so that, as on the death of the pelagic animals, the shells slowly sank down from the surface, they accumulated by the millions on the ocean floor and formed a limestone bed of great purity. The accumulation of this inconceivably vast number of minute shells must have been a process of extreme slowness, even if we suppose that large numbers of the animals were carried to this region by favorable currents. It must be noted, however, that in many localities this bed contains a considerable amount of foreign matter, showing that some deposition of detrital material was going on.

While this long age continued, it not infrequently happened that trunks of trees, which grew on the land to the northward, were carried out into the comparatively quiet water, where, becoming water-logged, they finally sank, and after a long time, were buried in the growing deposit of shells. Eventually, however, this long limestone making age came to a close, by the gradual shoaling of the water, and the return of the mud-bearing currents. While at first there were some oscillations in the region, mud deposits alternating with deposits of shells, the conditions finally became uniform, and for a long period of time the Genesee mud-flats with their paucity of animal life, and their richness of vegetable life, constituted the characteristic feature of this portion of the Devonian sea. Of course subsidence of the sea floor went on throughout this period, but it was a very slow subsidence, so that the filling in by the fine mud, went on at the same rate, the relative depth of the water remaining the same.

Not until the close of the Genesee age did the subsidence become more rapid, and when this occurred, the deposits became once more of a calcareous nature, giving rise to the thirty feet of calcareous and concretion-bearing Cashaqua or lower Naples shales.

While these shales were being deposited, the water was inhabited, amongst other animals, by *Goniatites*, the shells of which are found in some of the concretionary layers. These animals may have come to this American Interior Devonian sea by immigration from the seas which then covered Europe, or they may have arisen independently. This latter is hardly conceivable, for parallelism of development between America and Europe would probably not have resulted in identity of species. As already noted, the few members of the fauna in which *Goniatites intumescens* and other *Goniatites* are the predominating species in this region, mark only a westward extension of the fauna which found its more perfect development in the region now occupied by the Genesee River.

Eventually shallow, brackish, or nearly fresh water conditions returned, and the black shales, which succeed the gray, were deposited. These deposits became more and more sandy as time progressed, and eventually culminated in more or less argillaceous sandstones. The faunas of the Genesee shales returned in a more or less modified condition, fishes being especially prominent. As the shoaling of the water continued, sands were deposited exclusively, and so the thick beds of Chemung sandstones were formed, succeeded later by beds of subcarboniferous conglomerate. Then the mud making conditions, which had at intervals occurred, and during the existence of which the carbonaceous shales were deposited, returned with greater perfection and greater permanency. Continuing long, they permitted a luxurient growth of vegetation, which, becoming buried in detrital deposits, has given us the Pennsylvania coal-beds. Similar conditions existed in other regions, where beds of coal also accumulated. The Pennsylvania coal-beds may be regarded as the record of the consummation of that coal-making tendency, which was so continuously exhibited during the middle and later Devonian, in this region, but which, at no time preceding the coal-measure (meso-carbonic) period, produced results which were in any way comparable to those produced during these later ages.

The sandstone beds of the Chemung period were probably the last beds to be spread over the Erie County region, which shortly after the commencement of the Carbonic era became dry land. The shore-line was transferred to somewhere in the vicinity of the boundary line between New York and Pennsylvania, nearly all the area comprised within the latter state being under water. It was in this great bay-like indentation, and in another one which stretched north into Michigan, that the chief coal-beds were deposited.*

*Dana in the 4th Edition of his Manual of Geology, gives on p. 633 an instructive map of the outlines of the land at the beginning of the Carbonic era.

Post-Devonian Events.—We have now traced the history of this region from the time of the Lower Devonian to near the close of the Upper Devonian time, when it was raised into dry land. The changes which were going on outside of this area after its elevation, are out of place in this discussion. The interval which elapsed between the close of the Devonion era and the beginning of the Quaternary era, can be passed over briefly. It was a long interval, during which the atmosphere, the rivers, and the sea exerted their combined influences to destroy the new-formed land again. Much of the material deposited in the Carbonic sea was derived from the erosion of the land, which had been formed in the age just preceding.

It was during this interval of time that the slight crust-movements occurred, which gave rise, on the one hand, to the faults and folds, and on the other to the joint-cracks which traverse these rocks. The beds which at first were horizontal, or nearly so, were tilted until they stood at the present angle. The lithification of the beds, probably commenced while they were still submerged, continued, and ultimately, the shales and sandstones as we see them to-day, were produced.

At the end of this long period of erosion, we find some interesting topographical features, which are no longer in existence. A broad and deep river valley had been carved out of the strata where Lake Erie is now. A stream—the Idlewood River—coming from the south-east, entered this valley through a gorge, half a mile north of the mouth of the present Eighteen Mile Creek. Then came the great "Ice Age," and all the country was buried beneath the accumulating mantle of snow and ice. When, through its increased thickness, and through melting at its southern end, this great ice sheet began to move, it scratched and polished the bed rocks, by means of the pebbles and sand frozen into its under side.*

*The glacial history of this region is too intricate, and involves the detailed consideration of regions outside of those treated of in these chapters; therefore its complete discussion will not be taken up in this paper. See Gilbert's History of Niagara Falls, National Geographic Monographs, Vol. I., No. 7, and numerous papers in various Journals referred to in the appendix.

