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TO THE DIRECTOR OF THE
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WASHINGTON, D. C.

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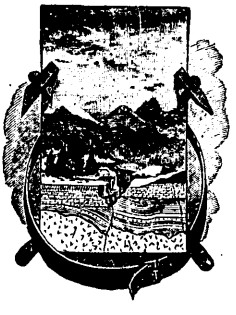
UNITED STATES GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

CORRELATION PAPERS

DEVONIAN AND CARBONIFEROUS

BY

HENRY SHALER WILLIAMS



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CONTENTS.

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
U. S. GEOLOGICAL SURVEY,
DIVISION OF GEOLOGIC CORRELATION,
Washington, D. C., March 15, 1891.

SIR: I have the honor to transmit herewith a memoir by Dr. Henry S. Williams on the Devonian and Carboniferous formations of North America, prepared for publication as a bulletin.

This memoir is the first of a series, and in order to show its relation to those which are to follow, I quote the following passage from the report of the Director for the fiscal year ending June 30, 1888:[1]

In order to develop the geological history of the United States as a consistent whole, it is necessary to correlate the various local elements. The events of one district—the succession of eruptions, sedimentary deposits, and erosions—must be connected with the synchronous events of other regions. It is especially important to determine the synchrony of deposits. So far as the outcrops of strata can be continuously traced, or can be observed at short intervals, correlation can be effected by the study of stratigraphy alone. The correlation of strata separated by wide intervals of discontinuity can be effected only through the study of their contained fossils. This is not always easy, and it is now generally recognized that it is possible only within restricted limits. As distance increases the refinement in detail of correlation diminishes.

Recent discussions in connection with the work of the International Congress of Geologists have shown that different students assign different limits to the possibilities of correlation, and give different weights to the various kinds of paleontologic evidence employed.

The study of the data and principles of correlation is thus seen to be a necessary part of the work of the Geological Survey, and by making the study at the present time it can offer a timely contribution to general geologic philosophy. It has therefore been determined to undertake the preparation of a series of essays summarizing existing knowledge bearing on the correlation of American strata. It is proposed to have a treatise prepared by a competent specialist on each of the following systems: The Quaternary, the Newer Tertiary, the Older Tertiary, the Cretaceous, the Jura-Trias, the Carboniferous, the Devonian, the Silurian, the Cambrian, the Eparchean, and the Archean.

Each essay will consider the several geographic provinces of the system it treats, the stratigraphic divisions that have been made in the several provinces, the extent to which these divisions can be correlated with one another, the degree of precision with which the upper and lower limits of the system can be correlated with the limits of the corresponding European system, and the extent to which the American subdivisions can be correlated with the European. It is proposed to treat sepa-

[1] Ninth Annual Report of the U. S. Geological Survey, p. 16.

rately the evidence from vertebrate fossils and the evidence from fossil plants as to all the systems in which they are found; and there will be prepared in connection with the work a thesaurus of North American stratigraphic terminology.

The work has been placed under the general charge of Mr. G. K. Gilbert, and a number of specialists to assist him have already been selected from the various divisions of the Survey.

Each of the systems indicated above was assigned to a paleontologist or a geologist for treatment, and several conferences were held for the purpose of developing a definite plan of work. Eventually the plan was formulated as follows, being incorparated in a circular letter addressed the Director to the several specialists chosen for the work in February, 1888:

PLAN FOR THE DISCUSSION OF AMERICAN GEOLOGIC SYSTEMS.

(1) It is proposed to prepare an essay on each of the following American geologic systems, namely: (1) Quaternary, (2) Plio-Miocene, (3) Oligo-Eocene, (4) Cretaceous, (5) Jura-Trias, (6) Permo-Carboniferous, (7) Devonian, (8) Silurian, (9) Cambrian, (10) x y z, (11) Archean.

The "Congress" committee of the American Association for the Advancement of Science at a recent meeting resolved (in effect) that "systems are determined primarily by fossils, secondarily by structure." This series of essays is planned on the assumption that for purposes of correlation the most important fossils are marine invertebrates. The evidence from vertebrates and that from plants will be discussed each by an appropriate specialist, but this arrangement does not preclude their consideration in the essays on individual systems.

(2) Each essay should show how the system of which it treats has been paleontologically and stratigraphically delimited in North America, and should recite and discuss the facts and principles on which such delimitation is based.

(3) Each essay should show into what series (major subdivisions) the system has been divided in various parts of North America, and on what facts and principles the division has been based. If these subdivisions are not uniform in all parts of the continent the various areas of exposure should be classified in provinces, and the essays should show whether and to what extent the series of the several provinces can be correlated with one another.

(4) Each essay should show whether and to what extent the subdivisions of the system in any or all of its American provinces can be correlated with the subdivisions of the system in Europe.

(5) Each essay should be prepared with the aid of a comprehensive review of the pertinent literature, so as to constitute a summary of the material at present available for the major taxonomy of the system.

(6) The names of systems in (1) are provisional. Each essay should consider the question of names for system and series.

The number of systems is likewise provisional, and it may eventually appear that those enumerated in (1) are not coordinate. It was necessary to prepare a scheme in order to apportion the work of assembling the facts, but after these have been assembled, their discussion may lead to an improved scheme. Provision will be made for such discussion after the series of essays has been prepared.

(7) The general purpose of the preparation of the series of essays is threefold: first, to exhibit in a summary way the present state of knowledge of North American geologic systems; second, to formulate the principles of geologic correlation and taxonomy; third, to set forth from the American standpoint the possibility, or the

impossibility, of using in all countries the same set of names for stratigraphic divisions smaller than systems.[1]

By comparing the list of geologic systems in this "plan" with the list in the passages cited from the report of the Director, it will be observed that there are slight discrepancies. The unsettled problems of nomenclature thus suggested were elaborately discussed by a conference of the geologists of the Survey held in January, 1889, for the purpose of establishing the conventions necessary to uniformity in the preparation of the sheets of the Geologic Atlas of the United States. By that conference it was determined that the stratigraphic units delineated on the sheets of the geologic atlas should be designated as formations, that no stratigraphic unit of a higher order should be recognized in the atlas, and that the only term of classification there employed should be the geologic "period."[2] The time-term "period" thus adopted for the geologic atlas has the same taxonomic rank as the stratigraphic term "system" employed in the "plan" for the instruction of the essayists and in the passage cited from the report of the Director. It was preferred by the geologists of the conference because it was believed that the major classification expressed by either term is essentially arbitrary and does not find in nature a universal expression, either physically through lithologic and structural differences, or biotically through the differentiation of faunas and floras. The chronologic term seemed to them freer than the stratigraphic from the implication that the classific units are natural and general rather than artificial or local.

The conference likewise indicated and defined eleven periods to be used in the classification of the formations represented in the atlas, and designated them as follows: (1) Pleistocene, (2) Neocene, (3) Eocene, (4) Cretaceous, (5) Jura-trias, (6) Carboniferous, (7) Devonian, (8) Silurian, (9) Cambrian, (10) Algonkian, (11) Archean.[1] These are the exact equivalents of the "systems" enumerated in the preceding quotations, but they differ somewhat as to name.

The conventions thus adopted for the work of the Geological Survey have modified and controlled the work of the division so far as they are applicable, and the substitution of "period" for "system" has changed the point of view of the essays in a manner conducive to their simplification and to their value as contributions to the subject of correlation.

Although the essayists, working under the same general instructions, have had before them the accomplishment of the same purposes with respect to the several groups of formations assigned them, no attempt has been made to mold their modes of treatment in a common form.

[1] This plan was published in the Tenth Annual Report of the Survey as part of a progress report of the work of the Division of Correlation (pp. 108–113). Further report of progress may be found in the Eleventh Annual Report, pp. 59–62.

[2] Tenth Annual Report U. S. Geological Survey, pp. 63–65.

[3] Ibid., pp. 65–66.

The present essay employs the historical method alike in the summarization of present knowledge and in the formulation of the principles of geologic correlation. It groups facts and opinions as to Carboniferous and Devonian formations about certain specific problems of correlation, and traces the history of the discussion of each problem. In connection with the historical summaries there is much incidental discussion of the principles of correlation, and they are afterward classified in a closing chapter. The author concludes, from the American standpoint, that in a universal classification of formations it is not practicable to employ classific units smaller than periods.

Very respectfully, your obedient servant,

G. K. GILBERT,
Geologist in Charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey.

OUTLINE OF THIS PAPER.

The following essay is a historical study of the classifications and nomenclatures of geological formations in America, made with the purpose of ascertaining how satisfactory correlations have been made and upon what principles they have been based. For this purpose the literature upon the whole Paleozoic for the first 40 years of the century has been reviewed, but for the period following the publication of the Final Reports on the Geology of the State of New York (1842–1844), the study has been confined to the literature of the Devonian and Carboniferous systems.

In the course of the historical development of the science, and as the geological surveys have extended over new territory, a number of specific problems have arisen for the solution of which it has been necessary to determine the relations between standard formations already named and classified and those newly discovered. In this essay the discussion of each of these problems has been followed out in detail, the various attempts at correlation have been noted, and the methods employed and the final results attained have been traced to the principles involved in their determination.

The following problems have been thus discussed:

(1) The general correlation of the Paleozoic formations of eastern North America with the corresponding formations of Europe.

(2) The determination of the parallelism between the upper Paleozoic formations of the Appalachian region and the rocks of the interior of the continent as far west as the Mississippi River.

(3) The correlation in the Northern Appalachian region of the various subdivisions of the Coal Measures and formations immediately underlying them.

(4) The problems connected with the correlation of the Chemung and Catskill groups, and with the correlation of the Waverly and Marshall groups.

(5) The elaboration of the Mississippian series, or "Subcarboniferous" formations of the Mississippi River basin.

(6) The Permian problem of Kansas and Nebraska.

(7) The correlation problems involved in classifying (*a*) the formations of the Acadian province, and (*b*) the formations of the Rocky Mountains and Western Plateau provinces.

In the discussion of these various problems several definite stages in the development of the principles of correlation have been recognized. At the opening of the century the Wernerian system of classification was generally adopted. In this classification the mineral characters of the formations were regarded as of fundamental importance, and constituted the chief criteria for their classification and correlation, and the order of deposition was supposed to be indicated by the actual and relative position of the present outcropping of the strata. The theory underlying this latter interpretation was, that the older rocks formed the core of the mountains; on the higher part and at an inclination were formed the next younger, and as the waters dried off the surface of the earth the successive rocks were deposited at lower and lower levels. The names "Primary," "Secondary," "Tertiary," and "Quaternary" preserve the memory of this theory, though the theory itself has given way to the more rational one of oscillation of the crust of the earth itself, with relative sta-

bility of the mean tide level of the ocean. The correlations of this period were defective, not so much on account of imperfect observation as on account of incorrect theories. "Red sandstone," "Mountain limestone," "Saliferous rocks," and "Grauwacke" were truly found in America, but they were not the correlatives of formations so named in Europe, because formations present no regularity in the order of sequence of their mineral characters. The perfecting of the New York system of Paleozoic rocks (published in 1842) marks practically the abandonment of the Wernerian school of opinion in America.

The second stage of development took definite shape in the New York system. Formations were considered as holding a fixed order of sequence, but differences in thickness or even in composition were to some extent allowed as compatible. Still, a general "parallelism of strata" was believed in, and in order to make the interpretation fit the facts, "gaps" and "intercalations" were assumed. The application of this principle of correlation is conspicuous in the various attempts at "parallelism" made in the period 1840–1860, and the method is most minutely carried out in the second Geological Survey of Pennsylvania, where the term "persistent parallelism of strata" is named and defined. Fossils were used in these correlations, but rather as arbitrary labels which were of value only when exact identity was recognized. This being rarely the case, fossils played only a secondary part. This principle did not reach satisfactory results, because stratigraphic order and stratification itself offer no intrinsic evidence of the age of the formation, and stratigraphic structure was found not to be uniformly persistent even for a few miles' extent.

In the first quarter of the century, an Englishman, William Smith, or "Strata Smith," as he was called, advanced the idea that strata could be identified by their fossils, and fossils have ever since been used with greater or less success in identifying formations; but when the fossils are not of the same but of kindred species, other considerations have been brought forward to establish the correlation. Within the last 20 years fossils have begun to be used on the principle that they contain in themselves intrinsic evidence of their relative age.

And this brings us to the third stage in the development of the methods of correlation in which fossils assume the chief rôle. Underlying these correlations are the following considerations: Geologic formations in their mineral and lithologic composition, their stratigraphic and structural characters, and as to their limitations are recognized as strictly local formations; hence the primary principle is that none of these characters can be relied upon for the correlation of formations of different localities. Secondly, fossils are recognized as remains of organisms which possess genetic relationship; and the specific and varietal characters of the organisms are believed to be indications of these affinities; and with evolution in time and modification coordinate with changed condition of environment, the organisms are believed to be extremely sensitive indicators of time relations. Thus the minute and exhaustive comparative study of fossils in their stratigraphic and geographic relations is now proving to be not only the best but the only reliable guide to correlation of geologic formations.

The conclusions reached from this historical study confirm the belief that the description and nomenclature of structural formations should be quite independent of their correlations, and that precision in correlation must be based upon mature and exhaustive paleontologic study, that the time scale must be made independently of the structure scale, and that the time scale of correlation is based fundamentally upon biologic data.

The investigation leads to the further conclusions that as nomenclature finds its basis in some intrinsic characters of the things named, *uniformity of nomenclature* for formations is impracticable, since the intrinsic characters of formations are local and have nothing to do with their geologic position; and that *uniformity of classification* can be looked for only through an exhaustive biologic study of the fossils, and is inapplicable to geological structure, stratigraphy, or formation.

THE DEVONIAN AND CARBONIFEROUS FORMATIONS OF NORTH AMERICA.

By Henry S. Williams.

INTRODUCTION.

THE STATE OF OPINION AT THE BEGINNING OF THE PRESENT CENTURY REGARDING THE CLASSIFICATION AND NAMING OF GEOLOGIC FORMATIONS.

THE STATE OF GEOLOGICAL OPINION PRIOR TO 1835.

Upon reviewing the works of geologists written in the early part of this century, we find a very well marked school of opinion pervading all the works of English and American geologists, who published their works prior to the year 1835. A gradual change was taking place 10 years before this, but it was not until after 1835 and about 1840 that the new school of opinion, as expressed in modern classification of geological deposits, became generally adopted.

The prominent English text-books upon geology which appeared prior to that date are those of Maclure, 1817; Maculloch, 1821; Eaton's "Index," 1820; "Erie Canal Rocks," 1824; Conybeare and Phillips, 1822; Lyell's "Principles," 1830; De la Bêche, first edition, 1831.

All these books are based upon the general principle for the propagation of which, if not for the entire origination of the idea, Werner is distinguished. This idea which characterized the Wernerian school consisted fundamentally in the attempt to classify geologic deposits by the minerals which they contained and their petrographic characters.

Abraham Gottlob Werner (1750–1817), who has been called the father of German geology, was undoubtedly the founder of the classification of rocks into formations arranged in stratigraphic order.

Although his "theory of formations" has been superseded by other theories, the proposition that the crust of the earth is divisible into formations and that these formations have a regular order of sequence in relation to one another is at the very foundation of modern geology.

Werner was an enthusiastic teacher, but he wrote little, and we are obliged to look to the writings of his pupils and their followers for an exposition of the views which formed the basis of geological science at the beginning of the XIX century.

In the Edinburgh Encyclopædia[1] there is an exposition of his views which will serve our present purpose.

The author divided the science of mineralogy into two divisions, geognosy and oryctognosy. He said:

> Geology, according to Werner, comprehends not only geognosy but also geography, hydrography, meteorology, and geogony. Geognosy makes us acquainted with the structure, relative position, materials, and mode of formation of the mineral masses of which the crust of the earth is composed.

WERNER'S SYSTEM.

In 1740 De Maillet maintained that the globe was composed of strata successively deposited one over another, by the sea, which gradually retired and uncovered the present continents. This view was adopted by Linnæus. Buffon accepted it also, in part, so far as regarding superficial strata as the deposition from water. It played a conspicuous part in Werner's system.

Werner had several pupils, of whom some of the more prominent are Mohs, Charpentier, Buch, Raumer, Freisleben, Humboldt, Steppen, Engelhart, Esmarck, D'Andrada, Brocchi, De la Rio. In the article before us we find Werner's system discussed under the following heads: "Werner on the structure of the crust of the globe." Then follow the subdivisions:

1. Original extent of the formations.
2. Their present extent and continuity.
3. Position and direction of strata in relation to fundamental rocks.
4. Position and direction of strata themselves.
5. Relation of the outgoings [outcrop] of the strata to the exterior of mountains.

Under the first head, "the original extent of formation," Werner distinguished as "universal formations" those that extend around the whole globe (not, however, without interruption), and constitute by far the greater mass of the crust of the earth. Almost all the Primitive, Transition, and Secondary formations are "universal depositions." Of these the following are named: "Granite, Gneiss, Porphyry, Limestone." "Partial formations," of which sandstones, limestones, shales, etc., are examples, were deposited only in particular places, and were due to lake or flood sediments. The author wrote:

> The spheroidal figure of the earth, its crystalline and stratified structure, and its numerous petrifactions are proofs of its original fluidity. The fluidity, according to Werner, was aqueous, and he conjectures that the various rocks were originally suspended or dissolved in water, and gradually deposited from it.[2]

Two grand epochs are recognized in his system, first, "the Primitive, containing no fossils or organic remains, always below the other rocks, and wholly of chemical origin." "Second, the Secondary: these rocks were formed posterior to the creation of organized beings." The rocks

[1] The Edinburgh Encyclopædia, conducted by David Brewster, LL. D., F. R. S. 1812–1831. Article "Mineralogy," prepared by Prof. Robert Jameson, D. D., F. R. S., L., and E., professor of natural history. Edinburgh. First American edition, 1832, vol. XIII.

[2] Op. cit., p. 437.

of this group which resemble the first group, but contain fossils, are called "Transition" by Werner, and "Intermediate" by other geologists. The Secondary are called "Floetz."

In addition to these two grand epochs, there were recognized by some geologists,

(3) The Tertiary, including the upper part of the Secondary class of Werner, which is distinguished as containing the remains of quadrupeds;

(4) An Alluvial class, consisting of gravel, sand, clay, marls, recognized by its resting upon the previously mentioned class; and

(5) The Volcanic class, the rocks of which were undoubtedly produced by fire.

In general, Werner believed all rocks were formed from one and the same solution by deposition, either chemical or mechanical. These "depositions" were made at various heights determined by the gradual departure of the water as it evaporated or sank away into cavities in the earth. But, to account for the formation of the "Secondary trap" and certain "Primitive porphyries," new inundations were assumed to have taken place.[1] In his system there were series of formations, and each series was denominated a "suite;" thus, there were eight of these suites, called—

1. Limestone formation suite.
2. Slate formation suite.
3. Trap formation suite.
4. Porphyry formation suite.
5. Gypsum formation suite.
6. Salt formation suite.
7. Coal formation suite.
8. Serpentine formation suite.

Thus, "the limestone formation suite" consists of—

1. White granular limestone in the Primitive class (with large, granular, distinct concretions).
2. Variegated limestone in the Transition rocks, having "less translucidity," and containing the first traces of petrifactions.
3. The gray Floetz limestone, scarcely translucent on edges, and full of petrifactions, and found in the Floetz or Secondary rocks.
4. Chalk.
5. Limestones and marls of the Paris Basin.
6. Calcareous tuff.

In these series, extending from the earliest to the latest period, there is a gradual disappearance of the crystalline, and a gradual increase of the earthy aspect, "corresponding with the relative age of the different members of the series, and the state of the solvent from which they were precipitated, and all serving as proofs of the immensely great but gradual alteration of the state of the universal waters." "Quietness of the water" was the characteristic at first, and as the

[1] Op. cit., p. 436.

waters shallowed they were more disturbed, and the resulting rocks were less crystalline and more earthy; and, lastly, the earthy limestones as a result of exposure of the rocks to erosion by withdrawal of the waters.

Another point conspicuous in his theory is that regarding the actual position of the rocks as indicative of the age when they were formed. In describing each of these formation series we find the following sentence, "with sinking levels of the outgoings of the newer and newer strata."

The following exhibits Jameson's idea of the classification, which is apparently an amplification of the scheme taught by Werner.

CLASSES OF ROCKS.

CLASS I. *Primitive Rocks.*—Urgebirge of Werner; Terrains primitifs of Daubuisson.

Those formed antecedent to that of the creation of organic beings. Chemical formation, no fossils, under the Floetz or Transition.

The rocks of this class are—

1. Granite, with syenite, protogene topaz rock.
2. Gneiss, and varieties of white stone.
3. Mica slate, and varieties of talc slate.
4. Clay slate, Thonschiefer, with alum slate, flinty slate, etc.
5. Granular limestone, and primitive gypsum.
6. Primitive trap.
7. Serpentine and euphotide.
8. Porphyry.
9. Quartz rock.

CLASS II. *Transition Rocks.*—Ueberganggebirge of Werner.

Contains fossils, is less crystalline than the Primitive, and interposed between the Primitive and Secondary.

The rocks are—

1. Grauwacke, Werner; Psammite of Brongniart.
2. Transition limestone.
3. Granite and porphyry.
4. Gneiss, mica slate, etc.
5. Serpentine,
6. Quartz rock.
7. Red sandstone.
8. Transition trap.
9. Gypsum.

Class III. *Secondary or Floetz rocks.*—Floetzgebirge of Werner; Secondary or Floetz rock of Jameson; Terrain secondaire of Daubuisson. It rests on Transition or Primitive, is less crystalline, has many fossils.

The principal Secondary rocks are—

1. Sandstone.
2. Limestone.
3. Gypsum.
4. Trap rock.

1. Sandstone: Conglomerate, Breccia, including—

First or Red sandstone, with the coal formation, or
Old Red sandstone of Jameson,
Aelter rother Sandstein of Werner.
Rothe-todte-liegende of German miners,
Grès ancien of Daubuisson.

The coal formation is the "coal measures" or "coal fields" of the English miners, the "Steinkohlengebirge" of Werner, "Terrain houiller" of Daubuisson, "Terrain à charbon de terre" of older French writers.

It includes coal, slate, sandstone, quartz rock, clay, trap, graphite. Coal is either black coal or "glance" or "blind." The coal formation rests on the Mountain limestone or Red sandstone, and underlies the Magnesian limestone.

The *second sandstone* is the New Red or Variegated sandstone, the "bunter Sandstein" of Werner, "Red Ground" of English geologists, "New Red" of Buckland, "New Red or Variegated sandstone" of Jameson. The second formation of "grès" and "grès avec argil," and "grès bigarre." It rests upon the second or Magnesian limestone.

The *third sandstone* formation, "Green Sand" of English geologists, "third sandstone formation" of Jameson and Daubuisson, "Quadersandstein" of Werner. It rests upon the upper Oolite, and is covered by the chalk.

The *fourth sandstone* formation is associated with the rocks that rest upon the chalk.

2. Secondary or Floetz limestone: There are five of these, called first, second, third, fourth, and fifth secondary limestones.

The *first secondary limestone* of Jameson is the "Alpine and Jura limestone" of the Germans and some French authors, and the "Mountain limestone" of English geologists. In regular succession it comes after the Old Red sandstone.

The *second secondary limestone* of Jameson is probably the "Erster Floetz Kalkstein" of Werner, the "Magnesian limestone" of English authors, and rests upon the coal formation.

The *third secondary limestone* of Jameson is the "Muschel Kalkstein" of Werner, "Oolite," of Buckland, "Lias and Oolite," of others.

The *fourth secondary limestone* is the "Chalk," the "Kreidegebirge" of Werner, and rests upon the third sandstone.

The *fifth secondary limestone.* (See the "Paris formation.")

3. The Secondary Gypsum of Jameson, the "Floetz Gyps" of Werner. This included the first and second gypsum, also the "Steinsalzgebirge," of Werner. In this second class were also included the formations above chalk, or the Paris formation, the "Terrain Tertiare" of Daubuisson, which includes seven different beds.

CLASS IV. *Alluvial rocks.*

Up to the end of the first quarter of the century very little knowledge was possessed of the characteristic fossils contained in geological de-

posits. William Smith, as all geologists know, early in the century recognized the importance of fossils in identifying geological deposits, and as early as 1812 a map of England and Wales was prepared by him with the order of the geological deposits marked upon it, and it was known, by William Smith, at least, that the several strata were characterized by different organisms. The order of these deposits was known by him, and a table was drawn up in 1799, some improvements were made in his map and in his table in 1815 and 1816, and in 1815 a small treatise was published by Smith, entitled "A Geological Table of British Organized Fossils," which identified the course and continuity of the strata.

It will thus be seen that in the earliest decade of the century there was one man, at least, who recognized the importance of fossils in determining and correlating geological strata. The methods of Smith were applied, however, no lower than the Carboniferous system, and it was not until later that they were adopted as a general principle for the classification and systematization of the whole geologic column.

Although fossils were recognized as important, they were so poorly understood, and so few individuals studying geology had any accurate knowledge even of their generic characters, that they were of very slight service in correlating strata.

Mineral characters, therefore, played the principal part in all the classifications, correlations, and even nomenclatures of the geologists of the first quarter of this century.

Much confusion is found, also, in the attempts to generalize, on account of ignorance of the true means of correlating the strata that cropped out in different regions. The early names used indicate the principles of these classifications, such as "Granular limestones," "Argillite," "Grauwacke," "Old Red sandstone," "Oolite," "Cretaceous," "Magnesian limestones"; and a great many others could be enumerated. These, it will be seen, are all names indicating the usage of mineral characters for the distinction of the strata, independent of their locality and independent of their order of sequence or position in a vertical scale.

In order to change this system, it was necessary that a careful study of fossils be made, that their biological relations be clearly understood, and that their characters be geographically and geologically known. The classification of the geological deposits for England was fairly well understood for the Mesozoic and higher strata as early as 1822, but the lower strata, the Paleozoic series, as we now understand it, were not well understood prior to the works of Murchison and Sedgwick and their associates. Murchison's "Silurian system" was not published till 1839, and the classification of the Paleozoic series, although studied by English and Americans between 1830 and 1840, can not be regarded as having been fully understood by geologists until about the year 1840.