Eventually the long reign of the ice came to an end, and the glaciers slowly melted away, leaving behind the debris, which had been brought from the regions to the north. Thus, when the land was again uncovered, a mantle of drift was spread over it, filling the ravines and smaller valleys which had been cut by the pre-glacial streams. The great valley now occupied by Lake Erie was filled up to a considerable extent, and its continuation through the Dundas valley into the valley of Lake Ontario was cut off by the drift. The old channel of the preglacial Idlewood River was also filled in by drift. All this, however, did not appear at first, for as long as the ice filled the Ontario valley, the drainage of the water, resulting from the melting ice, was impossible in the present direction, and it accumulated, forming a long lake at the front of the ice sheet. This lake, which Spencer has named Lake Warren, increased in size until its waters finally began to overflow across the lowest point on the southern watershed, which happened to be near where Chicago now stands. Thus the drainage of this great lake was into the Mississippi, for a long time. The beaches built by this old lake can be seen a short distance behind the present beach of Lake Erie, running southward through Hamburgh, and crossing the present gorge of Eighteen Mile Creek beyond the forks.* When, through continued melting of the ice, the Mohawk, and later the St. Lawrence valleys were opened, the drainage went by these channels, and the water in Lake Erie was lowered to near its present level. Then the waves began their work of cutting into the land leaving the cliffs, now exposed on the shore, which in some places are formed of the bed rock, and in others of the drift-heaps left by the ice in the valleys.

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*Leverett, Am. Journ. Science, July, 1895, gives a map of the beaches.

Much of the sand now found in the beaches along the shore of Lake Erie was derived from the drift deposits left by the ice. Only a comparatively small portion of this beach material has a local origin, having been worn by the waves from the shale cliffs. The material thus derived, is readily recognized by the flat thin character of the pebbles composing it, a feature which early caused it to be known by the name of "flat gravel." (See Plate XIX.).

The cliffs of unconsolidated material are of course much more readily eroded by the waves, than the shale cliffs. The active destruction of the drift cliffs can be seen at a great many points along the lake shore, and it is frequently emphasized by the trees, which, losing their foot-hold as the cliff is being undermined, slide down the banks.

The sands derived from the cliffs are carried away by the long-shore currents, and deposited where the force of these currents diminishes. Thus, bars are thrown across the mouths of all the streams and inlets, and sand-spits run out from the headlands, menacing the safety of the coast navigator.

The beaches between the headlands vary in the character of their material, as well as in the angle of the slope facing the water. Where the water deepens rapidly off-shore, so that the large breakers roll in and reach the shore, the material of the beach is usually coarse gravel, and the front slope a steep one, the beach often assuming a terrace form. Where, however, the water is shallow for a considerable distance from shore, or where a submerged sand-bar causes the breaking of the great waves long before they reach the shore, the beach is usually of a sandy character, and the slope a gentle one. In the first case (that of the deep water) the fine material is carried out by the undertow, so that only coarse material remains. This will naturally retain the steep slope given it by the great waves. In the second case (that of the shallow water) the sands dropped by the long-shore currents are washed on to the shore by the "swash" following the breaking of the off-shore waves. Hence the slope of the sand-beach will be comparatively gentle and uniform.

Where the drift contains boulders, these are usually left by the waves on the beach, a feature well illustrated in many of of the sections, particularly that of the old gorge of the Idlewood River. In such instances it frequently happens that shore ice will transport some of these blocks, which may eventually come to rest at the foot of a cliff, where there are other blocks, derived from the cliff itself. Thus, Corniferous limestone boulders from the drift, have been mingled with the blocks of Encrinal limestone from the cliffs at various portions along the shore, and there is danger of mistaking the former for the latter, unless this fact is borne in mind. Blocks and slabs of shaly limestone may also be frequently found projecting from, or lying on drift covered banks, and the fossils contained in these, differ from those found in the adjoining cliffs. Such rock masses are commonly derived from the Corniferous limestone in the northern part of Erie County.

At Stony Point, about three miles north of the Bay View cliff, Corniferous limestone boulders are exceedingly abundant on the beach. With them occur boulders of Niagara limestone, brought by the ice from Niagara County, as well as boulders of Waterlime from North Buffalo. These boulders constitute a portion of an old glacial moraine, which can be traced inland to West Seneca, where it is cut by the railroads, and exhibits the limestone blocks in the unconsolidated banks. The name "Limestone Ridge" which has been applied to this moraine, is derived from the presence of these limestone boulders.

Sand dunes are found at a great many places along the shore of Lake Erie. They are commonly low, but occasionally, as in the Crystal Beach dunes on the Canadian shore, they rise to considerable heights. These sand dunes are met with behind those beaches which are not bounded by shale or drift cliffs. It is here that the winds meet with little obstruction, and they can sweep the dry sands inland, until friction and the rise of the land prevent further advance. Low, swampy ground is commonly found behind such dunes, and the beach in front of them is usually a firm gently sloping sand beach.

The present shore features of Lake Erie are of post-glacial origin, and came into existence since the establishment of the present St. Lawrence drainage system. The gorge of Eighteen Mile Creek, as we know it, was cut since that time by the stream carrying the drainage from the high lands in the southern part of Erie County.

Thus the stream which we have been studying in such detail, was one of the last features to appear in the present landscape. It is still actively eroding its banks, and revealing fresh sections from which to study the past history of this region.