A glance at the general system of classification in the early text books

will give the best idea of the state of opinion in this first period of geological science. The rocks were classified at the beginning of the century by the Wernerian school into Primary and Secondary rocks; the idea contained in this distinction was, for the first, those rocks which were originally deposited from chemical solution and by evaporation from the ocean waters, and the Secondary were those which were produced by water erosion and reshaping of the Primary rocks, and deposition of the sediments above them. In the Secondary series fossils were observed, but the Primary series was supposed to have been laid down before the existence of organisms upon the earth. As observations accumulated, the rocks called Primary were found to include some which are now placed in the Paleozoic series. The name Transition came into use as a designation for the rocks, which were known to be stratified and occasionally to contain fossils, occupying a position between the original Primary and Secondary formations. The Germans applied the name "Grauwacke" to this Transition series, and we find in Eaton's classification, as presented in his "Index to the Geology of the Northern States," his "Erie Canal rocks," and his other papers, the use of the term "Grauwacke" in a sense which is different from that originally applied, but one necessitated by the discovery of the same kind of rocks at undoubtedly different horizons. The "Grauwacke" of Eaton was spoken of as "First," "Second," and "Third Grauwacke," etc., and we find him identifying the great mass of the rocks of western New York as belonging to the "Third Grauwacke," which he placed in the Secondary class. This "Third Grauwacke" is placed above the Carboniferous, and also above the "Saliferous rocks," a name which he used to represent the English Saliferous group, but which he identified with the Onondaga Salt group or Salina of the New York system. This was placed above the Conglomerates in the order of sequence because the "Millstone Grit," which they were supposed to represent in the English series, was below the New Red sandstone.

The imperfection in the methods of correlation of this time is well illustrated by Eaton's identification of the "Old Red sandstone" in New York.

In "Erie Canal rocks," 1824, "Old Red sandstone" is placed at the top of the "Transition class." It included the "Red sandstone of the Connecticut River," and the "Red sandstone of the Catskill Mountains," and in 1820 he reported the "Old Red sandstone" as outcropping in the Niagara gorge.

This example shows that the color and composition were the basis of correlation, and that the belief that the order or sequence of formations must be the same in New York as in Great Britain led to the erroneous classification.

This confusion is due not so much to poor observation, which Eaton can not be charged with, as to erroneous theories which were common to geologists in his time. The recognition of the position of the Car-

boniferous in the Paleozoic, and its relation to "Old Red sandstone" and "New Red sandstone," are two distinct issues. Stratigraphically, the relation of the Coal Measures and its associated Carboniferous limestones and Millstone Grit with the Old Red sandstone below and the New Red sandstone above, was well established, but the division line, which separates our Paleozoic from Mesozoic, was not drawn until the fossils had been carefully studied.

Originally, and beginning with the works of Bakewell and De la Beche, and Conybeare and Phillips, above mentioned, the Carboniferous Coal Measures were associated with the Secondary rocks of Werner, and we find in the latter work,[1] which, it will be noticed, was published in 1822, that the "Old Red sandstone" in part is also included in what is called the "Medial or Carboniferous order." This was the first step toward the modern classification into Paleozoic and Mesozoic. By the majority of geologists for several years later than 1822, the Old Red sandstone and the Carboniferous were included in the Secondary, and the rocks below[2] were placed in the Transition or Grauwacke of the older classifications.

It was John Phillips[3] who first clearly conceived the importance of associating the Carboniferous, the Devonian, and the Magnesian limestones together, and separating them from the rest of the New Red formation, to form the upper part of the Paleozoic strata. This brought the demarkation between the ancient (Paleozoic) fauna and the middle (Mesozoic) fauna at the top of the Permian, or, in England, at the top of the Magnesian limestones; and the distinction was based purely upon the study of the contained fossils. This was first suggested in the articles in the Penny Encyclopedia, in 1840 and 1841, entitled "Paleozoic Rocks" and "Saliferous system," and the statement that Phillips is responsible for so extending the Paleozoic is given in his "Paleozoic Fossils."[4] The term "Paleozoic" was suggested by Sedgwick to take the place of "Protozoic," the term which Murchison applied to the rocks described in his "Silurian system," and which were regarded as belonging to the Transition strata of the Wernerians.

Thus it will be seen that the grand distinction between Mesozoic and Paleozoic, as now understood, was entirely determined by the fossils.

The study of the Devonian rocks, and the determination of their position by Lonsdale in 1837, furnish another example of the application of paleontology in perfecting classification. The rocks themselves, their stratigraphy, their relations to other rocks, had been carefully studied by Murchison and De la Beche, and by numerous others in a more irregular way, prior to 1838, but the identification of their fossil contents by Lonsdale, and their comparison with the fossils of other formations, made it possible for him to assert positively that the posi-

[1] Conybeare and Phillips's Geology, etc.

[2] The Silurian, Cambrian, and, as we see in De la Beche, the Devonian systems.

[3] Author of "Paleozoic Fossils of Cornwall, Devon, and West Somerset," published in 1841.

[4] Page 160.

tion of the Devonian rocks chronologically, in the geological series, is between the Silurian system of Murchison, and the Carboniferous system of Conybeare, heretofore regarded as of the Secondary strata of Werner.

The demarkation of the Paleozoic by its fossils which we owe to Phillips and the determination of the intermediate position of the Devonian system by Lonsdale were two conspicuous examples of the inestimable value of fossils for geologic correlation. Heretofore the methods of the Wernerian school were dominant in all geologic classifications and correlations. Afterward in English and American geology paleontology became the indispensible ally of stratigraphic geology.

CHAPTER I.

THE HISTORY AND DEVELOPMENT OF OPINIONS REGARDING THE CLASSIFICATION OF ROCKS IN THE UNITED STATES FROM THE TIME OF WILLIAM MACLURE TO THE COMPLETION OF THE GEOLOGICAL SURVEY OF THE STATE OF NEW YORK, 1809-1843.

An article appeared in the Trans. Am. Phil. Soc., in the year 1809,[1] which is among the earliest careful expositions of the systematic arrangement of the rocks of North America, if not the very earliest.[2]

The classification adopted by Maclure is the Wernerian, and he defends the usage of this system by the following arguments[3]: "First, because it is the most perfect and extensive in its general outlines; and secondly, the nature and relative situation of the minerals in the United States, whilst they are certainly the most extensive of any field yet examined, may perhaps be found to be the most correct elucidation of the general exactitude of that theory as respects the relative position of the different series of rocks."

The following is the nomenclature adopted:[4]

CLASS 1. *Primitive rocks.*—(1) Granite, (2) Gneiss, (3) Mica slate, (4) Clay slate, (5) Primitive limestone, (6) Primitive trap, (7) Serpentine, (8) Porphyry (9) Syenite, (10) Topaz rock, (11) Quartz rock, (12) Primitive flinty slate, (13) Primitive gypsum, (14) White stone.

CLASS 2. *Transition rocks.*—(1) Transition limestone, (2) Transition trap, (3) Greywacke, (4) Transition flinty slate, (5) Transition gypsum.

CLASS 3. *Floetz or Secondary rocks.*—(1) Old Red sandstone or first sandstone formation, (2) First or oldest Floetz limestone, (3) First or oldest Floetz Gypsum, (4) Second or Variegated sandstone, (5) Second Floetz gypsum, (6) Second Floetz limestone, (7) Third Floetz sandstone, (8) Rock Salt formation, (9) Chalk formation, (10) Floetz Trap formation, (11) Independent Coal formation, (12) Newest Floetz Trap formation.

CLASS 4. *Alluvial rocks.*—(1) Peat, (2) Sand and gravel, (3) Loam, (4) Bog iron ore, (5) Nagel fluh, (6) Calc tuff, (7) Calc sinter.

It is singular to notice how persistently this original error of placing the "Coal formation" high up in the "Secondary" was perpetuated by later geologists. So, too, the position of the "Rock Salt formation," which was in the Mesozoic in England, was erroneously regarded, when

[1] Vol. 6, pp. 411-428.

[2] The article is entitled "Observations on the geology of the United States, explanatory of a geological map, by William Maclure, read January 20, 1809." For students of early maps, it is well to remember this map of Maclure's in the Transactions.

[3] Op. cit., pp. 411, 412.

[4] Ibid., p. 412.

discovered in New York and other places, as a central one in the "Floetz rocks."

The position of the "Independent Coal formation" is defined by Maclure as extending "from the head waters of the Ohio, with some interruption, all the way to the waters of the Tombigbee."[1]

This "Coal formation," as mentioned above, is placed in the upper part of the "Floetz," and is said to lie on "immense beds of Secondary limestone, intercepted in some places by extensive tracts of sandstone and other Secondary aggregates."

Maclure was familiar with the theoretical classification of Werner, and it is instructive to us, seeking a universal classification for the rock formations of the earth, to observe that the first geologist of America, in 1809, found the formations of America "the most correct elucidation of the general exactitude" of this German system. Perhaps American geologists are not at present in danger of imitating any foreign system with such reverence, but the attempt to harmonize or coordinate the classifications across the ocean leads to the same imperfect science, unless strict and even severe adherence to the facts be insisted upon.

In 1818 Elias Cornelius, in a paper on the geology, mineralogy, etc., of parts of Tennessee, Virginia, and Alabama and Mississippi Territories, defined two limestones which he distinguished as the "inclined strata" and the "horizontal strata," reminding us here of the Wernerian "Floetz" formation. His "inclined strata" were observed along the route of his travels over the Blue Ridge and the Cumberland Mountains, and all of the five ranges of the Alleghany Mountains. They were usually called gray limestones, sometimes reddish, as at Knoxville. The second, or "horizontal strata," of bluish color, he observed from the Cumberland Mountains for 200 miles southwestward. The editor explains in a note that the "highly inclined limestone" is the *Transition* of Werner; the "flat strata" belong to the *Secondary*.

John Grammar, jr., gave an account of coal mines in the vicinity of Richmond, in Chesterfield County, and noticed that the coal rests upon granite, is inclined 45° to the horizon, and has a thickness from 25 to 50 feet, thinning out southward; but he did not describe its geological horizon.[2]

In an article by John H. Kain, we find a reference to coal worked at Knoxville, Tennessee.

Daniel Drake published "A geological account of the valley of the Ohio."[3]

This is in a letter to Joseph Correa de Serra, and it presents his views in regard to the surface rocks and conditions, and some of the basement rocks are also referred to in the article, but the nomenclature for these is entirely Wernerian, as "Floetz," "Secondary," "Geest," etc.

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[1] Trans. Am. Phil. Soc., vol. 6, p. 425.

[2] This is the first notice we see of the Mesozole coal formations of this region.

[3] Trans. of the Am. Phil. Soc., vol. 2, new series, pp. 124–139.

In 1819 the American Geological Society was formed.[1] It was incorporated by the State of Connecticut and provisionally located in New Haven, and the first meeting was held in the philosophical room of Yale College, New Haven.

The Geological Society continued in existence for several years and gradually came to an end.[2]

It is evident from the honor bestowed upon William Maclure that in the first quarter of the century he was regarded as the most learned American geologist. In 1819, when the American Geological Society was started in New Haven, he was elected its first president. In a note at the foot of page 360, volume II, of the Silliman Journal, where a donation from him to the American Geological Society is referred to, he is described as a gentlemen who "has, in person, examined the geology of almost every portion of Europe as well as of the civilized portions of America. He has visited several countries repeatedly, and has inspected most of the interesting localities of minerals in Europe and America."

When we remember how few of the present facilities for travel and communication with foreign lands were existent in 1820, when this was written, some idea can be formed of the great influence such a man must have exerted over the opinions of American geologists.

W. B. Stilson, in a sketch of the geology and mineralogy of a part of the State of Indiana, briefly described the geological formations of the State, and referred them to the "secondary rocks." This was a correct correlation following Maclure's classification; the mistake, as before noted, was in the standard scale.

In 1820 Prof. Amos Eaton published "An Index to the Geology of the Northern States."[3] The observations recorded in his book are almost entirely the result of his own personal experience. He writes in the preface, page vi: "With respect to the theoretical part, as far as I have given in to any theory it is to that of Werner, with the improvements of Cuvier and Bakewell."

He recognized eighteen strata in order from the bottom upward, which he grouped into five classes. These were as follows:

	Strata.
I. Primitive class	1. Granite.
	2. Gneiss.
	3. Hornblende rock.
	4. Mica slate.
	5. Talcose rock.
	6. Granular limestone.

[1] Am. Jour. Sci., vol. 2, page 139.

[2] Prof. Dana informs me by letter, October 30, 1888, that by consultation of the records of the society in Yale College library he ascertained that the last meeting of the society was held in 1826, and the last member, E. Leffingwell, died in New Haven during the year 1888. Isaac Lea was a member of the society, and when he died there was but one member of the society still living. In the early numbers of the American Journal of Science frequent references are made to the reception of books and specimens by the society.

[3] Second edition, 286 pages, 12mo, Troy, New York.

II. Transition class	7. Argillite. 8. Metalliferous limestone. 9. Graywacke. 10. Red Sandstone (including those of "Catskill Mountains, Oswego River, Niagara River, and Connecticut River").
III. Secondary class	11. Breccia. 12. Compact limestone. 13. Gypsum (Manlius, Onondaga, Madison, etc.). 14. Secondary sandstone.
IV. Superincumbent class	15. Basalt. 16. Greenstone trap.
V. Alluvial class	17. Geest. 18. Alluvion.

This follows the general system of Bakewell, who was a disciple of Werner; but the individual strata are partly peculiar to his own system, although distributed in the several classes of the Wernerian classification.

In 1821 we find a notice of the occurrence of "blind coal" on the bank of the Arkansas, 500 miles from its mouth, "equal to the best Kilkenny coal;" this by L. Bringier.

In a letter to Silliman (the editor of the American Journal), dated 1820, Brongniart writes about fossils in a way to show how they were then used, and to what a slight extent they were of value in the interpretation of geologic strata. He says[1] in regard to Trilobites: "I learned from these specimens, and from some others which I received in different ways, that Trilobites existed in America as well as in Europe; that the animals differed very little (if, indeed, they constantly differed at all) from those of Europe, and that they are, in both cases, found in the *Schists phyllades*, or in the transition limestone, or, at least, in those which are very ancient."

Ebenezer Granger noticed some vegetable impressions from the coal formation of Zanesville, Ohio, and recognized them as *Lepidodendra* and *Calamites*, but did not further identify them.

Thomas Nuttall[2], of Philadelphia, records some "Observations on the Geological Structure of the Valley of the Mississippi." He gives an account of the probable limits and character of the "secondary formations" in the Mississippi Valley. He compares the calcareous platform of the Mississippi (as seen in the plains of Ohio, Michigan, Indiana, Illinois, Kentucky, western Tennessee, and Missouri) to the plains of the Tartarian district, traversed by the Kuban, as described by Pallas and Clarke, and he states that he thinks he meets in these calcareous deposits "almost every fossil described and figured in Martin's Petrifacta Derbiensia."

Although he makes no allusion to specific identification, this is a clear recognition of the "Carboniferous rocks" in these limestones of the interior.

In 1822 Zachariah Cist gave an account of the Lehigh and Schuyl-

[1] Am. Jour. Sci., vol. 3, p. 226.

[2] Jour. of the Acad. of Sci. of Philadelphia, 1821, vol. 2, pp. 14–65.

kill coal mines in the neighborhood of Wilkes-Barre, Pennsylvania, which were then being worked to the extent of 1,500 tons annually sent to market.

In 1823[1] Ami Borré discussed "European Geology, with remarks on the prevailing geological arrangements." The nomenclature is mainly Wernerian; such terms as "Encrinal limestone," "Old Red sandstone," and "Coal Formation" are associated with "Grauwacke," "Floetz," and "Red Ground," and in the next volume,[2] Conybeare and Phillips's Geology is reviewed.[2] In the review the supposition is made that our salt and gypsum beds may belong to the "original marl" of the authors, and doubt is expressed as to the Connecticut Old Red sandstone being really the equivalent of the "red marl."[4]

The "Rhode Island anthracite" is referred to "transition slates," graywacke slate.[5] It is distinctly stated[6] that in this country no distinction had theretofore been made between "rothe todte liegende" and the English "Old Red sandstone," and the argument is set forth that since the red sandstone in Connecticut lies below the coal measures therefore the "rothe todte" is not uniformly above the coal, as it is claimed to be by the authors, the Connecticut sandstone having been recognized by its fossils as equivalent to the "rothe todte."

Again, in this same year, Prof. Edward Hitchcock gave a considerable account of "the Geology, Mineralogy, and Scenery of the Connecticut River." He recognized the sandstone along the Connecticut River as unmistakably the "Old Red sandstone" of the English authors.[7]

Also, he referred to the occurrence of the "coal formations" along the river, at Chatham, at Middletown, and at Berlin.[8] The occurrence of fish in these coal beds at Westfield and Sunderland is mentioned on page 76, where one of them is referred to the genus *Palethrissum*. In the next volume[9] the "Rhode Island coal formation" is said to be older than that of Connecticut, and the supposition is made that they are both "transition." Hitchcock in his classification evidently followed Conybeare and Phillips's Geology, and from a foot-note[10] it is evident that he regarded the red sandstone to be the same with the "rothe todte liegende," "which," he says, "lies immediately below the bituminous marl formation of Germany, and below the coal formation in England." He quoted Conybeare as considering them distinct, and ventured the supposition that the "red sandstones of the Connecticut Valley" are not "Old Red" but "rothe todte," although he still considered the sandstones west of the Connecticut River as true Old Red sandstone.

This confusion in regard to the determination of our red sands was not altogether due to faulty stratigraphic observation on the part of

[1] Am. Jour. Sci., vol. 6, pp. 188–192.
[2] Ibid., vol. 7, pp. 203–240.
[3] This was published in 1882.
[4] Red marl of Conybeare and Phillips is in the Triassic.
[5] Am. Jour. Sci. vol. 7, p. 224.
[6] Ibid., p. 230.
[7] Ibid., vol. 6, p. 39.
[8] See ibid., pp. 41, 44.
[9] Ibid., vol. 7, p. 28.
[10] Ibid., p. 27.

our geologists, but to confusion in their identification of them with the red sandstones described in the English books. The English geologists themselves were not yet united in distinguishing the red sandstones in their own country, and here, too, the trouble was more due to an attempt at correlating them with the red sandstones of the European Triassic than a failure to understand their difference in England. It was not until considerably later that our geologists clearly distinguished and placed in their proper geological horizon the Triassic sandstones of the Connecticut Valley and southward along the Atlantic border, and the several Paleozoic red sandstones now known as Potsdam, Medina, and Catskill red sandstones.

The year 1824 is noticeable in the progress of American Geology by the publication of Amos Eaton's work on the Erie Canal rocks.[1]

Part 1 contains a description of the rock formations, together with a geological profile extending from the Atlantic to Lake Erie. The classification is substantially that adopted in his text-book, though somewhat modified. In the place of the sixteen strata he has twenty-five, distributed in the four classes, Primitive, Transition, Secondary, and Superincumbent. His favorite system in naming rocks is recognized in the new names which he proposes in his classification. These are after the pattern of "the metalliferous lime rock," that is, the Latin termination meaning "to bear," added to the name of the mineral, and applied to the rock. Such terms are "saliferous rock," "ferriferous slate," "geodiferous slate," "lime rock," etc. A few of these terms are still preserved in our nomenclature, but where they are used they are confusing, and the objection to them is the objection to all of the names of the Wernerian school, that they are attempts to define rock strata by their mineral and physical characters, under the supposition that these characters were traceable in other than the locality where the original stratum was described. Stratigraphic geology was impeded by the attempts to perpetuate this method of classification, and we are scarcely yet entirely free from the influence of this Wernerian school.

A review of this book is given in the eighth volume of the American Journal of Science.[2]

Objection is there taken to the "unnecessary innovations in geological nomenclature," or to "any deviation from the present highly improved state of the science on the eastern continent, unless it is where new facts and discoveries imperiously demand such a course." This is evidently a rap at Prof. Eaton's criticism of Phillips and Conybeare's Geology, published in the same volume of the American Journal of Science[3] a few months before.

[1] A Geological and Agricultural Survey of the District adjoining the Erie Canal, by Amos Eaton, 163 pages and a plate, Albany, New York, taken under the direction of the Hon. Stephen Van Rensselaer.

[2] Pp. 358-362.

[3] Pp. 261-263.

Eaton's article is entitled "Ought American geologists to adopt the changes in the science proposed by Phillips and Conybeare?" He protests against accepting such a radical change in classification as Phillips and Conybeare propose, which is practically a defense of the older Wernerian classification, while Conybeare and Phillips, conceding the importance of defining the various formations by their chemical and external characters and mineral contents, distinctly recognized also the importance of the organic remains as a means of determining and characterizing each individual geological formation, thus following directly in the steps of William Smith and Cuvier.

In 1824, in volume 1 of the second series of Transactions of the Geological Society, is an article by J. L. Bigsby, entitled "Notes on the Geography and Geology of Lake Huron." This, one of the earliest descriptions of a geological section in that part of the country, recognizes (p. 196) the following formations: "Primitive rocks, Secondary, limestone with Orthoceratites on High Cliff Island, Red sandstone equivalent to the Old Red of Werner, underlying Lake George, and the Straits of St. Mary, and limestones at St. Joseph, and on Drummond Island, with Orthoceratites, Milliporæ, Madreporæ, Encrini, shells," etc. Some of the fossils are described and figured; they are all referred to the "Secondary." A Trilobite is also figured[1] and described by Charles Stokes.[2] This is plainly a Lower Silurian fossil, and its identification indicates the use of the term "Secondary" in 1824 as including part of what we now call Silurian rocks.

In 1825 Chester Dewey spoke of Eaton's survey of the Erie Canal[3] and recognized its value, but mildly protested against the "needless novelties in technical language."

In 1825 a letter[4] William Maclure urges "perhaps the most useful classification in the present state of the science would be to retain Werner's five classes as being well defined, that is, as well as the graded variety of nature will permit, and to make some subdivisions in each class without deranging the system already best known, or the ideas of those who follow it."

Thus it will be seen that, at this date, the ablest geologists of America adhered to the old Wernerian system of classification, and when we remember that this system was based upon a study of the primitive rocks, and that the classification which was applicable to them was applied to the whole series as well, we need not be surprised at the retarding influence exerted upon all true progress in geological science.

During the year 1826, and for several years after, frequent papers were published descriptive of coal mines, and dealing particularly with the properties of coal considered as a fuel and in its economical aspects. The regions discussed in these several papers were principally three,

[1] Am. Jour. Sci., vol. 8, p. 20.

[2] It is called by him *Asaphus platycephalus*, and figured on Plate 27, Figs. 1, a-b-c, and 2.

[3] Am. Jour. Sci., vol. 9, p. 355.

[4] Ibid., p. 254, dated Paris, January 14, to the editor.

those of Virginia, Pennsylvania, and Rhode Island, but in none of these papers was there expressed any very clear appreciation of the stratigraphic relations of the coal.

Two such papers were by James Pierce.[1]

In the first paper the author gave no opinion as to the geological age of the coal in Virginia, but in the second paper he referred the coal of Lehigh, Mauch Chunk, Easton, and Pottsville to the "Grauwacke formation," and regarded the Grauwacke as in the Transition group. This was a recognition of a lower horizon for the coal than had been accepted by the geologists in America. The coal heretofore discovered was regarded as belonging to the "Secondary formation" of the prevailing classification. The author also noticed that the coal in the eastern part of Pennsylvania is anthracite and the coal of the western deposits in Pennsylvania is bituminous.

Prof. Silliman, the editor of the American Journal of Science, also published several papers, about this time, on the coals of Rhode Island, Pennsylvania, and other regions.[2] But in his discussions on the coal, it is its properties and economical uses rather than its geological position which he considered.

In 1827, William Meade[3] considered the anthracite in the region from the Susquehanna to the Penobscot as decidedly belonging in the Transition. Reference was made by him to the coal lately discovered near the Tioga River, Pennsylvania.[4]

In 1828, Amos Eaton published in Albany a small treatise of some thirty-one pages, entitled "A Geological Nomenclature for North America."[5]

This publication is a revision of the "Nomenclature" published in the first part of the Erie Canal Survey of 1824, after suggestions received from Prof. Parker Cleaveland, Dr. Steele, and others. There are also some corrections based upon his own observations. Among the latter are to be noticed the statement that "there is no mica slate in Berkshire County on the western slope of the Green Mountain Range,"[6] and "no Primitive Argillite in our district;" "neither do I believe there is such a rock as Primitive Argillite on this globe," in which he follows Bakewell's opinion. Another modification is his statement that the "Old Red sandstone of Werner is not a general stratum," but is found in the third Graywacke, and also in the second Graywacke. In this view he follows Conybeare's opinion, as found in the Introduction of Phillips's and Conybeare's Geology.[7]

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[1] The marl regions of Virginia and Maryland, and on the bituminous coal formation in Virginia; Am. Jour. Sci., vol. 11, 1826, pp 54–59. The mountain districts of Pennsylvania, and the mineral resources of that State, including its bituminous coal; ibid., vol. 12, 1827, pp. 54–74.

[2] Am. Jour. Sci., vol. 11, p. 78; ibid., 1830, vol. 18, p. 308; ibid., 1831, vol. 19, p. 1–21.

[3] Remarks on the Anthracites of Europe and America, Am. Jour. Sci., vol. 12, p. 76.

[4] Ibid., vol. 14, pp. 32–35.

[5] In the Am. Jour. Sci., vol. 13, pp. 145–159 and 359–368, is found substantially the same article under the title of Geological Nomenclature, Classes of Rocks, etc., by Prof. Amos Eaton.

[6] See op. cit. foot-note, p. 146.

[7] Ibid., pp. 147 and 155.

In the American Journal article, four pages, entitled "Geological Nomenclature Exhibited in a Synopsis of North American Rocks and Detritus," are inserted between the regular pp. 144 and 145, which appear to be a reprint of pages of the work as printed in Albany. This "Nomenclature" gives the following list of the classes of rocks:

CLASS 1. *Primitive rocks;* being those which contain no organic relics nor coal (including Granite, Mica slate, Hornblende rock, Talcose slate, Granular Quartz, Granular limerock).

CLASS 2. *Transition rocks;* being those which contain marine organic relics only, and in some localities Anthracite coal (including Argillite, First Graywacke, Sparry limerock, Calciferous sandrock, Metalliferous limerock, Second Graywacke).

CLASS 3. *Secondary rocks;* being those which contain, in some localities, dry-land or fresh-water organic relics, as well as marine, or bituminous coal (including Millstone grit, Saliferous rock, Ferriferous rock, Lias, Geodiferous limerock, Cornetiferous limerock, Third Graywacke).

CLASS 4. *Superincumbent rocks;* being those Hornblende rocks which overlay others without any regular order of superposition, and supposed to be of volcanic origin (including Basalt).

CLASSES OF DETRITUS.

CLASS 5. *Alluvial detritus;* being those masses of detritus which have been washed into their present situation (including Anti-Diluvion, Diluvion, Ultimate Diluvion, Post-Diluvion).

CLASS 6. *Analluvial detritus;* being those masses of detritus which have not been washed from places, showing they were first formed by the disintegration of rocks (including Stratified Analluvion and superficial analluvion).

The localities are given for each of the above mentioned kinds of rocks, and we find them in Massachusetts, Connecticut, and New York, in the latter State mainly along the line of the Erie Canal.

A few of the names used in this "Nomenclature" are still retained, with no, or but slight, modification. "Calciferous sandrock," and under "Metalliferous limerock," "Birdseye marble" is mentioned as a variety of it; under the term "Third Graywacke," with the subdivision "Pyritiferous rock," is described what we now know as the Devonian rocks of the State of New York, including the Catskill, or what were known as the Old Red sandstone of Werner, but not including the Lower limestones. Eaton's "Cornetiferous limerock" appears to be a name covering both Lower Helderberg and Upper Helderberg rocks of our present classification, and his "Third Graywacke" rested upon the "Cornetiferous limerock." In this paper Eaton pointed out the distinction between "general strata," which he finds in America "can be traced for an extent of 100 or 300 miles," and "beds or varieties" of the former.[1]

According to this proposed nomenclature, "the Lias, Geodiferous limerock, Cornetiferous limerock, and the Third Graywacke occupied as uppermost rocks more than half of the great States of New York, Pennsylvania, Virginia, and nearly all the States of Ohio, Indiana, Illinois, Kentucky, Tennessee, and Michigan Territory," and he says

[1] Am. Jour. Sci., vol. 13, p. 361.

"If we adopt the European nomenclature, one must treat of this vast territory under the Oolitic Formation."[1]

Prof. Eaton regarded this synopsis as expressing accurately "the order of superposition," as well as the definition and geographical locating of the strata named.[2] In the same article he stated that "No one is qualified for examining geological facts, nor for reading essays or systematic treatises on geology, until he has fixed in his mind a systematic arrangement of general strata."[3] And he informed us that Van Rensselaer spent more than $18,000 on the investigations and researches which were carried on in connection with his survey of the Erie Canal rocks.[4]

In 1829 there appeared[5] an interesting article by J. E. Doornik on "Observations concerning fossil organic remains," communicated by the author in French, and translated by Charles U. Shepard. The author made some remarks upon M. Cuvier's method of explaining the importance of organic remains for geology. (Cuvier's "Ossemens fossiles" had been published in 1825.)

Doornik combats the proposition of Cuvier that "to fossil remains alone is due the origin of the theory of the earth, and that there had been in the formation of the globe successive epochs and a series of different operations," and while combating this proposition he defends Werner as having laid the foundation of geology.

This article is interesting particularly as showing the progress of science caused by the opposition of the conservatives. Fossils were rapidly taking the place of mineral characters in the correlation of stratified rocks, and the old school (such men as Doornik and Prof. Eaton) strenuously advocated the system of Werner. A quotation is found in this article from Brongniart, which shows how thoroughly he, as a student of fossil botany, appreciated the value of fossils. He wrote as follows:

> I consider, then, those characters relating to the epochs of formations which are taken from organic remains as of the first value in geology and as superior to all others, however valuable they may appear.

Lardner Vanuxem wrote a letter to Prof. Cleveland the same year.[6] Among other remarks the following are worthy of quotation: He said that the "Alluvial" of Maclure includes both Tertiary and Secondary, and the different deposits are characterized by their fossils, which are not confused or mixed, but are found at different levels, and this is noticeable in the Southern States particularly. He pointed out an error, which was a generally accepted one, and is traceable to the identifica-

[1] Am. Jour. Sci., vol. 13, p. 361.
[2] Ibid., p. 362.
[3] Ibid., p. 359.
[4] Ibid., note to p. 360.
[5] Am. Jour. Sci., vol. 25, p. 90, et seq.
[6] On the characters and classification of certain American rock formations. Am. Jour. Sci., vol. 16, 1829, p. 254.

tion of Amos Eaton, viz, the covering "of the western country and the back and upper parts of New York with Secondary rocks." Vanuxem found them, by their fossils, to belong to the Transition, and remarked: "The analogy or identity of rocks I determine by their fossils in the first instance and by their position and mineralogical characters in the second or last instance." He mentioned instances of such determinations in regard to certain rocks of Ohio, Kentucky, and Tennessee, which he identified with the "limestones of Trenton Falls by the genera of the fossils," and recognized that they are different from the rocks lying above the Coal Measures. This appears to be the first, or at least one of the very earliest, expressions in American literature of the principle underlying the new school of geologic correlation which soon after took the place of the Wernerian school.

To show how the errors of the system of Werner led to mistakes of identity, it may be noticed that Eaton's determination of the rocks of western New York, etc., as belonging to the "secondary rocks" of his classification, appears to be influenced by the term "floetz" of the Wernerian nomenclature, which applied to these rocks.

In 1830 James O. Morse published an article[1] in which is an illustration of the arguments used for defending the Wernerian system. The author referred to the doubt which had been expressed as to the identification of certain rocks with the Greywacke, and argued as follows:

> Prof. Jameson describes Greywacke as composed of sand connected together by a basis of clay slate, and minute inspection of the rock of these regions will convince any one that our Greywacke has these component parts.

Prof. Amos Eaton made some "Observations on the coal formations in the State of New York in connection with the great coal beds of Pennsylvania."[2] In this article he recognized four distinct coal formations in the United States: First, "the genuine Anthracite or Glance coal," in the Transition Argillite, Newport, Rhode Island, and Worcester, Massachusetts; second, "coal destitute of bituminous matter," not true anthracite, but what he calls "Anasphaltic coal," occurring in slate rock, lowest of the second series, which he identifies with the greatest Coal Measures of Europe, Pennsylvania, Carbondale, Lehigh, Lackawaxan, and Wilkes Barre; third, the "bituminous coal" proper, in slate rock of the lowest of the upper Secondary rocks, Tioga, Lycoming, etc., Pennsylvania; fourth, "Lignite coal," as seen at the south shore of the Bay of Amboy, in New Jersey. The first or "Anthracite coals" are represented by slates which he traced from Canada to Orange County, New York, but the coal never occurs in seams thicker than an inch. The third, "bituminous coal," Eaton traced from Pennsylvania to Seneca and Cayuga Lakes, and the coal seams, he said, were not over 2 inches in thickness. It is said to "rest on what the English call Carboniferous limestone." This "Carboniferous limestone" is plainly the Tully limestone, and the "Coal Measures" above are the Genesee shale.

[1] Observations on the Greywacke region of the State of New York; Albany Institute Trans., vol. 1, pp. 84, 85.

[2] Trans. of the Albany Institute, vol. 1., pp. 126–130.

Eaton identified the Onondaga Salt group and the Medina sandstone and shales, and Clinton rocks, probably, with the English "Saliferous" and underlying "Millstone grit," and in accordance with the English precedent coal was supposed to lie below these. He believed that boring at Gasport, 6 miles east of Lockport, which at the surface was 274 feet higher than the surface of Lake Ontario, would reveal the Coal Measures at 600 feet below the surface, and he was so confident that he even suggested that legislative aid be furnished for boring down to this coal. And again he says:[1] "And it may be stated that if coal is not found beneath the Saliferous rock, which is more than 200 miles in extent, it will be truly a geological curiosity which has no parallel on the Eastern continent; but we find many deviations in America from the geological maxims which seem to be established in Europe."

This mistake of the first of American teachers of geology of that time in supposing that coal would be found below the Middle Silurian rocks is the legitimate outgrowth of the imperfection of the Wernerian system. The supposition that Saliferous rocks occupy a particular place in a scale of strata was not Prof. Eaton's fault; he followed the English and they the German school in this, and it was not due to the ignorance of the uneducated that attempts were made to find coal in New York State for years after this, but it was due to the ignorance of the best geologists of the time as to the right means of correlating rock equivalents across the Atlantic.

In 1830 Amos Eaton wrote a short article[2] entitled "Geological Prodromus." He announced that he intended to demonstrate that "all geological strata are arranged in five analagous series, and that each series consists of three formations, viz: the Carboniferous, Quartzose, and Calcareous." He referred to Bakewell's classification, and this idea is evidently a modification of the notion that strata were arranged in recurring suites of formations, a notion which was brought out in the later development of geology, in the theory of "circles of sedimentation," of which Dr. J. S. Newberry is the most conspicuous exponent.

Eaton particularizes in the article referred to, saying that he intends to show that "the Lehigh or Lackawannock coal * * * is embraced in the Second Grauwacke, Secondary, and that the Tioga coal is embraced in the Third Grauwacke or Upper Secondary of Bakewell and others"; and in this latter position, the Third Grauwacke, he mentions as belonging to the "thin layers of coal at Ithaca, on Seneca Lake, and Lake Erie shores."[3]

This error of Eaton's in identifying the rocks of Ithaca, Cayuga Lake, and westward to Lake Erie with the "Third Grauwacke," placing them above the Blossburg coal of Pennsylvania, was not corrected until several years later, when the study of fossils clearly revealed the fact that the rocks belonged below the Carboniferous.

[1] Am. Jour. Sci., p. 130. [2] Ibid., vol. 17, p. 63, dated Troy, July 28, 1829. [3] Ibid., p. 28.

The classification of De la Bêche is reported in the Journal,[1] a few points of which may be worth recording in order to show how opinion stood in England at this time. The rocks from the top down to what is called "the lowest fossiliferous" are divided into nine groups, and together are called "the superior stratified or fossiliferous rocks." These divisions are as follows:

1. Alluvial Group.
2. Diluvial Group.
3. Lowest Great Mammiferous.
4. Cretaceous.
5. Oolitic.
6. Red Sandstone.
7. Carboniferous.
8. Grauwacke.
9. Lowest Fossiliferous.

In this classification is seen also a separation of the Old Red sandstone from the Carboniferous, placing the Old Red in the eighth division, the Grauwacke.

Eaton identified the second coal with the formations below the "Saliferous," and the third coal, he stated, is the same with the outcrops in Ithaca and on Cayuga Lake.[2]

This opinion was controverted by David Thomas, who dates his article, Greatfield, Cayuga County, New York, 1830.[3] He pointed out the fact that the rocks on Cayuga Lake dip slightly to the south, which would bring them below the Tioga coal, and he modestly differed from the distinguished geologist, Prof. Eaton, and suggested that these rocks on Cayuga Lake must belong to different strata, below the coal deposits of Tioga, Pennsylvania.

In 1831 Silliman compared conglomerates associated with the anthracite coal in Pennsylvania with the Millstone grit of the English Coal Measures;[4] in 1832[5] Eaton supposed that he had established identity for the rocks in New York with European strata by their contained fossils, for "(1) Granular limerock with no organic remains; (2) the Metalliferous, mountain, or Carboniferous limerock," which he recognized by fossils in the rocks from Glens and Trenton Falls, Bethlehem, Catskill, Esopus Strand, and Rondout. "(3) The Oolitic series of calcareous rocks, the 'coral rag,'" recognized on the south shore of Lake Erie, and 23 miles southwest of Albany. "(4) Tertiary marls," recognized in New Jersey as "London clay," and "shell marl" in the bank of the Erie Canal, 10 miles west of the Onondaga Salt Works.

This article is dated October 2, 1831; the identifications, as it will be seen, are mainly utterly wrong, although the attempt shows how the principle of correlation by means of fossils was being forced into notice and adopted by even the extreme disciples of Werner.

In the same year and volume[6] Eaton published another article, enti-

[1] De la Bêche, Henry. Sketch of a classification of the European rocks. Am. Jour. Sci., vol. 18, 1830, pp. 26-39.

[2] Albany Institute, Transactions, vol. 1; also Am. Jour. Sci., vol. 19, pp. 21-26.

[3] Am. Jour. Sci., vol. 19, p. 326.

[4] Ibid., pp. 21-26.

[5] "On the four cardinal points in Stratigraphic Geology, established by organic remains." Am. Jour. Sci., vol. 21, pp. 199-200.

[6] Ibid., pp. 132-138.

titled "Geological Equivalents," in which is given a list of "names of strata which are known to geologists of both continents, with some of their organic associations in North America." In the list eighty species are named. The names were taken, of Mollusca, chiefly, from Sowerby, of Radiata, from Goldfuss, of Crustacea, from Brongniart. It is an attempt to recognize the European strata in America, adopting the Bakewellian adaptation of Werner's system, and there are necessarily many gross errors.

In an article in the American Journal of Science, Prof. Silliman, the editor, reviewed "Phillips's Geology of Yorkshire," which had been published in 1829. In the course of his remarks we find the following statement: "Werner and Smith are, therefore, the leaders of the modern school of geology," and "Smith has the great merit of establishing the facts that different strata contain different fossils, but that the same stratum over a very large extent of country contains generally the same fossils, hence he deduces the important conclusion that strata may be discriminated and indentified by their organic contents."[1]

Edward Hitchcock reported[2] on the "Geology of Massachusetts," which he had examined under the direction of the government of that State, during the years 1830–'31. Part first, or economical geology, was published in the Journal, and in a foot-note the editor said that "this is the first example in this country of the geological survey of an entire State." In this report the Connecticut River sandstone is called the "New Red sandstone," the opinion formerly expressed in regard to coal occurring in Connecticut and Massachusetts is reconsidered, and in the present article the coal formation of this region is regarded as belonging to the New Red sandstone or its equivalent.[3] The Worcester anthracite is regarded as in older rocks than that of Rhode Island, and the Pennsylvania anthracite is reported as occurring in the higher beds of the Grauwacke, and as belonging to a newer horizon than that of the Rhode Island coal.

Geo. W. Featherstonhaugh[4] did little more in the way of classification than theoretically to adapt the system of Conybeare to America. The table of formations is as follows: (details only of the parts pertaining to the present discussion are here given):

			Feet.
Secondary..	Supermedial order..	17. Lyas	
		16. Variegated or red marl	500
		15. Muschelkalk	300
		14. New Red sandstone	300
		13. Zechstein	500
		12. Exeter red conglomerate	500
	Medial order	11. Coal beds	1,000
		10. Millstone grit and shales	800
		9. Carboniferous limestone	850
		8. Old Red sandstone	1,500

[1] Am. Jour. Sci., vol. 22, pp. 4, 11–12.

[2] Ibid., pp. 1–70

[3] Ibid. p. 43.

[4] Featherstonhaugh, G. W.: On the order of succession of the rocks composing the crust of the earth. Monthly Am. Jour. Geol. and Nat. Sci., vol. 1, 1832, pp. 337–347.

Transition	Submedial order	7. Greywacke	
		6. Transition sandstone	

In 1833 Eaton gave reasons for referring the Pennsylvania coal beds to the Secondary Coal Measures of Europe.[1] In this article reference is made to coal plants collected by Mr. James Hall, then adjunct professor in Rensselaer Institute. Eaton defended his reference of the coal beds of Pennsylvania to the "Secondary," and mentioned his identification of twenty-three species of the specimens of ferns collected by Hall with species described by Brongniart from the great Secondary coal formation.

J. B. Gibson, in 1833, recognized in Pennsylvania, New York, Upper Canada, Ohio, and Michigan, two superior formations: the *New Red sandstone*, associated with which he reports Magnesian limestone, gypsum, and rocksalt; resting on this is a *calcareous formation*, forming the cataracts of Niagara, Onondaga, and Genesee.[2] Of the limestone along the Niagara River he said:

> It corresponds in all material respects to the Lias of the English geologists and corroborates the German doctrine of universal formations.[3]

And more of the same kind.

Bituminous coal in Alabama was reported by Alexander Jones in 1834, and a section was run across the country from Baltimore to the Ohio River by William E. A. Aiken.[4]

In 1834–'35 the Transactions of the Geological Society of Pennsylvania, vols. 1, 2, were published.

Richard C. Taylor had several papers in these transactions in regard to the geological position of the coal deposits of Pennsylvania and Richmond, Virginia.[5] He recognized in the plants from Lewistown, Mifflin County, Pennsylvania, "marine plants of the family Fucoids, from the Grauwacke group, and the Old Red sandstone."[6] In one article Taylor shows that coal is not to be expected to the northward, as the dip of the rocks is southward. In Pl. 8, Fig. 5, the true relation of the beds from Blossburg northward to the Chemung River is given, and from observations made upon the dip of the rocks, decreasing northward, he estimated that the rocks at the Chemung River, "Chimney Narrows," would be 6,275 feet below the summit of the hills of the Tioga Basin. These beds below the Blossburg coal basin are called "Old Red sandstone," and he regarded them as 6,000 or 7,000 feet thick.[7]

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[1] The coal beds of Pennsylvania equivalent to the great Secondary Coal Measures of Europe; Am. Jour. Sci., vol. 23, p. 399.

[2] This is the Niagara limestone.

[3] Am. Jour. Sci., vol. 23, p. 203.

[4] Aiken, Dr. William E. A.: "Some notices of the geology of the country between Baltimore and the Ohio River, with a section illustrating the superposition of the rocks." Am. Jour. Sci., 1st ser., vol. 26, 1834, pp. 219–232.

[5] Vol. 1, pp. 5–15.

[6] Pp. 204–223: "On the mineral basin of the coal field of Blossburg, on the Tioga River, Tioga County, Pennsylvania."

[7] P. 208.

Of fossils he named the following as occurring in these beds: "*Producta* and *Crinoidal* remains, and occasionally *Fucoides*, *Carophyllea*, *Pectens*, and *Spirifer* are interspersed." This is, apparently, the first identification of the Chemung group, as it is now called, of the Upper Devonian.

He discussed[1] "a section passing through the bituminous coal field near Richmond, Virginia," and gave a full account of "these interesting beds of coal," which he regarded as "probably of Transition age" rather than Secondary, to which position Mr. Maclure referred them.

At that time, apparently, the fossils had not been studied, ignorance in regard to which left the geologists in the dark as to the true position of these Mesozoic deposits.

An account is given[2] of studies of sections for 250 miles across Virginia and Maryland. In the discussion the Primitive, Transition, Old Red, and Secondary rocks are recognized, and the Fredericksburg plant beds were referred[3] to the "Oolitic" of Europe.

In another paper the coal beds of the Alleghany Mountains are called "Secondary, with Old Red Sandstone lying under them," and on the other side of the anticline were seen other coal beds, which Mr. Taylor called "Transition." A cut is given[4] presenting the true relations of the Chemung and Blossburg deposits, but the Blossburg coal is regarded as Secondary.

In the same Transactions,[5] Edward Miller described a portion of the Alleghany Mountains, in which he recognized the coal formations as belonging to the "Coal Measures."

Gerard Troost,[6] in a paper on certain Pentremites found in Tennessee, Alabama, and Kentucky, identified the rocks of Perry County, Tennessee, as "a stratum below the Coal Measures," regarded by him as "in the Upper Transition." In the same rocks with the *Pentremites* were found *Trilobites*, *Calceola sandalina*, *Calamopora*, *Terebratula*, *Spirifera*, *Producta*, etc.

In some cases the limestone had an oolitic structure. The limestone near Nashville, Tennessee, was referred to the "Mountain limestone of the English." The conclusion is that the beds containing the Pentremites of these Southern States characterize "the Upper Transition limestone" of the interior of America.

The same author[7] wrote "On the organic remains which characterize the Transition series of the Valley of the Mississippi." In this article he included "Mountain limestone" in the "Transition strata," be-

[1] On pp. 275-294.

[2] On p. 314.

[3] Vol. 2, pp. 177-193: "On the relative position of the Transition and Secondary coal formations in Pennsylvania, and description of some Transition coal, or bituminous, anthracite, and iron-ore beds near Broad Top Mountain, in Bedford County, and of a coal vein in Perry County, Pennsylvania, with sections."

[4] P. 194.

[5] Vol. 1, p. 251.

[6] Ibid, pp. 224-231.

[7] Ibid., 248.

cause, as he says, "the fossils of the Carboniferous limestone are those found in the Grauwacke of Europe, while his Grauwacke is without fossils except in the upper strata." The "Carboniferous limestone" he considered distinct from the "Coal Measures."

In 1836 S. P. Hildreth recognized in the State of Ohio, using the nomenclature of De la Bêche, the "Tertiary, Super-Cretaceous, New Red sandstone, Red marl, White Lias limestone, Millstone grit or Breccia, Bituminous coal, Old Red sandstone." The "Pittsburg coal strata" and the "Carboniferous limestone" are described. An "extensive spring of petroleum" is mentioned. A large number of fossils are figured, thirty plates of which are published with names and short descriptions.[1]

In 1836 Featherstonhaugh[2] compared the deposits of anthracite coal and bituminous coal, and stated that the former belongs to an entirely distinct geological position from that of the latter. The "anthracite," with the exception of Broad Top in Bedford County, Pennsylvania, is "without exception deposited low down among what have been called the Grauwacke rocks." And he thinks they will prove "the equivalent of Mr. Murchison's Silurian rocks."[3]

In 1837, George E. Hayes[4] gave his reasons for differing from those who considered the rocks of western New York as of Secondary age. He regarded them as "older than the Carboniferous" and of Transition age."

In 1838 Charles T. Jackson, speaking of the Coal Measures of Mansfield, Massachusetts, refers them to the "Conglomerate or Grauwacke."[5]

This brings us up to the time of the Geological Survey in New York, and the work of the Rogers in the Pennsylvania and Virginia rocks, and the clearing up of the classifications, due in great measure, for the lower rocks, to the publications of Murchison and Sedgwick in England, which had then reached America. It is interesting to notice that so long as the Transition and Grauwacke rocks were classified in accordance with the Wernerian system, nothing satisfactory was reached. The Coal Measures, the Saliferous rocks, the Grauwacke, the Old Red sandstone, and the Carboniferous limestones, when attempts were made to identify them in this country, were placed in the positions to which they were assigned by the Wernerian school; position being determined not by study of their stratigraphy alone, but by the primary identification of the rock from its mineralogical characteristics, which were supposed to be recognized, and then by an arbitrary reference of it to a position in the system corresponding to that found in the European series.

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[1] Observations on the bituminous coal deposits of the valley of the Ohio, and the accompanying rock strata, with notices of the fossil organic remains and the relics of vegetable and animal beds. Am. Jour. Sci., vol. 29, pp. 1–154.

[2] Report of a geological reconnoissance made in 1835, from the seat of Government by the way of Green Bay and the Wisconsin Territory to the Coteau de Prairie.

[3] Op. cit., p. 113.

[4] Am. Jour. Sci., vol. 31, pp. 241–247.

[5] Ibid., vol. 34, p. 395.

The new school of geologists, when they began work in New York State, made careful stratigraphic observations. Following the methods begun by Murchison and Sedgwick, although taking the data from the facts as they found them, they arrived at a correct interpretation of the strata of New York, which are peculiarly simple in their stratigraphic relations. And ultimately the "New York system," as it was afterward called (the name was proposed as a temporary name for convenience), became the standard section for American Paleozoic rocks. This New York system of rocks is for the Paleozoic one of the most perfect and satisfactory geologic sections found anywhere in the world, and may well stand as a classic section for the interpretation of the rocks which had been called Transition in the older nomenclature.

In 1837, the first annual report of the Geological Survey of New York was published. In this report, T. A. Conrad, who had previously studied the paleontology of Tertiary deposits along the coast, and was recognized as a paleontologist of ability, reported for the third district of New York. In classification, the nomenclature of Eaton mainly was used. We notice[1] that in the main the strata he studied were recognized as belonging to "the Silurian or Lower Transition rocks. Thus it will be seen that the Murchisonian classification had already reached America.

In this first report special attention is called to the importance of having the fossils carefully studied by a man specially appointed for that purpose, as State paleontologist. The next year Conrad was appointed paleontologist.

In the second report, 1838, Conrad, as paleontologist, reported the following points, which will show the progress that had been made during the year. He concluded that with the exception of the upper part of the Catskill Mountains, the rocks of the State terminate with the "Upper Ludlow rocks" of Murchison; and he noted that the fossils in the strata below the coal in Tioga County are the same as those in the Coldbrook Dale coal, and also that the same fossils are recognized in Ohio.[2]

Among the fossils discovered in the various strata he found what he regarded as equivalents of those reported from foreign rocks in the following places:

(1) Below the Catskill strata fossils equivalent to those of the Ludlow.[3]

(2) A limestone and two strata of sandstone with fossils equivalent to those of the Dudley.[4]

(3) The "Calciferous slate" of Eaton, containing the gypsum, was correlated with the "dye earth" of Shropshire.[5]

(4) The "Saliferous sand rock" of Eaton, was the Red sandstone at Niagara and Genesee Rivers (now the Medina sandstone.[6])

[1] Op. cit., p. 184.
[2] Op. cit., pp. 109, 110.
[3] Ibid., p. 110.
[4] Ibid., p. 111.
[5] Ibid., p. 112.
[6] Ibid., p. 113.

(5) Olive sandstone and slate of Salmon River, Oswego County (these two, 4 and 5 were recognized as equivalents of "the fourth group in the slate system of Wales," as defined in Phillip's Encyclopædia Metropolitana, article Geology, p. 568.)

(6) The black limestone and shale of Trenton, the "Birdseye limestone," and "calciferous sand rock" of Eaton, and the grauwacke and slate of Hudson River, he recognized as equivalent to the "Llandeilo flags" of Murchison.[1]

In this report, also, thirteen species of fossils are described from the first group above, which he regarded as equivalent to the Ludlow.[2]

The localities given are Norwich, Cazenovia, Madison, and Sherburne. Since all these localities are Devonian localities, and the fossils are Devonian fossils, it is evident that in 1838, the paleontologist Conrad regarded these Devonian rocks as equivalent to the Ludlow group of the Upper Silurian of Murchison.

Lardner Vanuxem reported for the third district[3] and appears to follow Eaton's nomenclature, except in a few new names, like "Trenton limestone," which had already been published. Fossils are given for "Trenton limestone, black shale," "green shale and sandstone," "upper limestone," "white sandstone" (which can be recognized as the Oriskany). The species in this report were evidently determined by Conrad.

James Hall reported for the fourth district. This, it will be remembered, includes the rocks of the State from Cayuga Lake westward. These rocks were regarded as equivalents of the Old Red sandstone and Carboniferous groups, and stratigraphically above the Silurian system of Murchison.[4] Some erroneous identifications, however, are evident; what is now the Medina sandstone was called in this report "Old Red sandstone," and the Corniferous limestone was identified as "Carboniferous or Mountain limestone."[5]

W. W. Mather, in 1838, published the first annual report of the Geological Survey of the State of Ohio. In his identifications he mentioned first the great limestone deposit, which he correlated with the "Mountain or Carboniferous limestone" of Europe. He defined this as covering the western border of the State. He named a number of fossils from this limestone, which are evidently erroneously identified, as the formation is Silurian, and not Carboniferous, as he supposed. His third formation he called "Waverly sandstone series." Other points of the correlation were made, as "conglomerates," and also an "upper coal series," but it is particularly important to notice that originally the formations called "Carboniferous limestone" in America were not correctly identified.

The second annual report of the Geological Survey of Ohio was

[1] N. Y. Geol. Surv., 2d Rep., p. 114.
[2] Ibid., p. 116.
[3] Ibid., pp. 253–286.
[4] Ibid., p. 291.
[5] See "map along the Genessee River from Rochester southward."

published in 1838. The director of the work, and editor-in-chief, was W. W. Mather. The volume contains reports by Mather,[1] C. Whittlesey,[2] J. W. Foster,[3] C. Briggs, jr.,[4] and J. Locke.[5]

In the geological parts of this report we have general descriptions of the regions surveyed and some location of the order of the strata, as seen particularly in a "table representing the geological structure of Ohio,"[6] prepared by C. Briggs, jr., which is as follows:

The rocks of the State are divided into six formations, which, from above downward, are in the following order: "(1) Alluvium, (2) Tertiary, (3) Coal Measures, (4) Fine-grained sandstone, (5) Shales, and (6) Mountain limestone."

The "Mountain limestone (6)," which is said to be about a thousand feet in thickness, and is defined as "beds of limestone intermixed with chert," judging from the localities in which it is identified, is probably the Corniferous limestone. The "Fine-grained sandstone (4)," underlying the Coal Measures, is apparently the "Waverly sandstone series" of the first report.

In John Locke's report[7] a generalized section of the southwestern part of Ohio is given. In this section the following deposits are recognized, beginning at the bottom with "(1) Blue limestone," [the Cincinnati limestone], "(2) Marle, (3) Flinty limestone, (4) Marle, (5) Cliff limestone, including basins of iron ore, (6) Bituminous slate, and (7) Fine-grained sandstone."

It will be seen from this report that nothing had been done to correlate accurately the deposits with any of the systems then in use. Mather was one of the corps of geologists engaged in the State survey of New York, and it was not until later than 1838 that the New York geologists had adopted any systematic classification of rocks.

In Houghton's report of the survey of Michigan, the coal formation was recognized, but the classification was not correlated with the European system, and merely the nature of the rocks and their order were defined.

In Indiana identifications had been made of the "coal formation" and "Subcarboniferous rocks," including the "Oolitic limestone, Hydraulic limestone, etc.," which were rightly identified in their stratigraphic relations to the Carboniferous. They were regarded by D. D. Owen as similar to the Mountain limestone of the Europeans.[8]

In Tennessee (fourth report, by G. Troost), the "Primordial," the "Grauwacke," the "Mountain limestone," and the "Coal Measures" were distinguished, and an immense deposit of sandstone was recognized between the Grauwacke and the Mountain limestone which was regarded as equivalent to the Old Red sandstone of the European geologists.[9]

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[1] Pp. 1–40.
[2] Pp. 41–72.
[3] Pp. 73–107.
[4] Pp. 109–154.
[5] Pp. 203–286.
[6] Loc. cit., p. 108.
[7] See p. 205.
[8] See Am. Jour. Sci., vol. 34, p. 193.
[9] Ibid., p. 187.

Pennsylvania: H. D. Rogers had been studying the rocks of Pennsylvania, and there was published in this year a generalized section of the Appalachian region of Pennsylvania.[2] The formations recognized by Rogers were as follows:

1. Sandstone of South Mountain.
2. Limestone of Kittatiny Valley.
3. Slate of Kittatiny Valley.
4. Sandstone and conglomerate of Kittatiny Valley and Blue Mountain.
5. Red and variegated sandstone and shale of the valley northwest of Kittatiny.
6. Blue limestone along the north base of Kittatiny and both sides of Montour's Ridge.
7. Sandstone of the first ridge north of Kittatiny.
8. Olive-colored slate of the valley between Kittatiny and second mountain.
9. Red sandstone and shale of southeast slope and base of Alleghany Mountains.
10. Sandstone and conglomerates of second mountain, and of southeast summit of Alleghany.
11. Red shale of anthracite coal regions.
12. Conglomerates and sandstones immediately below the Coal Measures (Broad Top and Alleghany coal region)
13. Anthracite Coal Measures.

It is interesting to note that this system of numbers for the various formations was made out about the same time that the system of nomenclature adopted by the New York Survey was being formed. Both systems have struggled for existence in some parts of the country. The system of Rogers was one based strictly upon the nature of the rocks and their stratigraphic sequence, and in so far is satisfactory for that particular region; but the New York system was defined in addition by the fossil contents of the various formations, and an attempt was made at the very start to correlate them with the several formations defined by the European geologists.

Whether we adopt local geographical names or not, it is doubtful if simple numbers, as proposed in the Pennsylvania system of Rogers, will ever be satisfactory except for a limited region.

In this same year, 1838, we have a report upon the Upper Illinois, by C. U. Shepard.[2] The name "Magnesian limestone" is applied to the "great limestone rock formation extending from near Chicago to the Kankakee River," and in various places the coal formation was recognized. Several sections of the coal formations and descriptions and figures of some plants and fossil shells are given.

Prof. Dewey, of Rochester, gave an account[3] of some observations on the rocks in western New York. The rocks south of Rochester were misunderstood by him on account of the misinterpretation of the fossils; for instance, the "limestones" were regarded as the same as those of Trenton Falls, and as belonging to the Transition, and were

[1] See Am. Jour. Sci., vol. 34, pp. 189, 190.
[2] Ibid., pp. 134-161.
[3] Ibid., vol. 33, pp. 121-123.

thought to "rank with the Mountain limestone of Europe, and rest on the Old Red sandstone."[1] By the latter term he evidently meant the Medina sandstone.

In 1839, T. A. Conrad published "Notes on American Geology."[2] He used the term "Trilobite rocks" for what had previously been called the Transition or the Silurian system. In this paper he stated that "Strophomena is the most characteristic of the Trilobite system;" that "Producta has as yet been found only in the upper term," or "Pyritiferous rock" of Eaton, and that the "Producta is abundant in the Mountain limestone where Strophomena is rare," and that this genus is "eminently characteristic of the Carboniferous system." This indicates a careful observation of fossils, although the identifications are broader than customary at the present time.

In 1839, Whittlesey, Ch., recognized the following classification of the rocks of Ohio:

1. Coal Measures.
2. Conglomerate.
3. Waverly series.
4. (Black shale, Hamilton and Marcellus).
5. Cliff limestone (including Corniferous and Onondaga).

The "Hamilton and Marcellus shales" extended from the lake to the base of the Newburg section. "Chemung and Portage" included the rocks of Newburg and Bedford and above to about half way to Hudson.

Murchison, in his "Silurian System,"[3] London, 1839, proposed the following names.

Oolitic system.[4]
New Red system.[5]
Carboniferous system.[6]
Old Red system.[7]
Silurian system.[8]
Upper Silurian rocks.[9]
Lower Silurian rocks.[9]

and quotes the term "Cambrian System,"[7] from Prof. Sedgwick. The words, "Oolitic," "New Red," "Carboniferous," "Old Red," were names used before and applied to certain rocks, but their use in connection with the word, "system," is apparently introduced for the first time by Murchison.

The following is the classification proposed by Murchison as it appears upon his map:

a. Inferior oolite	Oolitic system.
b. Upper lias and marlstone	
b. Lower lias	
c. Upper red marl	New Red system.
c. Keuper sandstone	
c. Lower Red marl	
d. New Red sandstone	
e. Calcareous Conglomerate (Magnesian limestone)	
f. Lower New Red sandstone	

[1] Am. Jour. Sci., vol. 33, page 123.

[2] Ibid., vol. 35, pp. 237–251.

[3] The Silurian System, founded on Geological Researches in the counties of Salop, Hereford, Radnor, Montgomery, Caermarthen, Brecon, Pembroke, Monmouth, Gloucester, Worcester, and Stafford, with descriptions of the coal fields and overlying formations. By Roderick Impey Murchison, F. R. S., etc. In two parts. London, 1839. Quarto, 768 pp., 37 plates, and large folding map.

[4] P. 13. [5] P. 27. [6] P. 79. [7] P. 169. [8] P. 195. [9] P. 265.

g. Upper Coal and Fresh-water lime			Carboniferous system.
g. Lower Coal Measures			
h. Millstone grit			
i. Carboniferous limestone			
k. Old Red Conglomerate			Old Red system.
l. Cornstone and marls of Old Red			
m. Tilestone of Old Red			
n. Upper Ludlow rock	Ludlow	Upper Silurian rocks.	Silurian system.
n. Aymestry and Ludlow limestone			
n. Lower Ludlow rock			
o. Wenlock limestone	Wenlock		
o. Wenlock shale			
p. Upper Caradoc (with limestone)	Caradoc	Lower Silurian rocks.	
p. Caradoc sandstone			
q. Llandeilo flags (and limestone)	Llandeilo		
r. Upper Cambrian (beds of passage)			Cambrian system (part of).
s. Slaty Cambrian rocks			

M. de Verneuil[1] gave the following classification:

Carboniferous System	1. Coal Measures and Millstone grit. 2. Mountain limestone. 3. Lower Carboniferous shales.
Silurian System	1. Upper Silurian (including Old Red sandstone and Devonshire strata). 2. Middle Silurian. 3. Lower Silurian.

Thus evidently following Murchison, and he pointed out the error of Foster of Ohio and other American geologists in identifying limestones containing Silurian fossils as "Mountain limestone."

In the same journal, in the following year (1841), J. W. Foster explains that the Silurian fossils came from a formation wrongly called by him "Mountain limestone."

In a review of the report of the geological and agricultural survey of the State of Rhode Island, by Charles T. Jackson,[2] the reviewer gave the following opinion: "In determining the geological age of rocks Dr. Jackson gives a preference to superposition of strata and the mineralogical composition over zoological and botanical characteristics, which, however, he allows to be of great value. He prefers also the Wernerian division of Transition rocks to the names Cambrian and Silurian proposed for certain groups in England, which he thinks will never be regarded in this country as appropriate terms for our rocks."

This is an indication of the prejudice which is not confined to the old geologists or to the early stages of geological science, but which troubles us at the present time. The names "Cambrian" and "Silurian," within 10 years of the time when Jackson wrote this, were almost universally adopted by Americans whenever the formations included under these names were under consideration, and the Wernerian system, for which Jackson and many of his associates at that

[1] Verneuil, Ed. de: Sur l'importance de la limite qui sépare le calcaire montagne des formations qui lui sont inférieures. Soc. géol. France, Bull., 1840, vol. 2, pp. 166–179.

[2] Am. Jour. Sci., vol. 40, 1840, pp. 182, 183.

time strenuously fought, has been entirely superseded. Attempts to fetter the progress of science by holding on to established systems are always to be avoided, and those who have the interests of true science at heart should jealously watch against the prejudices which tempt them to cling to those things which have been, merely because they have been.

In 1840 Conrad published a paper "On the Silurian system, with a table of strata and characteristic fossils."[1] This paper appears to be in its essential features the same as the table published in the fifth annual report of the State of New York in the following year. He had studied the Silurian system of Murchison and found spread over the greater part of New York, Ohio, Indiana, Kentucky, and Tennessee, and terminating on the south in the mountains or hill regions of north Alabama, rocks which represented the Silurian system. He reported in the vicinity of Florence and Tuscumbia, Alabama, the "Oriskany sandstone." At Blossburg, Pennsylvania, the "Old Red sandstone" was recognized by the presence of *Holoptychius*. On the western slopes of the Appalachian he found the Carboniferous system well developed, with the Mountain limestone rare and generally in thin deposits. The "New Red sandstone" was recognized in very limited areas. No traces of the "Oolitic," the "Lias," or "Wealden" were recognized. The "Cretaceous" was widely distributed and the "Tertiary formation" was reported as occurring on the sea border.

In New York State the "Llandeilo flags" were recognized and the "Caradoc sandstone" was regarded as the equivalent of the "Trenton limestone." The "Wenlock shale" was recognized in the "Rochester shale" and the "Calciferous slate" of Eaton. The "Wenlock limestone" was identified in the "Helderberg limestones," six of them. The "Ludlow rocks" were not defined in this paper. A table is given[2] showing the characteristic fossils of each of the formations and their English equivalents as represented in Murchison's Silurian system. This paper is particularly interesting as the first exhaustive attempt to correlate the formations of America with those of Murchison's Silurian system by means of their fossils alone. Previous attempts had been made by him to correlate the New York rocks with the English rocks in general.[3]

In a notice, by O. P. Hubbard, of the third annual report on the Geological Survey of New York,[4] a few remarks are made which show the confusion which existed at this time regarding the classification of the New York rocks. He shows that there was considerable difference of opinion as to the position of the rocks in central and western New York. "They have been alternately described as Transition and Secondary." "The Saliferous group" is counted as above the coal series,

[1] Am. Jour. Sci., vol. 38, pp. 86–93.
[2] Ibid., pp. 89, 90.
[3] See New York annual reports.
[4] Am. Jour. Sci., vol. 39, pp. 95–108.

and this with the "sandstone of Rochester" is regarded as New Red sandstone. The rocks of the fourth district are considered as belonging to the "Old Red sandstone and the Carboniferous group," and to lie "above the Silurian system of Mr. Murchison," a conclusion based in part upon the organic remains.

This confusion was doubtless due to the fact that the Wernerian method, which, somewhat modified, was seen in the earlier works of Eaton, was inconsistent with the new method which was being elaborated by the New York State geologists. Those who thought in terms of the first considered the new method revolutionary.

Prof. Eaton's systematic work heretofore followed the English treatise on geology by Bakewell. In an article which appeared in 1840[1] he quotes an outline of the system of Brongniart, proposed in 1829, which he states the author still maintained in 1840. As Eaton used this system and attempted to defend its application to American rocks, it may be worth while to record Brongniart's system of classification:

1. Primitive class (Agalysient, overthrowing or breaking up by internal forces).
2. Transition class (Hemilysient, half breaking up by internal forces).
3. Lower Secondary class (Abyssient, deepest abyss of the ocean).
4. Upper Secondary class (Pelagient, the ocean).
5. Tertiary class (Thalassient, the sea).
6. Diluvial class (Clysmient, the deluge).
7. Alluvial class (washed).

It will be seen from the terms used that Brongniart considered the rocks to be formed in the Primitive class by the overthrowing or breaking up processes due to internal forces; the Transition class, half to this operation; the Lower Secondary class, to the sedimentation of the deep abyss of the ocean; the Upper Secondary, to the ordinary deposition of the ocean; the Tertiary, to the shallow seas or modern seas; the Diluvial, to floods or deluges on the land; and the seventh, Alluvial, to the washing of rivers and streams.

The general theory of this interpretation of the strata was proposed earlier by Lehmann, and is associated with the general notion that the earth was formed from water solution—first, by a chemical crystallization and deposition, and later by sedimentation from the ocean, at first higher up in the hills, and, as the water evaporated, lower down in the valleys. This general theory pervades various systems of the early part of the century, and may be regarded as the fundamental theory of Werner, determining his method of classification and of correlation.

In the present article, Eaton attempted to point out the limits between the various divisions of Brongniart in our own strata. He recognized the well known Stockbridge marble of Massachusetts as the upper stratum of the Primitive class. Second, he regarded the "Cor-

[1] Amos Eaton: References to North American localities to be applied in illustration of the equivalency of geological deposits on the eastern and western sides of the Atlantic. Am. Jour. Sci., vol. 39, p. 149.

niferous limerock" as the uppermost Transition rock. This he identified further as equivalent to "some part or most of the Grauwacke group of De la Bêche, the Grauwacke limestones of some English writers, the Grauwacke slate of Bakewell, and perhaps the Carboniferous rock of Conybeare, and, surely, the Upper Transition (one of the Psammite) rocks of Brongniart."[1]

The limit between the Secondary and Tertiary, Eaton recognized along the south shore of Raritan Bay, in New Jersey. He says. "Uppermost of the Secondary deposits is the Cretaceous formation most perfectly characterized, but it contains no white chalk; the last of the Tertiary is the plastic clay.[2]

There is nothing particular valuable in this article, or new, even at that time, but the particular importance of quoting it is to show how the Wernerians were beginning to recognize the absolute importance of fossils in determining the relations of deposits.

In 1841 A. Clapp[3] correlated the "limestone of the Falls of the Ohio" with the Wenlock of Murchison; it is the "Cliff limestone" of Locke. The "limestone and marls of Madison and Hanover, Indiana" are correlated with the Wenlock; the "Middle and Lower Blue limestone and marls" of Cincinnati are correlated with the Caradoc; the "black bituminous shale" at the foot of the Falls is considered as equivalent to the Marcellus shale of New York; the "Oolitic" and the "Pentremite limestone" of Troost and Owen, of Kentucky, Indiana, and Illinois are identified as Carboniferous limestone. The author considered the "limestone of the Falls of the Ohio" in its upper portion to be identical with the Ludlow and Wenlock, the lower and middle portion as equivalent to the Niagara limestone and Gypseous shales of New York, and he further correlated the "Cliff limestone" of Locke with the whole of the rocks represented in New York by Niagara limestone, Gypseous shale, Water-lime, and Onondaga limestones. This constitutes the total rock deposit between the "Blue limestone and marls of Cincinnati" and the "Black shale" (Marcellus), and is the western continuation, as he says, of the Middle Silurian of Conrad. The 8 feet of fetid subcrystalline limestone immediately underlying the Black shale the author identified with the New York Water lime, and the "Black shale" above it he regards as not equivalent to the Ludlowville shale, as was asserted by Prof. Hall, but as lower and the true equivalent of the Marcellus shale.

In 1841 (which was the second year of the association), Edward Hitchcock delivered the "First anniversary address before the Association of American Geologists in Philadelphia."[4] A few points are interesting in this historical sketch, as signifying the progress which geology had made in America up to this time.

[1] Am. Jour. Sci., vol. 39, p. 153. It is now (1890) called the Corniferous limestone.

[2] This limit is apparently the line between the Green sand and the Raritan clays.

[3] Geological Equivalents of the vicinity of New Albany, Indiana, as compared with those described in the Silurian system of Murchison; Proc. Phil. Acad. of Sci., vol. 1 1841, pp. 18, 19, 177, 178.

[4] See Am. Jour. Sci., vol. 41, pp. 237-275.

The Association[2] was formed the year before at the call of the gentlemen of the New York Survey, who "issued a circular inviting those engaged in similar surveys in other States" to a meeting in Philadelphia. We learn from Hitchcock's address that the first attempt to classify American geology was made by William MacClure in 1807, who, in the field work preparatory to this, crossed the Alleghany Mountains in fifty places. In 1810, Dr. Bruce had started the Mineralogical Journal; in 1816, Dr. Cleveland's Treatise on Mineralogy and Geology was published; in 1818, Silliman's Journal was begun; in 1818, also, an American Geological Society was founded at New Haven, with William MacClure as its first president. In 1832 the Pennsylvania Geological Society was started.

In addition to this general activity in the early part of the century, from the year 1824, when the first State survey was begun by Prof. Olmstead in North Carolina, up to the date of this address (1841), State surveys had been started and more or less publication had been accomplished in the way of reports or accounts of the surveys made in twenty-one States and Territories. The men engaged in these State surveys were as follows:

North Carolina, Olmsted; South Carolina, Vanuxem; Massashusetts, Hitchcock; Tennessee, Troost; Maryland, Ducatel; New Jersey, H. D. Rogers; New York, Vanuxem, Mather, Emmons, James Hall, Conrad, and Beck; Virginia, W. B. Rogers; Maine, Rhode Island, and New Hampshire, Jackson; Connecticut, Percival and Shepard; Pennsylvania, H. D. Rogers; Ohio, Mather, Hildreth, Locke, Briggs, and Foster; Delaware, Booth; Michigan, Houghton; Indiana, D. D. Owen; Kentucky, Mather (only a reconnaissance); Georgia, Cotting (no report had been published up to 1841); Arkansas, etc., Featherstonhaugh; Iowa, D. D. Owen and Locke.

Besides these, a reconnaissance had been made by Nicollet west of the Mississippi, and in 1824 Eaton's Erie Canal Survey had been made, and private surveys had been made by Taylor, Johnson, Silliman, and Shepard in coal and mineral regions in Pennsylvania, Virginia, and Missouri.

Hitchcock made slight reference to the actual state of progress in the matter of correlation and classification of the geological terranes; this can be better learned from the study of the New York reports, for the Paleozoic at least, and the other reports, which it is not necessary here to discuss.

The last annual report of the New York State Survey was published in 1841; sufficient to say here that the Archean was fairly well recognized along the eastern border of the continent, and its general extent

[1]The Association of American Geologists held its first meeting in Philadelphia on the 2d of April, 1840. The following were the original founders present at this meeting: E. Hitchcock, L. C. Beck, H. D. Rogers, L. Vanuxem, William W. Mather, W. R. Johnson, T. A. Conrad, E. Emmons, J. Hall, C. B. Trego, J. C. Booth, M. H. Boyi, R. E. Rogers, A. McKinley, C. B. Hayden, R. C. Taylor, D. Houghton, B. Hubbard.

E. Hitchcock was elected chairman and L. C. Beck secretary. See Am. Jour. Sci., vol. 39, p. 189.

from Canada to the sources of the Mississippi. The Paleozoic was recognized in its distribution throughout the eastern part of the United States. The Coal Measures were recognized in Pennsylvania, Ohio, Indiana, Illinois, Michigan, and Missouri. The Devonian was recognized by some of its fossils in New York State, but its limitation was not determined precisely as at present. The Silurian had been recognized in at least the Caradoc sandstone, the Wenlock shale and limestone, and the Ludlow rocks, but it was not until the final reports were published (two or three years later) that a full classification of the Paleozoic series was accessible to American geologists.

The Rogers brothers used fossils to determine the age of the Maitland limestone, and concluded that "though they indicate relation to Onondaga, Seneca, and Marcellus strata, the exact age is not proven." In other respects these authors adopted the New York classification as a standard for comparisons.

The "Address before the Association of American Geologists and Naturalists for the year 1842" was given by B. Silliman.[1]

In it we have a few indications of the state of the science at that time. Silliman had the advantage of being in England in 1805, when the discussions of the rival schools, the Neptunists and the Vulcanists, the Wernerians and the Huttonians, were at their height; Prof. Jameson and Dr. John Murray defending the Wernerian views, and Sir James Hall, Prof. Playfair, and Prof. Thomas Hope defending the views of Hutton. Silliman appears to have taken a neutral position in regard to these schools, recognizing the good points of each. We find a statement made in the course of his description of his part in the progress of science that Dr. Dana read the title of what was probably the first geological report made on American geology, at the meeting of the Association in Boston, viz: "Beyträge zur mineralogischen Kentniss des östlichen Theils von Nordamerika und seiner Gebirge, von D. Johann David Schöpf."

Of William Maclure he said:

> He was the William Smith of this country, and not only did he add to the foreign collections of this country in mineralogy and geology, but he did great service in the direction of personal field-work and interpretation of our geology, and also in publishing his Geology of the United States with the first general map of the geology of the eastern part of the continent.

Mineralogy was studied prior to the cultivation of geology in America as well as in Great Britain. The earlier geologists were mineral geologists, and the collections of minerals constituted the principal cabinets of that time. Prof. Cleaveland, of Bowdoin, Maine, Dr. Seybert, in Philadelphia, Colonel Gibbs, at Yale College, the Messrs. Dana, in Boston, had each accumulated more or less valuable mineral cabinets, and a Journal of Mineralogy and Geology was started in New

[1] Am. Jour. Sci., vol. 43, pp. 217–250.

York by Dr. A. Bruce, in 1809, which lasted a year, and in 1818 the American Journal of Science and Arts was established in New Haven.

Silliman did not rehearse any detailed account of the state of the science at the time, but gave general statements referring to the past, with comparisons of the general results effected by the American geologists with what had been done by the English and European geologists.

In 1842 T. A. Conrad published an important paper in the Journal of the Philadelphia Academy of Science, entitled "Observations on the Silurian and Devonian Systems of the United States, with descriptions of new organic remains." A number of fossils were identified, and several points of interest are noted in this paper, indicating the limitation of the groups as they were then recognized. The "older Paleozoic rocks" were the equivalent of the Transition of the older nomenclature. The author notes the perfection of the series of rocks in New York State, and "the great convenience they afford for study, in that they lie nearly horizontal."[1]

In this paper the "Cambrian rocks" are included in the Silurian, and the Silurian thus includes all the rocks from the Archean upward to the Tully limestone inclusive. Thus it will be seen that the fossils described previous to 1842 as Silurian fossils may have been Silurian or Devonian to the base of the upper Devonian.

A list of supposed equivalents is given,[2] in which we find the Lower Silurian strata are: "(10) Clinton group, (9) Niagara sandstone, (8) Shales of Salmon River,[3] (7) Blue shale, (5) Trenton limestone, (4) Mohawk limestone, (3) Birdseye limestone, (2) Calciferous limestone, (1) Potsdam limestone."[4]

The "Trenton limestone" is reported as "forming the bed of the Ohio River from Cincinnati to Louisville."

The Middle Silurian strata are the "Niagara shale, which equals the Wenlock shale, and upward to Oriskany sandstone.

The Upper Silurian rocks included the lower Ludlow and succeeding rocks upward to the Tully limestone inclusive.

In the Devonian system, Conrad placed as Lower Devonian the Ithaca group; as Middle Devonian, the Chemung group; as Upper Devonian, the Old Red sandstone.

The subdivision into Lower, Middle, and Upper Silurian appears to have been original with Conrad, and he proposed the names "Mohawk system" for the Lower, "Helderberg system" for the Middle, and "Onondaga system" for the Upper Silurian groups, respectively, and stated that the systems are based upon the "distinctness of the fossil contents."

The year 1843 marks one of the most important periods in the history

[1] Jour. Phil. Acad. Sci., 1842, pp. 228–235.

[2] Ibid, p. 230.

[3] These three are regarded as the equivalents of the Caradoc.

[4] In his list there is no No. 6, and Conrad states that 7, 5, 4, 3, 2, and 1 are wanting in Europe.

of American geology. The final reports of the State of New York were published in the years 1842–'43.[1]

The classification which appears in the several final reports was already outlined by Conrad in 1841, and, in fact, the general order of strata was given in his report for 1839. The development of the classification of the rocks for New York State will bear minute study, and will yield valuable suggestions to students of systematic geology. The rocks with which the New York geologists were concerned were mainly confined to the series from the Archean or Primary rocks through the Paleozoic as far as to the base of the Carboniferous. The geologists, although working together, had the State separated into four divisions and developed the stratigraphical geology of each district independently, observing the character of the individual rock formations, their order, and the fossils contained in each. Conrad was the paleontologist during the field operations, and his contribution to the work was the identification of the fossils sufficiently well to make recognizable the relationship between the fossils of the New York rocks and the formations of England which had been studied so carefully and were so elaborately defined by Murchison and Sedgwick.

The fossils of the British sections had been described by John Phillips, J. De C. Sowerby, and Lonsdale, and their descriptions were accessible to the American geologists as early as 1839. Conrad had used this Silurian system with its fossils as a basis for the classification and correlation of the rocks of New York State. The attempt was made in 1839 to divide the New York rocks in accordance with Murchison and Sedgwick's classifications, and the fossils found in them, corresponding with those of the British rocks, were enumerated. Thus, in the third annual report, Conrad gave a "table of formations," showing the order of superposition and some characteristic fossils of the Transition strata. The Carboniferous strata (No. 10) were mentioned (but are in Pennsylvania), then the rocks of New York[2] were distributed as follows:

Under the "Old Red sandstone group (Murchison)" he placed:

"9. Old Red sandstone (?) and Olive sandstone," which, we find from study of the reports, includes the Chemung and Catskill groups.

"8. Dark-colored shales and black slate," which appears to be the Hamilton and Marcellus.

Under "Medial Silurian system," are found "(7) Gray Brachiopodus sandstone, Helderberg sandstones, Helderberg limestones, second Pentamerus limestones; (6) Gypseous shales, Rochester shales, and Pentamerus limestones, (5) Green slate, Lenticular iron, etc., and (4) Niagara sandstone (red)."

[1] The editors of these final reports were William W. Mather, report of the first district, published 1843; Ebenezer Emmons, report of the second district, 1842; Lardner Vanuxem, report of the third district, 1842, James Hall, report of the fourth district, 1843. It is important also to remember that T. A. Conrad published his final report on the paleontology of the survey in the year 1841, in the fifth annual report.

[2] N. Y. Geol. Survey, 3d Ann. Rep., pp. 62–63.

Under "Lower Silurian system" he placed "(3) Salmon River sandstone (olive) and green slate, (2) gray Crinoidal limestone, Trenton limestone and slate, Mohawk limestone, gray limestone with sparry veins, gray Calcareous sandstone."

Under the term "Cambrian system (Sedgwick)" he placed "(1) olive sandstone and slate, and varigated sandstone (Potsdam sandstone of Emmons)," and below all these the "Primary."

In the next report[1] James Hall gave a somewhat more elaborate list of formations, but distributed them substantially as was done by Conrad. As this classification was only temporary, I will not stop to enumerate it in detail, the final results published in the final reports will be given in the proper place.

But in the fifth annual Report, Conrad produced a more finished classification, and with slight modifications the order of sequence of deposits and the general relations of the groups to each other are those which appeared in the several final reports; but we do not find the classification into the "divisions of the New York system" in Conrad's reports.

We may mention a few points in regard to Conrad's classification of 1841[1]. The following names were used: "Tertiary," "Cretaceous System," "Oolitic system," "New Red sandstone or Saliferous system," "Carboniferous system," "Old Red sandstone or Devonian system," including the Chemung and Catskill rocks. Then the "Upper Silurian series" included the rocks from the "Oneonta group, No. 26," to the "Black slate, No. 21." The "Middle Silurian series" included from the "Onondaga limestone, No. 20," down to the "Rochester shale, No. 10;" the "Lower Silurian series" included from "Pentamerus oblongus limestone, No. 9," to the "Potsdam sandstone, No. 1," inclusive.

Thus we see, that to the end of his work in connection with the survey Conrad's influence was directed toward the correlation of the American classification with that already in use in Great Britain.

After the annual reports were finished, the several geologists prepared their final reports. We find no evidence that Conrad assisted in their preparation, and in these reports, from the first one published to the last, there is a general symmetry in the classifications, but a neglect of any formal recognition of the classifications already adopted in Murchison's Silurian system, although the authors refer to the correlation of some of the New York deposits with recognized horizons in Murchison's Silurian system. A most important feature of the completed reports is the introduction of the "New York system" into geological nomenclature. The New York system was constituted to include the geological deposits from the earliest fossiliferous rocks to the base of the Carboniferous, and we find the four authors disagreeing in their interpretation of what this system included, and as to the groups into which it was subdivided.

[1] Fourth annual report, 1840. [2] See Fifth Annual Report, pp. 31–46.

Vanuxem and Mather adopted the following plan: They had a "Primary system," including the Archean as we consider it to-day; second, the "Taconic system," including a conglomeration of strata, all supposed by Emmons to lie below the Potsdam sandstone; third, the "New York system," which included the Champlain division, the Ontario division, the Helderberg division, the Erie division, and the Catskill division or group. Above this, according to Mather, followed the "Coal system," the "Red Sandstone system," the "Trappean system," the "Tertiary system," and the "Quaternary system," but Vanuxem enumerates only the last, the "Quaternary system," the others being wanting in New York State.

On the other hand, Emmons and Hall recognized the New York system as including the Champlain Ontario, Helderberg, and Erie divisions, but placed the rocks of the Catskill Mountains in a separate system, calling it the "Old Red system." The division line in their scheme between the New York system and the Old Red was at the top of the Chemung group.

When we inspect the local distribution of the several formations in the "divisions" of the New York system we find like differences of usage on the part of the several geologists. For instance, the Champlain group of Emmons and Hall terminates above in the Oneida Conglomerate, whereas in the reports of Vanuxem and Mather it terminates with the Hudson River group. In the Ontario group Mather includes only the Oneida Conglomerate; Emmons includes the strata from the Medina to the waterlime; Vanuxem, those from the Oneida to the Niagara; and Hall, those from the Medina to the Niagara, inclusive. The Helderberg division was regarded by Mather, Vanuxem, and Hall as extending from the Onondaga salt group through the Corniferous limestone, while Emmons made it begin with the Pentamerus limestone and carried it to the top of the Helderberg limestone. All four of the geologists in their final reports agree in the limitation of the Erie division, including the rocks from the Marcellus shales through the Chemung group.

Another point may be mentioned: While individual formations are substantially alike as named by the several reporters, there are frequent differences in usage, as in the use of "Loraine shales" by Emmons for the Hudson River group of the other reports, and of "Corniferous limestone" by all the authors but Emmons, who uses "Helderberg limestone." Besides these differences we notice that deposits are mentioned in some of the reports which are left out in others, and in some reports the name of the rock is given, while in others the word "group" is attached to a geographical name, as "Niagara limestone" and "Niagara group."

These differences which appeared in the final reports accentuate the difficulties which the geologists met with in attempting to classify the rock formations according to the methods then in use. The old sys-

tem of correlation by means of the petrographic characters of the deposits was used in part by these geologists and formed the original basis of the classification. In the field work the formations were distinguished by their petrographic features and were so defined. In most cases local names were applied to them; the geographic designation of the place where the particular formation was discovered, or was found to be exposed in a good condition, was applied to the rock, and as the surveys went on the name as applied was extended to the other outcrops of what appeared to be the same stratum or series of strata. This was all very well so long as no correlation was attempted, but as soon as correlation of the several formations with those of other regions was attempted the necessity of some other means of identification was apparent. This means was recognized in the fossil contents, but in the field the fossils were not studied, and could not be studied by the field geologists. It was necessary to take them home and compare them with other fossils from other parts of the country and world, and to describe them, and ascertain their range and distribution. All this required time and learning, which could not be attained at once by any one of the geologists. This learning was the special province of the paleontologist, and the wide knowledge requisite to correlate the various strata of the New York system accurately with those of Great Britain was, we may imagine, clearly recognized by Conrad before he left the survey; but, as we have learned since, many years of study have not enabled geologists to establish with certainty the correlation between the several faunas of the formations in New York and those abroad.

The great desideratum at that time, and for geologists at the present time, is such a system of nomenclature and classification as shall enable the field geologist at once to record his observations correctly and systematically, and to preserve the records of fossil contents which he discovers for the careful detailed study of the paleontologist. The nomenclature adopted in many cases by the New York geologists, which has satisfied the demands of the progress of science, at least up to the present time, is that which is based upon the simple practice of giving a geographic name to a rock terrane, connecting it with the name of the particular rock which is exhibited at the locality in which it outcrops; for example, "Trenton limestone," "Oriskany sandstone," "Schoharie grit," "Genesee slate," although in the latter case slate is not appropriate, because it is a false name, shale being the right name. These several terms applied to definite rock masses located in particular regions in New York State, having their typical outcrops designated by their names, can be applied with exactness at all times, and suggest the progress of the science. Whenever wrongly applied to deposits outside the original region where discovered, new names can be easily substituted.

The groupings of these separate formations, made without regard to

the fossils characterizing them, were purely arbitrary, and were ultimately discarded. We have already entirely ignored the "New York system," the "Champlain," "Ontario," etc., "divisions," and the only part of the New York classification which is retained, is the nomenclature of the individual formations in their stratigraphic sequence. It is evident, therefore, considering how important the work of this New York survey has been for all American geology, that the most important part of the work of the geologist is that of carefully observing the characters of the individual formation, describing its petrographic, stratigraphic, and geologic relations, preserving the fossils accumulated, and describing his observations so that distinct association will be found in the name applied to each formation with the observations actually made in the field. The reference of each particular formation to a place in some standard scale should not be made without careful study. This careful study can not be made independently of the fossils, for fossiliferous rocks, and in order that the paleontologist may make his studies without prejudice, the names of the formations, their localities, and their petrographic characters should be described and recorded, quite independently of the fossils which they contain.

The following tables will exhibit the final results of the four State geologists in their attempts to classify the geological formations of the State of New York.

They are taken from the final reports of the "Geology of New York," and are arranged in the order given them by the authors.

CLASSIFICATION BY MATHER. 1843.

[Final Report, First District, p. 2.]

1. Quaternary system. { Alluvial division. / Quaternary division. / Drift division.
2. Tertiary system.
3. Trappean system.
4. Red Sandstone system.
5. Coal system.
6. New York system .. { Catskill division. / Erie division. / Helderberg division .. { Corniferous limestone, Onondaga limestone, Scoharie grit, Cauda-Galli grit, Oriskany sandstone, Catskill shaly limestone, Pentamerus limestone, Water lime group, Onondaga salt group. / Ontario division.....Oneida or Shawangunk Conglomerate. / Champlain division... { Hudson River group, Utica slate, Trenton limestone, Calciferous group, Potsdam sandstone.
7. Taconic system.
8. Primary system... { Metamorphic rocks. / Primary rocks.

CLASSIFICATION BY EMMONS. 1842.

[Final Report, Second District, p. 429.]

Tabular view of the sedimentary rocks of New York.

Taconic system		Taconic slate, Magnesian slate, Stockbridge limestone, Granular quartz.
New York system.	Champlain group	Potsdam sandstone, Calciferous sandrock, Chazy and Birdseye limestone, marble of Isle La Motte, Trenton limestone, Utica slate, Lorraine shales, Gray sandstone, Conglomerate.
	Ontario group	Medina sandstone, Green shales and Oolitic iron ore, Niagara limestone, Red shale, Onondaga salt and plaster rocks, Manlius water-lime.
	Helderberg series	Pentamerus limestone, Delthyris shaly limestone, Oriskany sandstone, Encrinal limestone, Cauda-Galli grit, Schoharie grit, Helderberg limestone.
	Erie group	Marcellus and Hamilton shales, Tully limestone, Genesee slate, Ithaca and Chemung shales and grits.
Old Red system		Old Red sandstone, with its beds of Conglomerate and its greenish shales of the Catskill Mountains.
New Red system		New Red sandstone associated with volcanic rocks and greenstone trap of the Palisades.
Tertiary		Blue and yellowish clays of Champlain and white and yellowish sand.

CLASSIFICATION BY VANUXEM. 1842.

[Final Report on the Third District, p. 13.]

Classification of rocks of New York State.

1. Primary system.
2. Taconic system.

3. New York system	Champlain division	Potsdam sandstone, Calciferous group, Black River limestone, Trenton limestone, Utica slate, Hudson River group.
	Ontario division	Gray sandstone, Medina sandstone, Oneida Conglomerate, Clinton group, Niagara group.
	Helderberg division	Onondaga salt group, Waterlime group, Pentamerus limestone, Catskill shaly limestone, Oriskany sandstone, Cauda-Galli grit, Schoharie grit, Onondaga limestone, Corniferous limestone.
	Erie division	Marcellus shale, Hamilton group, Tully limestone, Genesee slate, Portage group, Ithaca group, Chemung group.
	Catskill group.	

4. Quaternary system.

CLASSIFICATION BY JAMES HALL.[1] 1843.

[Final Report, Fourth District, pp. 18, 19.]

Tabular view of rocks and groups of New York.

I. Primary or Hypogene system.

II. Taconic system.

III. New York system ....

- Champlain division..
  1. Potsdam sandstone.
  2. Calciferous sandrock.
  3. Black River limestone group, embracing the Chazy and Birdseye.
  4. Trenton limestone.
  5. Utica slate.
  6. Hudson River group.
  7. Gray sandstone.
  8. Oneida or Shawangunk Conglomerate.
- Ontario division.....
  9. Medina sandstone.
  10. Clinton group.
  11. Niagara group, including shale and limestone.
- Helderberg series....
  12. Onondaga salt group.
  13. Water-lime group.
  14. Pentamerus limestone.
  15. Delthyris shaly limestone.
  16. Encrinal limestone.
  17. Upper Pentamerus limestone.
  18. Oriskany sandstone.
  19. Cauda-Galli grit.
  20. Schoharie grit.
  21. Onondaga limestone.
  22. Corniferous limestone.
- Erie division .....
  23. Marcellus shale.
  24. Hamilton group. (Moscow shales, Encrinal limestone, Ludlowville shales.)
  25. Tully limestone.
  26. Genesee slate.
  27. Portage or Nunda group. (Portage sandstone, Gardeau flagstone, Cashaqua slate.)
  28. Chemung group.

IV. Old Red system, or Old Red sandstone.

V. Carboniferous system.

VI. New Red sandstone.

VII. Tertiary.

VIII. Quaternary system.

RÉSUMÉ OF CLASSIFICATIONS.

Champlain group ...Emmons and Hall agree in terminating it with the Oneida Conglomerate.
Vanuxem and Mather terminate it with the Hudson River group.

Ontario group .....Emmons, Medina to Water-lime, inclusive.
Hall, Medina to Niagara, inclusive.
Mather, Oneida Conglomerate alone.
Vanuxem, Oneida to Niagara (but order wrong).

Helderberg series....Emmons, Pentamerus limestone to Helderberg limestone.
Hall, Onondaga salt group through Corniferous limestone.
Vanuxem, Onondaga to Corniferous.
Mather, Onondaga to Corniferous.

Erie division.....Marcellus to Chemung, inclusive, by all.

[1] According to this author the formations 1, 2, 3, 4 were correlated with the "Cambrian system" of Sedgwick, the Potsdam (1) doubtfully included. "Silurian system" Murchison=Utica slate (5) to Hamilton (24). "Devonian System" of Phillips=Chemung and Portage and part of the Hamilton (24 to 28). (See p. 20.)

CHAPTER II.

THE GENERAL APPLICATION OF THE NOMENCLATURE OF THE NEW YORK SYSTEM AS A STANDARD OF CORRELATION IN OTHER PARTS OF THE UNITED STATES. 1840 TO 1851.

The termination of the New York State Survey and the publication of the final reports practically established the new ideals for the classification of the Paleozoic rocks of North America.

The Final Report on the Geology of the Fourth District (the western quarter of the State) by James Hall was published in 1843. This may be regarded as expressing the more perfected views in regard to classification and nomenclature.

The New York system was the comprehensive term applied to the series of rocks beginning with the Potsdam sandstone and terminating in the "Chemung group." The rocks of the Catskill Stage were called the Old Red system or Old Red sandstone. The New York system was made up of twenty-nine "systematic subdivisions," "founded upon the fossil and lithological characters."[1]

These were grouped into four "geographical subdivisions." The lowest, from the Potsdam to the Oneida Conglomerate, inclusive, was named the "Champlain Division;" the second, including the Medina, the Clinton, and the Niagara, was called the "Ontario Division." From the Onondaga Salt group to the Corniferous limestone, inclusive, was the "Helderberg series." From the Marcellus to the Chemung, inclusive, was the "Erie Division."

Comparisons had been made with the Silurian system of Murchison and the Devonian of Murchison and Phillips, and a general correlation recognized, but the equivalencies were not minutely accordant.

In respect of the part of the scale with which this essay is concerned, the author wrote, "If the Devonian is to be regarded as a distinct system, we shall find its repesentatives in the Chemung and Portage groups, with perhaps a part of the Hamilton group. In New York, however, as already stated, no subdivisions can be made which are entitled to the name of systems."[2]

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[1] (No. 3 of p. 18 was expanded into two sub divisions on p. 517 (i. e., Nos. 27, 26) by the recognition of the Chazy limestone as distinct from the Black River limestone.)

[2] Geology of New York, part IV. comprising the survey of the fourth geological district, by James Hall, 1843, p. 516,

In the table the following equivalencies are given:[1]

Rocks of the New York system.	Subdivisions in Great Britain.
Old Red sandstone	Old Red sandstone.
1. Chemung group	Upper and Lower Ludlow rocks including the Devonian system of Phillips.
2. Portage group	
3. Genesee slate	
4. Tully limestone	
5. Hamilton group	
6. Marcellus shale	
7. Corniferous limestone	Wenlock rocks.
8. Onondaga limestone	
9. Schoharie grit	
10. Cauda-galli grit	
11. Oriskany sandstone	
12. Upper Pentamerus limestone	
13. Encrinal limestone	
14. Delthyris shaly limestone	
15. Pentamerus limestone	
16. Water-lime group	
17. Onondaga salt group	
18. Niagara group	

Correlations with the Pennsylvania and Virginia rocks and those of Ohio and Michigan are expressed as follows:

Pennsylvania and Virginia Survey.	Ohio Survey.	Michigan Survey.
28. Chemung group	No. 9	Waverly sandstone series.	Soft light-colored sandstones, argillaceous slates and flagstones of Lake Huron, sandstones of Point aux Barques.
27. Portage group		
26. Genesee slate	No. 8	Wanting(?)	
25. Tully limestone		Wanting	
4. Hamilton group	No. 8	Wanting, or but partially developed.	Shales, black aluminous shales.
23. Marcellus shale	No. 8	Black slate.	
22. Corniferous limestone		Upper part of Cliff limestone.	Corniferous limestone.
21. Onondaga limestone			
20. Schoharie grit			
19. Cauda-galli grit	No. 7		Several limestones represent this and lower beds.
18. Oriskany sandstone	No. 7		

Some of the results thus far attained were permanently satisfactory; others have already been modified, and there are still others which await correction.

The classification of the rocks of the New York system into "systematic subdivisions, founded upon the fossil and lithological characters," and the application to them of geographical names suggested by the locality where the typical sections occur have stood the test of common use for 50 years. The classification is based upon observed facts, and the nomenclature is expressive of actual facts with no mixture of theory.

The groupings of these stages into "geographical subdivisions" is faulty, in that it expresses only accidental relations, and produces purely artificial groups. There are no geological reasons for drawing

[1] Geology of New York, part iv, comprising the survey of the fourth geological district, by James Hall, 1843, p. 517.

[2] Ibid., p. 619.

the lines between the "Champlain" and "Ontario," or the "Ontario" and "Helderberg divisions," and this part of the classification has accordingly fallen out of use, because useless.

Like objection exists to the term "New York system." While the base is well marked, the rocks of Pennsylvania, to the top of the Coal-Measures, should be added to them to complete the system. Adding the Carboniferous system, as expressed in Pennsylvania, Ohio, and Virginia, a natural group of the first order is produced which nearly corresponds to what we call the Paleozoic era. Were we to adopt for this grand terrane the name *Appalachian group*, we should have a properly constituted name for an actual, existing geologic group, free from theory, and its use would probably assist in the progress of science.

This classification of the New York State survey is further defective in the retention from the old nomenclature of such definitive terms as Corniferous, Encrinal, Water-lime, etc. Intrinsically they are not distinctive of any particular stage and therefore do not fulfill the true purpose of names for the stages.

A similar objection holds in the case of such names as Cauda-galli grit, Pentamerus limestone, and similar terms. Although the fossils indicated may characterize the formations so named in their typical outcrops, the fossils may fail in the geographic extension of the formation, or further study may show that the fossils are not confined stratigraphically to the zone represented by the particular formation in question.

The only kind of name which can be applied without objection to the ultimate subdivisions of the terranes, is a binomial term composed of the lithologic name of the rock and the geographic name indicating its typical exposure.

The use or the name "Old Red sandstone system" has been discarded, and its use in 1843 indicated that the name *system* gave such dignity to a terrane that it was supposed necessary to find it in every complete section of rocks. It was later that geologists agreed that the Old Red sandstone represents the Devonian system, but represents it in a different type of deposits.

The imperfection in the nomenclature, even at the present time, is seen in the fact that English geologists[1] still use the phrase "Devonian and Old Red sandstone" for the rocks between the Silurian and Carboniferous systems. This error and confusion comes from the difficulty in ridding ourselves of the old notion that the *age* of rocks may be indicated by their lithologic or stratigraphic characters. Age can be indicated only by something which persists through time; the lithologic characters of rocks indicate what they were made of and how; the stratigraphy indicates the order of sequence. The age of rocks can be indicated only by something which changes with the passage of time according to some definite law. The organisms represented by

[1] 1887. Geikie Text-Book: Woodward's Geology of England and Wales.

fossil remains alone meet these requirements. A continuous rock section furnishes us with the order of sequence of these changes, but a classification of the rocks based upon the age of the fossils must not be hampered by stratigraphic or lithologic limits. The time classification can be built up only gradually by wide study of the fossils, and the nomenclature of the formations must be applied, and applied with precision, before the time limitations can possibly be fixed with precision.

Besides these defects in the final results of the New York survey, there were two imperfections occasioned by lack of evidenc, and others due to false generalization. The Devonian system was scarcely more than recognized by its general fauna—the limits above and below were not determined. The upper limit excluded the Catskill formations which were subsequently placed in the system. An equivalency was supposed to exist in Ohio and Michigan between the Chemung and the rocks now called Waverly belonging in the Carboniferous system. The attempts to correlate with the English models resulted in fixing the limit between the Wenlock and lower Ludlow of Murchison between the Corniferous limestone and Marcellus shale of the New York system. The rocks above this limit were correlated with Murchison's Ludlow group and Phillips's Devonian system.

The imperfection of this work was mainly due to ignorance of the precise relations existing between the two faunas; and, secondly, to the fact that Phillips's fossils were mainly middle and upper Devonian forms, while the lower Devonian species and the lower Devonian type of deposits were not well understood by the New York geologists.

It was the comparative study of the fossils, and particularly a more careful discrimination of them and better appreciation of the range of the characters they exhibited, which finally cleared up these imperfections.

Having perfected a scheme of classification, the next step of progress was the correlation of the formations west of New York with the scheme. This was mainly accomplished during the decade from 1840 to 1850. The chief discussions of the subject were published between 1842 and 1851.

James Hall published an article in 1842[1] in which an attempt was made to correlate the rocks of the States of Ohio, Indiana, Illinois, part of Michigan, Kentucky, Missouri, Iowa, and Wisconsin, with the rocks of New York State. He classified the basins of the Coal Measures into four groups, as follows: first, that of Pennsylvania and eastern Ohio; a second extending over portions of Indiana, Illinois, Kentucky, and Tennessee; a third in Missouri, and a fourth in Michigan. He traced the underlying "conglomerate" from Pennsylvania to the Mississippi River. The "Old Red sandstone" was not recognized west of the Genesee River in Allegany County, New York; the Chemung formation, which, he remarked, "Lyell compares with the lower part of the

[1] Notes upon the Geology of the Western States, Am. Jour. Sci., vol. 42, p. 312.

Old Red in Forfarshire, etc., Scotland, in its gray, thin, laminated sandstones and green shales," Hall recognized in Ohio, at Cuyahoga Falls, Akron, etc. He also correlated the Portage and Gardeau with rocks at Cuyahoga Falls and Newburg in Ohio, but found them of diminished thickness. He said, "The Portage sandstone (known as Waverly sandstone)" is found in many places in Ohio. The thin-bedded limestones which he found often Oolitic in structure, and in some places becoming thick beds of limestone interstratified with sandstone, in Indiana, Illinois, and Kentucky, Hall found to contain fossils which were different from those of the limestones of New York, and he thought them to be identical with the Carboniferous limestone of Europe, recording one of the fossils, *Productus hemispherica*, which was a characteristic of that formation.[1] The conglomerates which occur above this he correlated with the Millstone grit of the British classification. This identification of the carboniferous rocks in the West, or in the Mississippi Valley Basin, was not new with Hall, but had been made several years before by D. D. Owen, as will be shown further on.

In 1842 Hall[2] read a paper before the Association of Geologists and Naturalists, which was published the following year with a plate explaining a section from Cleveland to the Mississippi River. In this plate the Waverly sandstone series of the Ohio report is called "Chemung and Portage groups." The term "Subcarboniferous rocks" is applied to "friable gray sandstone with intercalated beds of oolitic limestone" lying between the "Waverly series" and the "Carboniferous limestone." Where the latter outcrops in the Mississippi River Valley it is called the "Great Carboniferous limestone."

At Newburg "the Portage sandstone or upper part of the group is seen, and is there underlaid by the green shale. These are equivalent to the Waverly sandstone of the Ohio reports, as was afterward ascertained by visiting the quarries at Waverly. From Newburg we pass over the shales and sandstones of the Chemung group, till we arrive upon the Conglomerate, which is well developed at Stow and Cuyahoga Falls. This Conglomerate, which, so far as I could discover, is identical with the outlier of a similar mass in the southern part of New York, is the fundamental rock of the great coal formations."

The "black, bituminous shale underlies this Portage and Chemung on the road toward Columbus, and represents Hamilton and Marcellus, particularly the latter."[3]

In the vicinity of Louisville and New Albany, at the Falls of Ohio, the "black, bituminous limestone" he correlated with the Marcellus shale of New York above the "Corniferous limestone." This is followed by the "green shales and slaty sandstones of the Portage group

[1] Notes upon the Geology of the Western States, Am. Jour. Sci., vol. 42, p. 57.

[2] Hall, James: Notes explanatory of a section from Cleveland, Ohio, to the Mississippi River, in a southwest direction, with remarks upon the identity of the western formations with those of New York. Assoc. Am. Geol., Trans., 1843, pp. 474-531.

[3] Ibid., p. 272.

or Waverly sandstone series of Ohio."[1] Above this were seen "friable gray sandstones with intercalated beds of oolitic limestone."

"These rocks are marked in the section by the name '*Subcarboniferous*,' and although the fossils and the character of the intercalated beds of limestone indicate the commencement of the same era as the Carboniferous limestone, yet it requires that a limit should be fixed between what is to be strictly referred to Carboniferous and older deposits."[2]

In a foot-note the author referred to Dr. Owen's denomination of "the rocks here described as well as the succeeding limestone as Subcarboniferous," and remarks that he had not seen the report when his section was prepared.

D. D. Owen first applied the term *Subcarboniferous* to the limestones underlying the Coal Measures, having included with them the Silurian limestones, and to the whole series be applied the designation *Cliff limestone.* James Hall introduced the name *Subcarboniferous* to indicate rocks which he regarded as lying below the "Carboniferous limestone," the intercalated calcareous beds of which contained fossils like those of the Carboniferous era.[3]

The "Carboniferous limestone" of Hall's paper was not recognized east of New Albany, Indiana, where it is reported as resting upon the "Subcarboniferous rocks." From there it was traced westward, and along the Mississippi Valley in Illinois, Iowa, Missouri, and Tennessee.

The author held that upon going westward the character of the deposits changes, and the nature of the species changes with indications of difference in depth.

It will be seen that Hall's interpretation was based upon tracing the continuity of the strata. Though fossils were considered in a general way, the differences noted were regarded as due to changed conditions rather than to lapse of time. So that the more minute comparison of the fossils for a long time failed to convince geologists of the errors of correlation.

The misinterpretation of the relation of the Waverly formation of Ohio to the New York system was very difficult to correct, since the State geologist who best knew the New York system had claimed, as the result of personal examination, tracing the rocks step by step all the way from New York to the Mississippi Valley, that these rocks were identical. It was difficult to get people to believe in the testimony of fossils against such assertions.

In the year 1843 H. D. Rogers[4] expressed the opinion that the black bituminous shales which appear in the States west of Ohio, between the Silurian and the Carboniferous, represent the Marcellus shales of New York State, and in this opinion he differed with Hall, who re-

[1] Hall, James: Notes explanatory of a section from Cleveland, Ohio, to the Mississippi River, in a southward direction, with remarks upon the identity of the western formations with those of New York. Assoc. Am. Geol., Trans. 1843, p. 280.

[2] Ibid., p. 281.

[3] See Chapter VIII.

[4] Rogers, Henry D.: On Marcellus and Hamilton of the West; Am. Jour. Sci., vol. 45, 1843, pp. 161, 162.

garded them as representing both the Marcellus and the Hamilton, although not equivalent to either.[1]

In 1843[2] David Dale Owen commented "On the Geology of the Western States." In this paper a fine-grained sandstone and chert with iron ore was described from Tennessee, Kentucky, and Indiana, and examined on its outcrop near the Knobs. In its lower part this formation was correlated with the Devonian system of England and with the Chemung group of New York, and was described as resting on black bituminous shales and as equivalent to the Marcellus shales of New York.

The high appreciation of the results of the New York State survey is indicated by the frequent references which were made in the Journals to the reports.[3]

In D. D. Owen's review a tentative scheme of a chronologic table is given as follows:[4]

Protozoic rocks or New York system.

Transition series	1. Potsdam sandstone.
First or Lower Division	2. Calciferous sandrock.
	3. Black River limestone.
	4. Trenton limestone.
	5. Utica slate.
	6. Hudson River group.
Transition series	7. Oneida Conglomerate.
	8. Medina sandstone.
	9. Clinton group.
Second or Middle Division	10. Niagara sandstone.
	11. Onondaga Salt group.
	12. Water limestone.
	13. Pentamerus limestone and Catskill shaly limestone.
	14. Oriskany sandstone.
Transition series	15. Cauda-galli and Schoharie grit.
	16. Onondaga limestone.
	17. Corniferous limestone.
Third or upper division	18. Marcellus shale.
	19. Hamilton group.
	20. Genesee slate.
	21. Portage group.
Transition series	22. Chemung group.

Owen speaks of the Marcellus shale as "the base of the third division of the American Protozoic rocks." The equivalents to this are given as the "lower part of F. VIII of Pennsylvania and Virginia, Postmedidial, Older Black slate of Rogers."[5] The transition from the underlying Corniferous and Seneca limestone is sharp.

He expressed the opinion that the black shale at the Falls of Ohio is probably the representative of the Genesee, and that the Encrinital limestone of Tennessee and Kentucky (Button Mould Knob) may represent the Encrinital limestone of the Hamilton of New York.[6]

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[1] See Am. Jour. Sci., vol. 43, pp. 161–162.

[2] Am. Jour. Sci., vol. 45, pp. 151–165.

[3] Among these may be mentioned particularly, "Review of the New York Geological Reports," by D. D. Owen, published in the Am. Jour. Sci., vol. 46, pp. 143–157; vol. 47, pp. 354–380; vol. 48, pp. 296–316; 2d ser., vol. 1, pp. 43–70, vol. 3, pp. 164–171.

[4] Ibid., vol. 47, p. 355. (This article is signed "D. D. O.," p. 380.)

[5] Am. Jour. Sci., vol. 3, 1847, p. 57.

[6] Ibid, p. 72.

In 1844 Henry D. Rogers delivered the annual address before the association of geologists and naturalists at the meeting held in Washington, May, 1844.

At that time the geological publications of the United States had reached a stage of considerable perfection, the author remarked.[1] The "Geology and Mineralogy of the State of New York" had been issued. Reports on surveys covering the greater part of the Eastern States of the Union had been published, furnishing information in regard to the Paleozoic, Mesozoic, and Tertiary formations of this half of the United States. In regard to the Paleozoic formations he said:

> From Lake Champlain, therefore, westward to the mouth of the Wisconsin River, a distance of at least 1,100 miles, and southward to Alabama, over a still larger and very complicated tract, and throughout the entire triangular area included between these limits, the boundaries of each of our Paleozoic Appalachian formations have been determined and with very considerable precision.[2]

He and his brother had prepared a map of the United States, 14 feet by 12 feet in size. This was apparently of the eastern part of the United States.[3]

The paleontology of the Appalachian basin at this time had been carried on by the researches of Messrs. Conrad, Emmons, and Hall, in New York, and by Messrs. Hall, Owen, Troost, Locke, and Clapp, in the Western States, until "five hundred well characterized marine fossils had been made known." The work of study and description was pushed further, particularly by James Hall. Rogers acknowledged, in 1844, that "the most elaborate classification of our Appalachian Paleozoic strata hitherto is that of the New York geological survey." "It embraces, under the title of the New York system, the entire body of strata from the bottom of the lowest fossiliferous rocks to the base of the Red sandstone of the Catskill Mountains."

Although the New York geologists were acknowledged to have provided a valuable classification of these formations, the author did not feel satisfied with recommending this for general adoption. He appreciated the difficulties attaching to the application of local names to the geological formations, and because of the necessity of a general nomenclature for rocks he gave an account in this address of a scheme of grouping and naming the Paleozoic strata, which his brother, W. B. Rogers, and himself had been maturing during the last three years.[4] Their nomenclature was purely artificial. To quote he says:

> We propose to distribute the whole great body of strata, from the base already designated to the top of the Coal Measures, in *nine* distinct *series*, the products of as many great successive *periods*, and resorting to the analogy between these periods and the nine natural intervals into which the day is conveniently divided we have named them in ascending order, the *Primal*, the *Matinal*, *Levant*, *Preme-*

[1] Rogers, Henry D., on American geology and present condition of geological research in the United States. Am. Jour. Sci., vol. 47, 1844, pp. 137-161, 247, 278.

[2] Ibid, p. 146.

[3] See p. 147. I find no evidence that it was published.—H. S. W.

[4] Ibid, p. 154.

didial, Medidial, Post-medidial, Ponent, Vespertine, Seral series; the deposits of the Dawn, Morning, Sunrise, Forenoon, Noon, Afternoon, Sunset, Evening, and Twilight periods of the great Appalachian Paleozoic day.

The author goes to some length in explaining the application of this scheme to the formations of the "Appalachian system" and their corresponding limits in the formations of the New York geologists, and we notice that he has attempted to cover very much the same field already covered by the nomenclature of the New York State survey. The advantages of his nomenclature it seems to the writer are entirely negative; the names are entirely arbitrary, and on that account have not the objections attaching to them which were raised against mineralogic or paleontologic names. The greatest objection to the scheme as a whole is that it is necessarily local, both geologically and geographically, since it is a scheme of nomenclature which does not permit intercalations without disturbing its symmetry, and it does not allow of expansion to cover what might be found below or to cover the higher rocks.

The author discussed in the latter part of his address the formations of the Mesozoic period, named the Red sandstone along the eastern border "Mesozoic Red sandstone,"[1] and enumerated some of the fossils occurring in the "Mesozoic Coal Measures of Eastern Virginia." The Cretaceous deposits are briefly referred to and a few of their characteristic fossils enumerated. The Cainozoic or Tertiary period is also briefly described, and above that the Post-Pliocene period is reported in Maryland and North Carolina and elsewhere along the coast, and a few of the fossils which Conrad had been so active in describing are named.

In 1847 Daniel Sharp[2] reported the Oriskany sandstone, Cauda-Galli grit, and Schoharie grit as locally distributed in New York, the first being most prominent in Pennsylvania and Virginia. The whole series is classified in the Devonian system.

The Marcellus shale, the Hamilton group (Moscow shales, Encrinal limestone, Ludlowville shales), Tully limestone, and Genesee slate are especially distinguished by their faunas, which consist chiefly of Brachiopods and Lamellibranchs, the majority of them peculiar to the Devonian while a few occur in the higher Carboniferous deposits. This is by far the most fossiliferous series in the Devonian system. The Portage group, consisting of sandstones and shales and having a thickness of 1,000 feet, is nearly barren of fossils, while the Chemung rocks, which have a thickness of 1,500 feet and occur just above the Portage group, are highly fossiliferous. Both of these series are considered as belonging to the Devonian system, and with the Hamilton group constitute the "Erie division." The Devonian system closes with the Chemung group, above which comes the Old Red sandstone formation.

[1] Am. Jour. Sci., vol. 47, 1844, p. 247.

[2] Sharpe, Daniel: Report on the fossil remains of mollusca from the Paleozoic formations of the United States (etc.), with remarks on the comparison of the North American formations with those of Europe. Quart. Jour. Geol. Soc., 1847, vol. 4, pp. 145-181.

The author in the main agreed with American geologists in the line of division between these two great groups of rocks. He then correlated the system of America with that of Europe, after which he added a tabulation of the faunas of both countries, giving references to synonyms, strata, localities, and formation in country.

In 1848, before the American Association of Geologists and Naturalists, James Hall presented a paper[1] in which some valuable comparisons are given of the characters expressed by the rocks as they outcrop in different areas. The Hudson River group was recognized in Ohio, Indiana, Kentucky, and elsewhere in the interior. It becomes more calcareous and is called "Blue limestone" in the more western exposures. Hall noticed that it contains Conchifera in the East with few Brachiopods; that in the West, Brachiopods are conspicuous with Corals and Crinoids, Crustacea, and Trilobites. The Oneida conglomerate, the Medina sandstone, and the Clinton formations of New York were very slightly represented in the Southwest. The Niagara shale and limestone in the East were both fossiliferous; in their western exposures the limestone is reported as thicker and containing abundant Corals, and the calcareous matter is reported as increasing on coming westward. The Onondaga Salt formation thins out on coming westward, the Helderberg formations mainly disappear west of New York, except the Upper Limestone, which appears in Ohio, Indiana, and Kentucky, but is of lighter color than its representatives[2] in New York. The Marcellus and the Hamilton formations are reported as sandy in the East, and the muds diminish and the sands increase in western New York, and in Ohio only the lower, Shale, and this of limited thickness appears. The rocks from the Hamilton group upward, and the Old Red sandstone are more sandy in the East, and more argillaceous and thinner westward. The rocks of the Catskill Mountains, called the "Old Red sandstone," also appear in eastern Pennsylvania, but disappear westward, allowing the Coal Measures to rest on the conglomerate in the East, but in the West, on the Chemung, and still farther west on the limestone.

As a conclusion from these observations the author pointed out that a continent supplying sediments must have existed eastward of the great deposition of sediment along the border, extending from New York through Pennsylvania southward.

M. Ed. de Verneuil, after a visit to the United States and examination of our formations and their fossils, published in the Bulletin of the Geological Society of France the most valuable paper on correlation which had appeared up to this time.[3]

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[1] The Geographical Distribution of Fossils in the Older Rocks of the United States.

[2] The Corniferous and Onondaga limestone.—H. S. W.

[3] Note sur le parallélisme des roches des dépôts paléozoïques de l'Amérique septentrionale avec ceux de l'Europe, suivie d'un tableau des espèces fossiles communes aux deux continents, avec l'indication des Étages où elles se rencontrent et terminé par un examen critique de chacune de ces espèces. Soc. géol. France, Bull., 2e sér., vol. 4, 1847, pp. 646–709.

A few copies of the paper doubtless came to America, but the form in which it had most effect upon American geology was the condensed translation and review of it by Mr. James Hall, which appeared in the American Journal of Science.[1]

In the present essay the original paper and Hall's comments upon it will be discussed together.

Mr. Hall's Review of M. de Verneuil's Study of the American Paleozoic was entitled "On the Parallelism of the Paleozoic Deposits of North America, with those of Europe; followed by a Table of the Species of Fossils common to the two Continents, with indication of the positions in which they occur, and terminated by a critical examination of each of these species; by Ed. de Verneuil (translated and condensed from Bulletin of the Geol. Soc. of France, 2d ser., vol. 4 for this Journal; by James Hall, New York State Geologist)."

This review is of great importance historically, as it shows how the classification of the New York strata was perfected by comparisons with the European strata and their fossils.

M. de Verneuil, one of the ablest paleontologists of the time, had been associated with Murchison in studying the Russian series. This had led to a careful comparison of the English Silurian and higher rocks with those of Russia, and had fitted him preeminently to recognize corresponding species, zones, and faunas in the New York and American series. And this "review" of his report on the "parallelism" was by the rising paleontologist of New York, who, better than any other American, understood the fossils and the arguments presented.

De Verneuil appreciated the great value, for classificatory purposes, of the New York series. He said, "No country in Europe offers us so complete and uninterrupted a development of the Silurian and Devonian systems," and "this series presents a continuous succession of deposits which are superimposed in regular stratification."[2]

The various strata of this New York system had been defined and named in their stratigraphic order, each different kind of rock receiving a distinct, generally geographic name. These formations had been grouped together arbitrarily on grounds of their geographic outcrops; as Champlain, Ontario, Helderberg, and Erie divisions. By some of the State Geologists they were regarded as merely convenient groupings of the rocks for reference, and of no scientific value.

In the final reports attempts had been made to correlate them with the English subdivisions, as given by Murchison and others, but these correlations were incorrect, as the result has shown.

No satisfactory method of classifying the individual formations into more comprehensive groups had been attained. De Verneuil proposed to unite them into groups according to their paleontologic affinities.

[1] Second series, vols. 5 and 7, 1848.

[2] Am. Jour. Sci., 2d ser., vol. 5, p. 178.

This had been roughly attempted by Hall, but, as we examine the changes proposed by De Verneuil, it is evident that the final grouping was greatly influenced by his suggestions.

In the first volume of the Paleontology of New York, published in 1847, no attempt was made by Hall to form subordinate groups of the several formations included in the lower or "Champlain division," the Potsdam sandstone, Calciferous sandrock, Chazy limestone, Birdseye limestone, Black River limestone, Trenton limestone, Utica shales, Hudson River shales). De Verneuil thought there were several subordinate groups, viz, (1) Potsdam, (2) Calciferous, (3) Chazy, Birdseye, and Black River limestone, (4) Trenton limestone, Utica and Hudson River shales. The placing of the Oneida conglomerate and the Medina sandstone with the Niagara limestone was supported by de Verneuil. It had been proposed by Vanuxem and Mather, but was not followed by Hall; in this review the latter expressed his assent to its propriety.

The combination (Water-lime, Pentamerus galeatus limestone, Delthyris shaly limestone, Upper Pentamerus) to form the Lower Helderberg group, was the suggestion of de Verneuil.[1] This is in accordance with Conrad's identification of this combination with the "Wenlock limestone" in 1841, but does not agree with Hall's previous grouping of the equivalents of the Wenlock limestone.

The inclusion of the Oriskany with the Corniferous in the Devonian was suggested by de Verneuil. The combination Marcellus, Hamilton, Tully, and Genesee as a lower group, and Portage and Chemung as an upper group of the Erie division of the New York reports was also his.

De Verneuil's parallelisms of the strata of Europe and America were as follows:

The Potsdam sandstone he regarded as the equivalent of the "sandstone with obolus" of Russia and the "Carboniferous sandstone" of Scandinavia. The siliceous limestone and Black River and Trenton limestones were the "bituminous schist and Orthoceratite limestone" of Sweden and Russia. The Utica shales and Hudson River group were the "Graptolite slates" of Sweden and of Bain, France. These together form the equivalent of the inferior stage of the Silurian system, and as we study his classification of the next division, it is apparent that the groupings suggested are not those arising from the particular American sequence of rocks, or alone from the faunas themselves, but from their equivalency to the divisions of the European classifications.[2]

In the western exposures in Indiana and Ohio, he recognized a union of the faunas of the Lower and Upper Silurian, but in New York these are separated by the Oneida and Medina arenaceous deposits, and he drew the line so as to include the latter in the Upper Silurian with the Clinton and Niagara. The limestones and shales of the Niagara he regarded as the equivalent of the limestones and slates of Wenlock and

[1] Am. Jour. Sci., 2d ser., vol. 5, p. 180. [2] Ibid., pp. 179, 180.

of Gothland, and the five inferior groups of the Helderberg division as the equivalent of the Ludlow rocks.

In M. de Verneuil's opinion the Devonian begins with the Oriskany and includes the five superior groups of the Helderberg division and the six groups of the Erie division and the Old Red sandstone. His argument for beginning the Devonian with the Oriskany is the paleontologic equivalency of its fauna with the fauna of the European Devonian, the occurrence of *Asterolepis* in Schoharie grit, and the characters of the numerous *Spirifera*, some of which reminded him of *Spirifer cultrijugatus* and *S. macropterus* of the Eifel, and the fact observed by Hall that the Oriskany was preceded by a violent movement of the waters, denuding and wearing depressions in the underlying rocks. The Oriskany he regarded as the equivalent of the fossiliferous schists of the border of the Rhine. The Chemung, Portage, Genesee, Tully, and Hamilton represented for him the formations of the Eifel and Devonshire; the Marcellus shales, those of Wissenbach in Nassau; the black (Devonian) schists of Ohio, Indiana, and Kentucky, he regarded as representing the Genesee slates of New York, and the calcareous band below represented the Corniferous and Onondaga limestones and the Hamilton group of the East. He held that the Devonian disappears entirely on the borders of the Mississippi, where the Carboniferous system rests directly on the Silurian.[1]

M. de Verneuil first pointed out the fact that the "Waverly series" of Ohio and Indiana in great part belonged to the Carboniferous system, and not to the Devonian or Chemung, as American geologists held.[2] This determination was based upon study of the fossils from near Medina, and from Cuyahoga, and Newark, Ohio. He showed that the representative of the Portage in Ohio was possibly at the base of the Waverly sandstone, but found it difficult to draw a line on account of the lack of fossils, and held the view that in Indiana, Kentucky, and Tennessee all above the black slates is Carboniferous.

In a foot note[3] Mr. Hall explains that he had called rocks at New Albany, Indiana, lying above the black slates and containing Carboniferous fossils, "Subcarboniferous, from the fact that up to that time I was not aware that anything below the base of the great Carboniferous limestone had been recognized as belonging to the Carboniferous period."

In Tennessee the siliceous strata of Prof. Troost are also reported as belonging to the Carboniferous system. Those "Psammites and siliceous strata" M. de Verneuil regarded as equivalent to the "yellow sandstone of Ireland" and the "slates and sandstones of Westphalia."

The reviewer at the close still differed from the author in his definition of the Devonian system above and below, insisting that the limit between Silurian and Devonian should be at the base of the Schoharie

[1] Am. Jour. Sci., 2d ser., vol. 5, p. 181. [2] Ibid., vol. 7, p. 45. [3] Ibid., p. 461.

grit, with the Oriskany left out of consideration, and that the line between the Devonian and Carboniferous was not established and should be regarded as a matter for future determination.[1]

Mr. Hall in this review quotes M. de Verneuil's views as to the great importance of the Paleozoic formations of America:

> No series of formations extended in continuous manner over a vaster surface than the Paleozoic strata of North America. * * *
>
> By one of those happy chances of which the history of science offers us examples, the territory of the State of New York presents us, below the Carboniferous system, the Paleozoic series most complete. Every favorable condition is there also united to facilitate that study, and to give to superposition, and consequently to paleontology, of which it is the foundation, a certainty truly scientific.[2]

Hall as well as de Verneuil objected to the unfortunate grouping into "Champlain, Ontario, etc., divisions" of the rocks of New York.

The finer subdivisions are, however, of permanent value. As Hall wrote:

> In truth, we are satisfied that what has given certainty and security to our labors are the minute subdivisions which have never been attempted elsewhere.[3]

The reason for this is not far to seek. These "minute subdivisions" are the natural stratigraphic units of the rocks and express the historical changes of local conditions. They express for each geographic province the epochs of its geologic history and are the units of which the geologic history of the world was built. The fossils they contain are the means by which the history of geographically separate provinces may be compared, and, as will be seen by tracing the effect of de Verneuil's work, the coordinating and systematizing of the several stages of relative uniformity of condition for each separate province are to be accomplished by a comparative study of the fossil contents.

The reason for grouping any particular formation with those below rather than with those above is not found in its mineral constitution, nor in its stratigraphic condition, but in the character of its fossil contents.

The New York geologists attempted to make groupings of the fundamental formations based upon their relation to the present geographic features of the surface. This plan failed because there is no natural connection between the two sets of phenomena.

When de Verneuil discussed the matter with Hall on a basis of the fossil contents of each particular formation for each particular geographic province, a natural classification was reached, which, as far as the state of knowledge permitted, was satisfactory, and which persists because it is based upon facts which have a history, and therefore can be historically classified.[4]

In Tennessee, according to the reports of Troost and Owen, Silurian,

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[1] Am. Jour. Sci., 2d ser., vol. 7, p. 231.

[2] Ibid., vol. 5, p. 177.

[3] Ibid., p. 179.

[4] Comparison of the geological features of Tennessee with those of the State of New York, by James Hall; Proc. Amer. Assoc., 1851, vol. 6, pp. 256-259.

Devonian, and Carboniferous species occur together. Hall accounted for this fact by the absence in this basin of the rocks which in New York separate these great limestones, thus bringing the representatives of the Niagara, Lower Helderberg, and Corniferous together, and causing some confusion of the species at their junction.

This was in the direction of clear definition for the faunas. Up to this time (and to some extent even to the present), geologists did not appreciate the essential importance of knowing the precise order and association of species making up the successive faunas met with in geological sections.

James Hall also prepared a paper on "Parallelism of the Paleozoic deposits of the United States and Europe."[1] This was written after the work on the geological survey of the State of New York had been completed. Interest had also been excited in Europe, and he had the benefit of the studies of several very able European geologists. Lyell had visited America the first time; de Verneuil had written his paper on the Parallelism of the Paleozoic formations of America with those of Europe; Daniel Sharpe had written a paper on the Paleozoic rocks of North America;[2] Murchison's Silurian System had been published several years before; also Phillips's Fossils of Devonshire, and McCoy's description of Carboniferous Fossils; these were all published and at hand for comparison.

The first part of Mr. Hall's paper was devoted to a comparison between the Paleozoic rocks of New York and those of the West. As bearing upon our present discussion the only point of particular interest in this comparison is the correlation of the "Cliff limestone" with the Niagara, Clinton, and Corniferous limestones of the East. In the West a black shale was found to follow this limestone in some parts of Ohio, Indiana, and Kentucky, which was believed to represent the remaining part of the Devonian; above it, all over the Mississippi Valley area, the Carboniferous limestone appeared. Several interesting points appear in the discussion of the comparisons between the American and the European sections made by Messrs. Sharpe, de Verneuil, and others. In these comparisons the use of fossils was paramount, and all the arguments were based upon the presence of fossils, irrespective of the lithologic characters of the deposits. The determinations were based chiefly upon a numerical comparison of the recorded lists of fossils; resemblance of genera and identity of species were recorded as determining the correlation in each case. This principle was carried to the extent of recognizing, in species from what are called now Devonian deposits of America, correlations with Silurian, Devonian, and Carboniferous species in the different groups of organisms which were compared. For instance, in a table[3] the Brachiopods of the Oriskany sand-

[1] It appeared as chapter XVIII of Foster and Whitney's Report on Lake Superior, part II, pp. 285-318, published in 1851.

[2] Quar. Jour. Geol. Soc. Lond., August, 1848.

[3] Ibid., p. 316.

stone are said to indicate a "close affinity with the Carboniferous;" the Cephalopoda of the Marcellus and the Brachiopoda and some Cephalopoda of the Chemung and Hamilton groups are reported as "of Carboniferous facies." Again, the Brachiopods and Lamellibranchs of the Chemung and Hamilton, and the Brachiopods of the Corniferous are indicated as presenting a "Devonian facies," while the Lamellibranchiata and Orthocerata of the Chemung and Hamilton, the Cephalopoda of the Corniferous, and the Cephalopoda and Crustacea of the Schoharie grit are regarded as "equivalents of the corresponding faunas of the Ludlow rocks in Europe."

This indicates considerable confusion, and the inference to be drawn from a study of these results is that the determination of the fossils was not sufficiently accurate to make the comparisons with precision. It is probable that the difference between the species which were defined as "Carboniferous," or "Devonian," or "Upper Silurian (Ludlow)" in Europe, belonging to the same genera, was not so great as the difference which the species, belonging to the same horizon, might exhibit on the two sides of the ocean; but at this stage in the progress of paleontology there was apparen tly very little appreciation of the amount of variation which species of the same genus undergo during the same geologic epoch.

Hall was of the opinion that the Upper Helderberg of the New York system represented the Ludlow group of Murchison, and while he recognized the fact that the Ludlow beds were separated by the English from the Devonian, he insisted that the fossils of the Ludlow were represented by the fossils of the Schoharie grit and Corniferous limestone more closely than by any of our Lower Helderberg species. He insisted that either the Ludlow beds belonged to the Devonian or that there must be some consider able gap in the New York series between the Lower Helderberg and the Upper Helderberg. He said, after stating that he could not agree with M. de Verneuil in placing the Lower Helderberg limestones in parallelism with the Ludlow:

> Leaving out of consideration the Oriskany sandstone and Cauda-Galli grit, we feel disposed to regard the Schoharie grit as possessing zoological features more in accordance with those of the Lower Ludlow series than any other rock in our classification. We shall thus place it for the present.[1]

And in his table of equivalents the Wenlock series is represented by the Clinton group in part, Niagara group, and Lower Helderberg limestones; and the Ludlow series and Devonian system are represented by our Upper Helderberg limestones, Hamilton group, Chemung group, and the Red sandstone and shale of the Catskill Mountains.[2]

As indicative of the stage of refinement reached in the identification of species and its results, the following quotations may be made:

> Although it is not difficult to find the evidence of a general parallelism in our suc-

[1] Foster and Whitney, Rept. on Lake Superior, pt. 2, p. 310. [2] Ibid., p. 317.

cessive groups with those of Europe, yet when we come to more minute and critical comparisons the difficulties increase rather than diminish.

The relations of our divisions often appear to be in two directions, and it is impossible to account satisfactorily for the apparent divergence in the direction of groups, as shown by the evidence afforded by the recognized species of European authorities.[1]

This determination of (correlation with) the Ludlow was independent of his determination of the true representative of the Devonian system in America; for in another place he said:

The Oriskany sandstone, however, marks an important horizon, since we now regard it as commencing the Devonian period.[2]

Although fossils were used for the purpose of correlating formations across geographic intervals, as from England to America, it was not by paleontology pure and simple. It was an identification of strata by likeness of fossils irrespective of the question of paleontologic history. The fossils were mere "medals of creation;" those possessing the same marks were supposed to belong to the same creation. The time had not come for an examination of the relations of the various fossils to each other. The law of paleontologic succession did not become a factor of correlation till the idea of the evolution of species furnished a rational basis of confidence in the naturalness of the observed order of sequence of forms. The idea of evolution suggests the true biologic system of correlation, in which the data of the classification are fossils, and the distinctions made are into periods in the history of organisms, the strata taking their relative position in the series according to the period in this history which their contained fossil remains may indicate.

[1] Foster and Whitney, Rept. on Lake Superior, pt. 2, p. 314. [2] Ibid., p. 302.

CHAPTER III.

THE DIFFERENTIATION OF THE CARBONIFEROUS SYSTEM.

In matters of correlation the Carboniferous system is particularly unfortunate, in that there is nothing in the name nor in the usage to determine precisely the limits of the system above and below. The grand divisions Lower Carboniferous, Millstone Grit, and Coal Measures have been handed down from the early classifications before strict methods were in use. The question whether the Permian shall constitute the third age of the Carboniferous period or not must be settled either arbitrarily or by reference to precedent. In order to establish a precedent it must be determined what is the standard Carboniferous system. If the original Carboniferous system excluded the Permian as a distinct system it is important that a name be found to designate that usage and to distinguish it from the present common usage, which includes the Lower Carboniferous, the Coal Measures, and the Permian in the one Carboniferous system. A review of the literature shows that a classification of the rocks to form a system to which first the name Carboniferous was applied was made by W. D. Conybeare in 1821.[1] It was called the "Medial or Carboniferous order," and was defined to include: (1) The Coal Measures, the "independent coal formation" of Werner; (2) the Millstone grit and shales; (3) the Carboniferous or Mountain limestone; and (4) the Old Red sandstone.[2] This grouping of the rocks was suggested by their "association together in the districts which afford the principal deposit of fossil coal."[3]

In this classification the "New Red sandstone," including what is now called "Permian" and "Trias," was distinctly excluded, and we discover that the New Red sandstone beds in England generally rest unconformably upon the Carboniferous. The line of unconformity gave occasion for the distinction between "primary" and "secondary," and later "transition" and "secondary," and for the classification of the rocks and faunas below the line as "Paleozoic" and those above as "Mesozoic." In the Wernerian nomenclature the term "Floetz class" was applied to the flat-lying rocks, beginning with those New Red sandstones in the English series and running upward.

Conybeare's Carboniferous order also included rocks correlated as Old Red sandstone, and he recognized that the "Old Red approaches in its lowest beds very nearly to the characters of the graywacke upon which

[1] Conybeare and Phillips: Outlines of the Geology of England and Wales, London, 1822, p. 333.
[2] Op. cit., p. 335.
[3] Op. cit., p. 333.

it reposes, and indeed graduates insensibly into that rock, so that the line of separation between them is frequently only an imaginary and arbitrary demarkation."[1]

Thus we see that the Carboniferous as originally understood was grouped about the Coal Measures, had its upper limit a line of unconformity, and below had no sharp line of demarkation.

Murchison and Sedgwick had previously recognized the importance of the Old Red Sandstone as a distinct terrane, and as holding a peculiar and interesting fauna,[2] and in 1839, in the Silurian system, Murchison raised it to equal rank with the Silurian and Carboniferous, calling it the "Old Red system."

Murchison included in the Carboniferous system the rocks associated with the Coal Measures, which are terminated above by the rocks of the New Red system, and below by those of the Old Red system. The three divisions of the Carboniferous system (Coal Measures, Millstone grit, and Carboniferous limestone) were recognized by Murchison.

The Old Red system of Murchison included: (1) Quartoze Conglomerate and sandstone; (2) Cornstone and marl; (3) Tilestone.

Immediately under the Tilestone at Ludlow village was the Upper Ludlow and top of his Silurian system. The Tilestones were regarded as beds of passage to the Silurian. They were afterward called "Downton sandstone," a name proposed by John Phillips.

This was the classification with which the New York geologists sought to correlate the rocks of the New York system in 1840.

The Carboniferous system was made up of the Coal Measures at the top, the Millstone grit, and at bottom the Carboniferous limestone. Above the Carboniferous came the New Red sandstone or New Red system, in which the Magnesian limestone, the Saliferous group, and the New Red sandstone were conspicuous divisions. Below the Carboniferous came the Old Red system, which in Murchison's classification filled the interval between the Carboniferous and Silurian systems.

The confusion about the Devonian in the final reports of the New York survey arose partly from the original confusion in England. The series in New York are perfectly simple up to the Conglomerate. The Red rocks of the Catskill were identified with the Old Red system. The Devonian rocks were clearly below these Catskill rocks, and while some of their fossils were similar to Phillips's Devonian fossils, others were also like Murchison's Ludlow fossils, and as the Ludlow group immediately preceded the typical Old Red rocks of England, and as the chief of Phillips's Devonian fossils were really Upper Devonian, it was natural to conclude that the rocks of our Middle and Lower Devonian were to be correlated with the Ludlow rocks of Murchison.

The correcting of this mistake could come only from a careful study of the fossils. When this had been done by de Verneuil the correc-

[1] Op. cit., p. 862.

[2] Geol. Trans., vol. 3.

tion was made; but Hall accepted it only after making a careful study of the fossils for himself. To Hall the New York rocks were the standard. To de Verneuil, Sharp, and Lyell the English rocks were the standard, and they had no prejudices in favor of any particular interpretation of the American rocks. The lithologic characters were prominent in Hall's correlation; to the English geologists, and particularly to de Verneuil, fossils were the chief criteria.

In the Carboniferous system the lack of a representative of the Carboniferous limestone in the Pennsylvania sections led to confusion, in early reports we read of the Coal Measures as "secondary," and of "transition coal-beds." (1835.) It was, doubtless, this supposition that the true order was (1) limestone, (2) grit, (3) Coal Measures, that led the Ohio geologists[1] to correlate the Corniferous limestone underlying the shales and fine-grained sandstone (Waverly) with the Mountain limestone.

The Wernerian idea that anthracite coal belonged to the "greywacke" or "transition," as taught in Conybeare and Phillips's geology in 1822, and imitated elsewhere,[2] was the influencing cause of the erroneous views as to the position of the eastern coal-beds of Pennsylvania, as seen in the papers of James Pierce and William Meade,[3] and others following up the discussion. In Tennessee the Mountain limestone was rightly classified, because there the limestone was actually next below the Coal Measures.

A remarkable example of error arising from this firm belief in the identity in the order of lithological deposits for America and England is seen in the paper of Prof. C. Dewey,[4] who in 1838 interpreted the red rocks about Rochester (Medina) as Old Red, and the overlying limestones (Niagara) as ranking wtih the Mountain limestone of Europe.

In the Mississippian province the identification of the rocks from the Coal Measures downward was correctly made, not because of accurate knowledge of the fossils, but because the three grand divisions of the typical English Carboniferous system were there present in the same order: first, a series of limestones, then conglomerate or sandstone, then Coal Measures.

Thus it came about that the true classification of the Carboniferous was through the western or Mississippi Valley formations, and not through the typical Appalachian sections in Pennsylvania and southward, and their subdivision was made independently of the European usage. The base was determined by the fossils of species allied to the species of the Carboniferous limestone of England.

In the Appalachian province the limit was determined by the top of the marine Devonian rocks. But in the case of the upper limit, while the general custom in America has been to regard the Coal Measures as

[1] Ohio Geol. Survey, 2d Ann. Rep., by W.W. Mather, 1838.
[2] Geological Nomenclature, by Amos Eaton, 1828.
[3] See Am. Jour. Sci., 1st ser., 1827, vol. 12, pp. 69, 76,
[4] Am. Jour. Sci., vol. 33, p. 121.

the top of the Carboniferous system and to treat the appearance of the Permian type of fossils as indicating a new system, there has been no recognized standard for the settlement of the question.

In the same way at the base, where the last Devonian fossils are separated from the Coal Measures by deposits lacking marine fossils, the determination of the line of division between Devonian and Carboniferous has occasioned considerable dispute, which would certainly have been less had there been a recognized standard section of the Carboniferous system outside America which might be referred to as a standard in all cases of difference of opinion about our own rocks.

In order that we may have such a standard, I shall describe more in detail the Carboniferous system as first defined for English geologists.[1]

The English author who first appreciated the importance of grouping certain rock formations with the Coal Measures to form what now is called a system, was W. D. Conybeare.[2] The German geologist, Werner, and the school of geologists that followed him, had called the Coal Measures the "Independent Coal Formation" or "Stein Kohlengebirge." Conybeare subdivided the "Transition and Secondary formations" of Werner into orders, and his medial order was called the "Medial or Carboniferous order." Here were included "the rock formations, which ought to be considered together with the Coal Measures." In his classification these formations were, "I. The Coal Measures. II. The Millstone grit and shale. III. The Carboniferous or Mountain limestone. IV. The Old Red sandstone."[3] His "Supermedial order" included all the rocks from the Coal Measures to the Tertiary, substantially what we now call Mesozoic. His Submedial order was the "Grauwacke" of Werner.

Conybeare prominently notices that the formations of the "Medial or Carboniferous order" are the rocks which form the "Pennine chain" (spelled by him *Penine*) of mountains in northern England. He carefully defines the position and structure of the range, and proposes the retention of the name "Pennine," which was first applied to them by the early Roman colonists of the island.[4] Other exhibitions of Carboniferous rocks are mentioned by him, but here alone he found the whole series represented, and the rocks of the Pennine range were the typical rocks of the system which Conybeare defined.

In Hughes's "Geography of British History" (London, 1863), we find the "Pennine range" defined as "applied by general consent to the extensive range of high ground stretching south from the Cheviot Hills to the district of the Peak in Derbyshire, about 170 miles in length," stretching from the border of Scotland southward to the val-

[1] A portion of this chapter has been read before the Indianapolis meeting of the American Geological Society, and an abstract appears in its bulletin, vol. II, pp. 16–19.

[2] Conybeare and Phillips, Outlines of the Geology of England and Wales. London, 1822, p. 323.

[3] Op. cit., p. 325.

[4] See Outlines of the Geology of England and Wales, pp. 365, 366.

ley of the Trent."[1] It is composed "entirely of rocks belonging to the Carboniferous series."[2]

H. B. Woodward, in "Geology of England and Wales" (1887), describes this range as "a faulted anticlinal of Lower Carboniferous rocks supporting on the east the coal fields of Northumberland, Yorkshire, and Derbyshire, and on the west the Lancashire and Cheshire coal fields."[3]

As was pointed out by Conybeare, the rocks of this range not only contain the typical rock formations to which he applied the name "Carboniferous order," but each of the members of that system.

De la Beche (1831–1833) followed the classification of Conybeare, but dropped the term "Medial" as a synonym. John Phillips (1837) adopted the name "Carboniferous" with "system" instead of "order" in the same sense as proposed by Conybeare. And Murchison, in the Silurian system (1839), made classic the names "Silurian system," "Old Red system," "Carboniferous system," "New Red system," and "Oolitic system."

After them, geologists in general adopted the name Carboniferous system for one of the great groups of rocks composing the grand geological column.

All of these early English authors were in unison in distinctly excluding the rocks afterward (in 1841) called "Permian" by Murchison, and at that time going under the names "New Red sandstone" and "Magnesian limestone," "Saliferous system" and "New Red system." Conybeare, De la Beche, and John Phillips agreed in including the "Upper Old Red sandstone" in the Carboniferous system, while Murchison, after them (in 1839), separated from the Carboniferous the lower member as a distinct system. On page 169 of his Silurian system he says that he "applied the name 'Old Red system' to the Old Red sandstone of previous writers in order to convey a just conception of their importance in the natural succession of rocks, and also to show that as the Carboniferous system in which previous writers have merged it * * * is surmounted by one red group, so is it underlaid by another."

Thus, all four of these early authorities in English geology agree in their definition of the original Carboniferous system, which is that of *the series of rocks typically represented in the Pennine range of England, and not fully represented in any other one section of England.*

When we seek to determine the precise definition of the Carboniferous system, we are led directly to this typical section in the Pennine range, first clearly defined by Conybeare, and afterward adopted as the typical section by the founders of geological science in England, and afterward by correlation recognized as the standard section of the Carboniferous system throughout the world. The section of this typical Pennine Car-

[1] Op. cit., p. 20. [2] Op. cit., p. 22. [3] Op. cit., p. 149.

boniferous system consists of, first, the upper part of the Old Red sandstone resting upon lower beds of Old Red sandstone, unconformably about the Cheviot Hills, or upon the Cheviot Volcanic series, or upon Silurian rocks, as in Northumberland. The second formation, resting conformably upon the first, is the Mountain or Carboniferous limestone. The third member of the series is the Millstone grit and shales. The fourth, the Coal Measures, including the familiar coal fields of Lancashire and Cheshire, of Yorkshire, Northumberland, and Derbyshire; these latter are terminated where contacts are seen by the "New Red," in some places apparently conformably, but generally unconformably. The system in this Pennine range was evidently terminated both below and above by geologic disturbance of greater or less extent, furnishing natural deliminations, thus peculiarly fitting it for a standard of geologic definition.

An analysis of the standard systems in geologic classification shows us that a system is a series of rock formations whose stratigraphic order and lithologic composition are thoroughly well expressed in some definable geograpic region, and whose fossils indicate a continuous biologic sequence, more or less distinctly broken at its lower and upper limits from contiguous formations. Thus a typical section has definite geographic position, geologic delimitation, and biologic definition. The Silurian system in Wales and western England, the Devonian system of south and north Devonshire, the Jurassic system of the Jura Mountains, are examples, and no less perfect is the Pennine Carboniferous system of the Pennine range of north England to which the unsatisfactory name of Carboniferous has been so long applied.

While so much is true of the standard or typical expression of a geologic system, it can not be expected that any system will offer precisely the same features in other regions of the world or on other continents. We conclude, therefore, that: (1) Because the composition, the size of particles, and the order and thickness of deposits are all determined by conditions that are geographically dissimilar, therefore a geologic system can have but one typical geographic position; (2) because the geologic events, such as elevation of land, breaking of strata recorded in faults, and volcanic eruptions, do not take place either uniformly or simultaneously in different parts of the earth, it is certain that intervals or breaks in sedimentary formations will not be uniform for separate regions; and (3) because organisms in the past can not be regarded as having ceased to carry on the ordinary functions of life and reproduction, all the breaks in the sequence of organisms, all the sharp lines distinguishing the faunas or floras of one formation from those of a preceding or following formation, are local and not universal.

To apply these reflections to the present case, it will be seen that the settlement of the question as to which is the typical section upon which the Carboniferous system was founded, will greatly facilitate all attempts to determine the limits of the system in other regions. It is evident

that the typical section is the section exhibited in the Pennine range, and as the name Carboniferous is a misnomer geologically (for we now know that carbon or coal-bearing rocks are not confined to the system generally so called), and as the name does not indicate the geographic position of the typical section, it is believed that the adoption of the name "Pennine system" may be of advantage to the science, for this particular type of the Carboniferous system.

This Pennine Carboniferous system may be defined as to its *geographic position*, as the rock formations of the Pennine range of northern England and equivalent formations in other parts of the world. In *geologic delimitation* the Pennine system begins with a red sandstone and terminates with the upper rocks of the Coal Measures. In *biologic definition* its first marine fauna is that of the Mountain limestone; its final fauna and flora are those of the Coal Measures. The brackish fauna of the Old Red sandstone had not ceased at its opening; the characteristic Permian fauna or flora had not appeared at its close.

Whatever may prove to be the correlation between the Old Red sandstone and the Devonian systems, the definition of the Pennine system is explicit in including fishes, such as *Holoptychius*, characteristic of the Old Red system of Murchison, and is as explicit in the exclusion of the Devonian marine fauna above which its earliest marine fauna belongs. The rocks and faunas of that which was later called the Permian system, are definitely excluded by the original author from the Pennine Carboniferous system. The problems of the Devonian Old Red system and of the Permian system must be discussed on their own merits. This original section of the Carboniferous has its relations to each clearly defined.

In correlating our American rocks the recognition of the Pennine Carboniferous system as typical, settles for us several disputed questions. For the Paleozoic rocks along the Appalachian and eastern border region the limits between Devonian and Pennine Carboniferous are in the following positions: The Chemung marine fauna is strictly Devonian; the brackish water fish fauna of the Catskill is as strictly Pennine. Hence the red rocks of the Catskill formation of New York, the Ponent, Umbral, and Vespertine formations of Pennsylvania, belong to the Pennine Carboniferous.

When, as in western Pennsylvania and Ohio, the species of the Carboniferous or Mountain limestone fauna of England appear to follow the marine Chemung, the line should be drawn between them for a strict correlation.

On passing westward the formations called Waverly, Marshall, Kinderhook, Chouteau, containing as they do a fauna distinctly related to the Carboniferous limestone fauna, must be placed in the Pennine Carboniferous system.

In Kansas and Nebraska, and other localities where the upper Coal Measures gradually assume species of the types described from the

Russian Permian, the problem of correlation is definite. Both the stratigraphy and the biological evidence indicate that there is no sharp division between the representative of the Pennine Carboniferous system and that of the Permian system. The division line here must be arbitrarily drawn, and the fact that a system is a local series of formations, and not a universal subdivision of the geologic time scale, becomes evident. It is in such cases that the paramount importance of the determination of the geographic position of the typical representative of a system is seen, and the only way to make this apparent to all is by all the association of the geographic name with the system.

CHAPTER IV.

THE COAL MEASURES OR PENNSYLVANIA SERIES. THE DEVELOPMENT OF ITS NOMENCLATURE AND CLASSIFICATION IN THE APPALACHIAN PROVINCE.

The classification of the rocks of middle Pennsylvania in 1836 furnished the basis for the system of numbers which have played so conspicuous a part in Pennsylvania geology ever since. The State geologist was Henry D. Rogers, and his assistants were D. C. Booth and J. F. Frazer, with R. E. Rogers as chemist. The classification was as follows:

XII.	Coal Measures.
XI.	Red shale.
X.	White sandstone, } of the second mountain.
IX.	Red sandstone, }
VIII.	Olive shales, etc.
VII.	Cherry sandstone.
VI.	Limestone.
V.	Red shale and Fossil ore.
IV.	Gray sandstone, } of the first mountain.
III.	White sandstone, }
II.	Slate, } of the Lebanon Valley.
I.	Limestone, }

The State geologist believed that this series of formations in the order given could be recognized "under slight variations of color, size, and mineral ingredients, across the Old Dominion and into Tennessee and Alabama."[1]

This constituted the "series of Appalachian formations," which Prof. Rogers "for the first time systematically classified and described in the years 1836, 1837, and 1838.[2]

The geological survey of Pennsylvania was begun in 1836 and several annual reports were published, but the final report was not published till 1858.[3]

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[1] Second Geol. Survey of Pennsylvania, 1874-'75-'76. Historical sketch of geological explorations in Pennsylvania and other States. By J. P. Lesley, 1876, pp. 54, 55.

[2] Second Annual Report on the Geological Exploration of the State of Pennsylvania. By Henry D. Rogers, State Geologist. Harrisburg, 1838, pp. 82, 83.

[3] The Geology of Pennsylvania, a Government survey, with a general view of the geology of the United States; essays on the coal formation and its fossils and a description of the coal fields of North America and Great Britain. By Henry Darwin Rogers, State Geologist. 4to, 2 vols., Edinburgh, London, and Philadelphia, 1858.

Prof. Rogers's system of classification and nomenclature is exhibited in the following synopsis:[1]

A SYNOPSIS OF THE APPALACHIAN PALEOZOIC STRATA OF PENNSYLVANIA IN THE ASCENDING ORDER.

Primal crystalline schists (or Azoic group).

	Feet.
Primal series:	
Primal Conglomerate in Virginia and Tennessee	150
Primal older slate in Virginia	1,200
Primal White sandstone, Potsdam sandstone of New York	? 300
Primal upper slate	? 700
Auroral series (blue limestone of the Western States):	
Auroral Calcareous sandstone, Calciferous sandstone of New York	60
Auroral Magnesian limestone, the Chazy and Black River limestones in part	2,500–5,500
Matinal series:	
Matinal argillaceous limestone, Trenton limestone of New York	300–550
Matinal Black slate, Utica slate of New York	300–400
Matinal shales, Hudson River slate	? 1,200
Levant series:	
Levant gray sandstone, Oneida Conglomerate of New York	250–400
Levant Red sandstone, division I, or lowest member of Medina sandstone of New York	500–700
Levant White sandstone, apparently divisions II, III, IV, Medina sandstone of New York	450
Surgent series:	
Surgent lower slate, ? equivalent of lower green shale of Clinton group of New York	200
Surgent iron sandstone	80
Surgent upper slate	250
Surgent lower ore shales, ? in horizon of upper green shales, Clinton group	760
Surgent ore sandstone	10–30
Surgent upper ore shales, ? in horizon of upper green shales, etc	300
Surgent red marl, Clinton group	350
Scalent series:	
Scalent variegated marls, Scalent gray marls } ? Onondaga salt group of New York	400–800
Scalent limestone, Water-lime group of New York	250
Pre-Meridian series:	
Pre-Meridian limestone, Lower Helderberg limestone of New York	50–100
Meridian series:	
Meridian slate	170
Meridian sandstone, Oriskany sandstone of New York	150
Post-Meridian series:	
Post-Meridian grits, Cauda-Galli and Schoharie grits of New York (New Jersey)	300
Post-Meridian limestone, Upper Helderberg or Corniferous limestone of New York, and part of Cliff limestone of Western States	80
Cadent series:	
Cadent lower black slate, Marcellus shale of New York	250
Cadent shales, Hamilton group of New York	600
Cadent upper black slate, Genesee shale of New York	300

[1] Op. cit., vol. 1., pp. 105–109.

	Feet.
Vergent series:	
Vergent Flags, Portage flags of New York	1,700
Vergent shales, Chemung group of New York	3,200
Ponent series:	
Ponent Red sandstone, Catskill group of New York	5,000
Vespertine series:	
Vespertine Conglomerate and sandstone	2,660
Umbral series, or Carboniferous shales and limestone:	
Umbral Red shales and limestone	3,000
Seral series, or Coal strata:	
Seral Conglomerate, or lowest division of Coal Measures	1,100
Lower Productive Coal Measures.	
Lower Barren Coal Shales.	
Upper Productive Coal Measures.	
Upper Barren Coal Shales.	

The numbers corresponding to the names here proposed are as follows:

XII. Seral.
XI. Umbral.
X. Vespertine.
IX. Ponent.
VIII. { Vergent. Cadent.
VII. Meridian.
VI. Pre-Meridian.
V. { Scalent. Surgent.
IV. Levant.
III. Matinal.
II. Auroral.
I. Primal.

In 1850 H. D. Rogers[1] discussed the coal formations of the United States, considered from the following points of view:

First. The source, stratigraphical relations, and conditions of deposition. The land-derived deposits, attaining a maximum thickness of 1,400 feet in the southeast, thin out westward to less than 100 feet, and the Coal Measures gradually thicken toward the northwest. The immense range and horizontal extension of the conglomerates and coal seams prove that it could not have been deposited by any local *estuary* or *deltal* actions, but along a broad, shallow sea shore, which was disturbed by violent interior forces, producing enormous undulations.

Second. The author discussed the structural conditions and position of the anthracite basins, and found them arranged in two systems of flexures, the larger series with an amplitude of many miles and a length of 100 miles, with average direction of about N. 75° E., the smaller series trending N. 70° E.

Third. He treated of the metamorphism of the anthracite coal-bearing strata, showing it to be more complete in the east, the products of the western region being bituminous and those of the east anthracitic.

Fourth. Erosion is considered.

Finally, a summary of the statistics of the coal fields is presented, in which the author states that the productive area of the anthracite fields of Pennsylvania does not exceed 200 square miles, with an aggregate thickness of 100 feet.

[1] On the coal formation of the United States, and especially as developed in Pennsylvania. Proc. Am. Assoc., vol. 4, 1850, pp. 65–70.

The same author[1] determined the age of certain footprints from the red shale near Mount Carbon.

Ancient footprints discovered by Mr. Isaac Lea in the "Red Shale" at Mount Carbon, in Pennsylvania, and assigned by him to the Devonian period, were considered by the author to belong in reality to the "Reds" of the Carboniferous, a few hundred feet below the productive coal series. They are accompanied by a series of similar footprints attributed to batrachian reptiles, trails, prints of some unknown four-toed animal apparently reptilian, and trails analogous to those of worms and mollusca. The larger footprints are mainly five-toed, alternate in the steps, and nearly equal in size.

In 1856 Mr. J. P. Lesley reported on the Broad Top coal basin.[2]

The Broad Top coal basin, situated between Huntingdon and Bedford Springs, was imperfectly reported upon in 1838 by Mr. McKinley, the substance of the report appearing in the annual reports of the Geological Survey.

In 1855 the author made a more complete survey of this region, covering about 80 square miles, established the levels of over nine thousand points, and reached the following conclusions: (1) That the succession of the measures is not different from the system made out in western Pennsylvania and eastern Ohio. (2) That the structural results lead to the conclusion that the abruptness of the anticlinals could be produced only by side pressure. (3) That the Precarboniferous Coal Measures are represented in this region by beds of black slate containing little coal, the Subcarboniferous limestone being present in small amounts.

J. P. Lesley,[3] remarking on the Subconglomeratic Coal Measures of northwestern Virginia, thinks those beds represent early Carboniferous formations, such as are seen in Ireland, Scotland, and possibly in Melville Island. Similar beds occur in southern Virginia, in southeastern Kentucky, and in Nova Scotia. The lowest Devono-Carboniferous slate represents a still earlier period, and may be correlated with the German Devonian Coal Measures.

Mr. J. M. Hale[4] (1864) reported at the junction of the Beaver Dam and eastern branches of Clearfield Creek, a boring of 548 feet. At the depth of 199 feet a vein of coal 4 feet 4 inches in thickness was reached. This is probably in the author's view the same vein as at Osceola or Phillipsburg.

Mr. B. S. Lyman,[5] in 1867, commenting on the Great Carboniferous

[1] Rogers, H. D.: On the position and character of the reptilian footprints in the Carboniferous Red Shale formation of eastern Pennsylvania. Proc. Am. Assoc., vol. 4, 1850, pp. 250–251.

[2] Lesley, J. P.: On the Broad Top coal basin in central Pennsylvania. Am. Assoc., vol. 10, pt. 2, 1856, pp. 78–81, map.

[3] Lesley, J. P.: On the Subconglomeratic or false Coal Measures of West Virginia and Pennsylvania. Am. Phil. Soc., Proc., vol. 7, 1860, p. 294.

[4] Hale, John M.: Record of an old salt boring in Clearfield County, Pennsylvania. Am. Phil. Soc., Proc., vol. 9, 1865, pp. 459–460.

[5] Abstract on the Great Carboniferous conglomerate in Sullivan County, Pennsylvania. Phil. Acad. Sci., Proc., vol. 19, 1867, pp. 125–127.

conglomerate, stated that it was the general opinion that the Great Conglomerate (No. XII) at the bottom of the Coal Measures thins out rapidly from a thickness of 1,200 feet at Mauch Chunk to less than 100 feet in Wyoming Valley. But he found in Sullivan County a thickness of 400 feet, consisting of two main layers of pebbly rock separated by strata of light brown and greenish sandstones resembling those of the productive Coal Measures. The lower bed is well exposed at Shinerville, where it dips 15° S., and again on the south side of Loyal Sock. Farther south are the red, iron-stained shales (No. XI) north of Painter Den Run, and still farther south the sandstone (lower bed) outcropssouth of Bear Swamp Run. The sand rock also occurs at Long Point, where it has a thickness of 190 feet. Close examination of the sand rocks at this point led to the conclusion that they are the same as at Shinerville and Birch Creek, 1 mile distant.

Mr. J. S. Newberry,[1] in 1871, gave an account of some sections of the lower Coal Measures in Holmes, Tuscarawas, Jefferson, and Columbiana Counties, which in some cases extend down to the Waverly, and show alternations of shale, sandstones, and limestones, with beds of coal. The sections average from 300 to 400 feet in depth, the coal seams individually rarely more than 4 feet. The coal beds are numbered according to altitude, from 1 to 7, No. 1 being the lowest, and are described in detail. Coal, No. 6, in Holmes County, is overlaid by a black bituminous shale, rich in marine fossils, *Chonetes mesolaba*, etc. At the mouth of the Yellow Creek, Jefferson County, the "Big Vein" of coal is underlaid by 4 inches of cannel, full of the remains of fishes and amphibians; the fishes, species of *Cœlacanthus* and *Eurylepis*, *Palæoniscus* and *Rhizodus;* the amphibians were aquatic carnivorous salamanders.

William M. Fontaine,[2] in 1374, stated that the Great Conglomerate on New River consists of a great formation of sandstones containing important beds of coal, underneath a massive white sandstone, which itself underlies the lowest strata of the Lower Coal series. This formation is considered by William Rogers the equivalent of the Great Conglomerate, here much expanded, while others hold that it is a great development of the Lower Coals. To the east it is underlaid by the enormously expanded Subcarboniferous group.

Fontaine gave facts concerning the overlying and underlying formations of this peculiar series, beginning at the mouth of the Kanawha River where the strata are of Upper Coal series, diminished in thickness. Under these is found the barren upper portion of the Lower Coal series, increased rather than diminished in thickness, developing both to the south and to the northeast. The strata under these barren

[1] Newberry, J. S.: Sketch of the structure of the lower Coal Measures in northeastern Ohio. Geol. Survey Ohio, Report Progress in 1870, pt. 1, pp. 14–53. Columbus, 1871.

[2] Fontaine, Wm. M.: The "Great Conglomerate" on New River, West Virginia. Am. Jour. Sci., 3d ser., vol. 7, pp. 459–465, 573–579.

measures are of great thickness, and the author gives a section showing the number and thickness of the coal seams in this Lower Coal series. After this series comes the Conglomerate series, introduced by a massive white sandstone, remarkable for its resistance to erosion. The strata underneath it, best exposed at Sewell Station, resemble strongly the rocks of the Lower Coal series, are argillaceous, and contain considerable amount of oxide of iron, but they differ from the latter by the almost entire absence of shales in connection with the coal beds. The coal seams are inclosed in flaggy sandstones; all the evidence goes to show that they were formed under sudden and violent changes. Measurements are given of the different seams showing a great variation in thickness. Some Devonian plants have been found in the roof of the deposits, of which *Alethopteris serlii* is the most abundant. Underneath these conglomerate sandstones and coal seams is another massive white sandstone, evidently the base of the formation. The next lower deposits are heavy bedded sandstones succeeded by the red shales of the Subcarboniferous formation.

This lowest coal series on New River has the same triple structure shown by the Conglomerate in other portions of the country, a summit and base of conglomeritic sandstones, and a central portion of more argillaceous rocks containing beds of coal, and the thickening of the whole formation is mostly due to the expansion of the middle portion followed by an increase in the amount of coal. Brief descriptions of the Conglomerate at other points are given to confirm these statements. The Conglomerate is seen to expand in two directions, to the northeast into Pennsylvania, and to the southwest in West Virginia, while it diminishes to the northwest. The expansion to the southwest is followed in each case by the increased formation of coal. The similar expansion of the underlying rocks, the Subcarboniferous and the Catskill, is treated in detail. A thin seam of coal is found in the latter containing many beautifully preserved Devonian plants, confirming the supposed Catskill age of the strata. Several species of *Lepidodendron*, *Cyclopteris*, *Neuropteris*, and others are found.

The great expansion of the Conglomerate on New River is thus found to be like others, the effect of a condition of things which began in much older formations and continued until a later era. The author asks the question, "Does not the successive formation of coal on an extended scale, along the southwest border of the Appalachian coal field, commencing in the Devonian period, point to the existence at this time of a continental mass nearer than the Azoic of Canada?"

J. J. Stevenson,[1] in 1874, made the following report on the coals of the Kanawha Valley:

The Upper Coal group along the Great Kanawha River has two coal beds of workable thickness. The lower one is the Pittsburg, usually known as the "Raymond

[1] Stevenson, John J.: Notes on the coals of the Kanawha Valley, West Virginia. New York Lyceum Nat. Hist., Annals, vol. 10, 1874, pp. 271–277.

seam." The limestone overlying this coal in northern Ohio and Pennsylvania, as well as in the northern part of West Virginia, is greatly diminished in thickness, and is represented in this locality by calcareous shale only, containing a few nodules of limestone.

The Barren group has about 300 feet of thickness, and contains no workable coals; it varies but little in thickness from Pittsburgh to the Great Kanawha, running north and south.

The development of the Lower Coal group in this valley is extraordinary. In northern West Virginia the thickness is scarcely 200 feet; in the first geological district of Ohio it is rarely more than 300 feet; in either case containing only six or seven coal beds. In this valley it can be separated into two portions, the upper of which is no less than 900 feet thick, with fifteen beds of coal, and the other about the same thickness with two or three more coal beds. This development continues southwesterly until its thickness becomes about 2,500 feet in Tennessee.

The Mahoning sandstone, at the top of the group, is conspicuous in the river hills above Charleston, and holds a coal about midway, as in its northern extension in Ohio and Pennsylvania. It rests upon a variable bed of black flint, 5 to 12 feet thick. A few feet below the flint, and separated from it by shale sometimes arenaceous, is a coal partly cannel and partly bituminous, from 5 to 7 feet thick. It is regarded as identical with the Upper Freeport of Pennsylvania, and is known locally as the Stockton seam. Below this is a variable bed, at Cannelton a cannel of insignificant thickness, at Coalburg, it is the "Great Splint Coal," in some respects the most important bed along the river, and at the Kanawha Salines the place is occupied by several thin beds considerably separated. The bed is from 6 to 11 feet in thickness. In the thin layer of clay between the sandstones and coal are numerous impressions of *Lepidodendron* and *Sigillaria*, and there were remarkably fine leaf-scars of *Bothrodendron* discovered in one locality. The dark slate found in this bed is rich in bitumen. Five hundred and fifty feet below the Stockton seam, at Cannelton, is a bed of bituminous coal nearly 7 feet thick, known as the "Gas Coal," and below this coal a limestone was observed by Mr. Ridgway which he identified as the "Ferriferous" of Pennsylvania; if he is correct, the "Gas Coal" is probably the "Kittanning" of Pennsylvania.

J. J. Stevenson,[1] in 1874, presented a paper to the New York Lyceum of Natural History which embodies the results of an examination and comparison of the Ohio coals with those of Pennsylvania and West Virginia. The observations recorded cover only that portion of the field north of the Baltimore and Ohio Railroad in West Virginia and Ohio.

The limits of the Upper coals are first considered, and the conclusion reached that the Pittsburg coal, the base of the Upper Coal Measures, "once reached as far west as Sonora, 71 miles west from Wheeling, and to a point northward not less than 50 miles from that city, a tortuous boundary line connecting the two points."

Several sections from Ohio, West Virginia, and Pennsylvania are compared in order to ascertain their relations to each other. From this comparison it is found that only Coal VIII, VIIIa, VIIIb, and Coal XI can be seen in all the sections. Coal VIII is the Pittsburg, VIIIa appears as the Redstone, VIIIb as the Sewickley, while Coal XI is the Waynesburg.

[1] The Upper Coal Measures west of the Alleghany Mountains. New York Lyceum Nat. Hist., Annals, vol. 10, 1874, pp. 226–252, pl. No. 12.

A detailed description of each bed is then given. Coal VIII is regarded as the "parent bed of all the Upper coal in Ohio, remaining in existence as a flourishing swamp from the beginning of the epoch until its close."

The conditions of the Upper Coal Measures during deposition are treated at length, and the author is led to the following conclusions:

(1) The great bituminous trough west of the Alleghanies does not owe its basin shape primarily to the Appalachian Revolution.

(2) The Coal Measures of this basin were not united to those of Indiana and Illinois at any time posterior to the Lower Coal Measure epoch, and probably were always distinct.

(3) The Upper Coal Measures originally extended as far west as the Muskingum River, in Ohio.

(4) Throughout the Upper Coal Measure epoch the general condition was one of subsidence interrupted by longer or shorter intervals of repose. During subsidence the Pittsburg marsh crept up the shore, and at each of the longer intervals of repose pushed out seaward upon the advancing land, thus giving rise to the successive coal-beds of the upper coal measures.

(5) The Pittsburg marsh had its origin at the east.

I. C. White,[1] in 1874, before the same society, discussed the Coal Measures of western Virginia and Pennsylvania.

Two sections are given from the region under consideration, one from the eastern and one from the western flank of the "Dividing Ridge," an elevation between Morgantown and Wheeling, rising in Pennsylvania and extending south into West Virginia. The eastern section has a thickness of 800 feet in the Upper Barren group and 340 feet in the Upper Coal group; total thickness, 1,140 feet. The western section has a total of 822 feet, 544 feet in the Barren group and 278 of the Upper Coal. The sections show the well known fact that the coals and sandstones in this district thin out toward the west, while the limestones thicken up. The eastern section in Monongalia County is described in detail. The upper sandstones and shales are very coarse, showing that that they were deposited by pretty strong currents.

The different thicknesses and characters of the various coal beds are fully given.

In 1875 J. P. Lesley,[1] State geologist of Pennsylvania, prepared a brief digest of the state of classification and nomenclature of the rocks in New York, Ohio, and Pennsylvania at that time. The article might be quoted entire were there space, as no further condensation of the statements can be satisfactorily made; but a single scheme of equivalents will suffice to show the ideas of the author as to correlations at the beginning of the second survey of Pennsylvania. On page 97 we find—

[1] White, I. C.: Notes on the Upper Coal Measures of western Virginia and Pennslyvania. New York Lyceum Nat. Hist., Annals, vol. 11, 1874, pp. 46–57.

[1] Second Geol. Survey of Pennsylvania, 1874, Report of Progress, I: Note on the comparative geology of northeastern Ohio and northwestern Pennsylvania, and western New York, pp. 57–108.

The following scheme will show the old problem and its recent probable solution:

In Ohio.	In northwestern Pennsylvania.	In New York.	In middle Pennsylvania.
Conglomerate			Seral Cong., XII.
Cuyahoga shale			Umbral, XI.
Berea grit	Second Mountain sandstone	Conglomerate	Vespertine, X.
Bedford shales		Old Red sandstone (fish).	Ponent, IX.
Cleveland shales	Oil sands	Chemung	Vergent, VIII.
Erie shales		Portage	Vergent, VIII.
Huron shales		Hamilton	Cadent, VIII.
Corniferous		Upper Helderberg	Post Medidial, VIII.

The author states in a foot-note that he does not adopt "the general term Waverly sandstone formation of the Ohio Reports because of the controversies to which it has given rise." Also, that "Erie shales" should stand opposite both Chemung and Portage.

In a letter to the editor of the Journal,[1] dated June 26, 1875, Prof. Lesley speaks of Mr. Ashburner's discovery of what he calls "baby coal beds" in No. X, Upper or White Catskill, Rogers's Vespertine, in Huntingdon County, Pennsylvania, and considers it of great importance to American geology, as it explains the presence of the two coal beds on the face of the Alleghany Mountains and the fourteen small coal beds counted by Prof. Lesley years before, west of the Peak Mountain, in Wythe County, Virginia.

E. B. Andrews[2] compares the Ohio and West Virginia coal fields. In this comparison the author takes the Pittsburg seam of coal as the base of measurement. This seam occupies the northern portion of the Alleghany coal field, and extends through Pennsylvania, Ohio, and West Virginia. From its outcrop to the base of the productive Coal Measures the intervals remain quite uniform. In Ohio Dr. Newberry's measurement is from 700 to 800 feet and Prof. H. D. Rogers's from 600 to 700 feet. But in the southern part of West Virginia the interval is much greater. Prof. Fontaine estimates 3,100 feet as the total thickness from the horizon of the Pittsburg seam to the base of the productive Coal Measures. This does not include the shales and the adjacent Lewisburg limestone, which are probably local. Hence we find about 2,400 feet more of Coal Measures in Virginia than in Ohio and Pennsylvania, and hence in West Virginia the series of productive Coal Measures make up a great geosynclinal, which is probably due to continental folding. The various coal seams, separated by small layers of shale, indicate that it was subject to alternate depression and elevation. In West Virginia, above the Pittsburg seam, over 1,200 feet of Coal Measures rock occur, showing several seams of

[1] Lesley, J. P.: Coal beds in the Subcarboniferous of Pennsylvania. Am. Jour. Sci., 3d ser., vol. 10, 1875, pp. 153, 154.

[2] A comparison between the Ohio and West Virginia sides of the Alleghany coal field. Proc. Am. Assoc., vol. 24, pt. 2, 1875, pp. 84–92.

coal. In the anthracite coal fields of Pennsylvania there is so much uncertainty as to the true equivalent of the Pittsburg seam that there is little chance for comparison.

Considerable difficulty arises in attempting to determine the exact situation of the Coal Measures conglomerate in the various States, nor is the Millstone grit of Indiana and Illinois synchronized, or its equivalent in the Alleghany field determined. In Arkansas a Millstone grit is reported, which Mr. Lesquereux declares is part of the coal formation. Mr. Dawson also describes a similar Millstone grit along the Bay of Fundy, but its relation to those of Great Britain or of the United States is not known.

E. B. Andrews,[1] in 1875, reported some interesting coal plants from Ohio:

In Perry County, Ohio, a thin bituminous shale occurs at the base of the Ohio Coal Measures, containing pieces of plants similar to branches of Calamites, fish scales, and a small *Lingula*. Just above this layer is a thin stratum of shale carrying leaves of *Lepidodendron*. In the higher shales are found numerous ferns, etc. The plants found here were well marked Devonian types, with a few more recent than the Coal Measures, while those belonging to the Coal Measures are new species. A new species of *Archæopteris* is one of the Devonian forms: *Megalopteris* (Dawson) is another Devonian genus. One species of the genus was known in New Brunswick only, and described by Prof. Hartt as *Neuropteris dawsoni*. With these was found a fern of a new genus, of the order of the *Tæniopteridiæ*. The new Ohio genus the author calls *Orthogoniopteris*. A new form of *Alethopteris* was noticed resembling the one found in the coal field of Cape Breton, but specifically different. Also a new *Asterophyllites*, *Hymenophyllites*, *Eremopteris*, and two species of *Lepidodendron*, with a few others. These are to be figured in the Ohio reports.

Mr. Lesley proposed a scheme of the formations[2] called "Table of rock formations, arranged in the order of the ages from above downwards, as they are recognized in America and according to the present state of our knowledge."[3]

Recent.
Glacial.
Tertiary.
Cretaceous.
New Red.
The Coal Measures, anthracite and bituminous.
The Great Conglomerate, No. XII, of Mount Pisgah, called by Rogers, "Seral."
Red Shale, No. XI, Umbral, around Mauch Chunk.
White Catskill, No. X (Vespertine), of the Second Mountain.
Red Catskill, No. IX (Old Red of England), Pocono Mountain.
Chemung shales (VIII, Cadent) holding the oil rocks.
Portage sands and shales (VIII, Vergent).
Hamilton black slates (VIII, Scalent); streaks of coal.
Upper Helderburg limestones, etc. (VIII, Postmeridial).
Oriskany sandstones (VII, Meridial), Stone Ridge, Lehigh Gap.
Lower Helderburg cement layers, etc.

[1] Andrews, E. B.: Notice of new and interesting coal plants from Ohio. Am. Assoc., Proc., vol. 24, pt. 2, 1875, pp. 106–109.

[2] See Geol. Survey of Pennsylvania, Report of Progress D on the Brown Hematite Ore Ranges of Lehigh County, by Frederick Prime, jr., 1874, p. 73.

[3] Ibid., p. 63.

In 1876 W. M. Fontaine[1] proposed the name of "Conglomerate series" for the strata in West Virginia which occupy the interval between the floor of the Productive Coal Measures and the Devonian (or lower productive coals and red shales of the Umbral). Important coals are said to occur in the equivalent of the Conglomerate series, and also well developed coals in the Vespertine of Montgomery County, Virginia, near White Sulphur Springs, West Virginia, etc.

D. D. Owen, nearly 20 years before, had recognized coals below the Conglomerate in Kentucky, although not in marketable quantities, and the Conglomerate was regarded by him as the base of the Coal Measures.

I. C. White,[2] in 1876, made some comments before the New York Lyceum on the Beaver County Coal Measures.

The line of section presented at the opening of this paper begins at the village of Homewood, in Beaver County, and follows the Beaver River to Rochester. The strata exposed extend from the Mahoning sandstone to the base of the Tionesta sandstone, dipping eastwardly at the rate of little more than 25 feet to the mile. The thickness of the Mahoning sandstone varies from 30 to 75 feet. It is usually a massive rock, but its composition is not persistent, sometimes it being merely a mass of shale.

Below it is the upper Freeport coal, of little importance, and then the Freeport limestone, a pure white limestone and very persistent. The bed of shale under this is fossiliferous, containing species of *Productus*, *Spirifer*, *Athyris*, etc. Then comes a thin seam of coal rich in vegetable remains, the lower Freeport coal, not workable, and the Kittanning coal, the most important bed in this part of the country, at one place yielding 200 tons daily.

To this succeeds the Ferriferous limestone, varying in thickness from 8 inches to 25 feet. It is richly fossiliferous in species of *Productus*, *Spirifer*, *Pleurotomaria*, etc. Shaly beds and thin beds of coal follow, one of the beds of shale containing many fossils, one stratum being made up almost entirely of *Aviculopecten whitei*, with *Spirorbis carbonarius* attached to these shells in vast numbers, the latter fossil occurring at this locality only.

The Tionesta sandstone is a very hard, coarse white rock. It is 50 feet above the river at Homewood, but passes under the river opposite New Brighton, 7 miles below.

Mr. Charles A. Young[3] describes the Conglomerate on New River as made of alternating sandstones and shales, the former numbering five, and the latter containing the workable coal seams. The total thickness is about 1,000 feet.

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[1] Fontaine, William M.: The Conglomerate series of West Virginia. Am. Jour. Sci., 3d ser., vol. 2, 1876, pp. 276-284, 374-384; the Virginias, February, 1880, vol. 1, pp. 27-29.

[2] White, I. C.: Notes on the Coal Measures of Beaver County, Pennsylvania. N. Y. Lyceum of Nat. Hist., Annals, 1876, vol. 11, pp. 14-18.

[3] Young, Charles A.: On Conglomerate No. XII (in West Virginia). Philadelphia Acad. Sci. Proc., vol. 28, 1876, p. 262.

Mr. Andrew Roy,[1] in 1876, reported that the Mahoning Valley coal region lying in the northern part of the Ohio coal field belongs to the "lower coal of the Lewis No. 1 of the Ohio Geological Survey," and has a varying thickness from an inch to 6 or 7 feet. This deposit rests upon the "Waverly" sandstone, which is so folded as to form numerous troughs, in which the coal has reached its maximum thickness. The synclinals were probably formed by erosion anterior to the formation of the coal vegetation, and not by the mountain-building forces exhibited in the anthracite fields of Pennsylvania.

In the year 1876 there appeared, as one of the volumes of the Second Geological Survey of Pennsylvania, the "Historical Sketch of Geological Explorations in Pennsylvania and other States, by J. P. Lesley, the State geologist."[2] This was reprinted without revision in 1878. It contains so much of interest to the readers of this essay that I refer them to it without abstracting its contents.

Chapter I is entitled "Early Observations of the Geology of Pennsylvania."[3] Titles of papers and comments on some of them are given dating back to 1780.

Chapter II is entitled "The Geological Society of Pennsylvania; and what it did to bring about the first geological survey of the State."[4]

Chapter III, "A history of the first geological survey of Pennsylvania,"[5] an elaborate description of the "Final Report of 1858," occupying pages 134 to 197.

Chapter IV is "A sketch of the history of other State geological surveys in the United States, and of their relations to that of Pennsylvania."[6] The press of other duties prevented the author from completing this chapter; only one State, that of North Carolina, is discussed.

In these chapters may be seen an account of the development of the knowledge regarding the geology of Pennsylvania up to the close of the first survey and publication of the final report in 1858. The new survey, begun in 1874, in matters of correlation adopted the classification of the first survey, but modified and amplified its nomenclature.

With the opening of the Second Geological Survey of Pennsylvania, Mr. Franklin Platt was engaged as assistant to work up the bituminous coal fields of western Pennsylvania. As a working scheme of classification and nomenclature he modified the scheme of the first survey as published in the final report of 1858 to adapt it to results of the investigations of the year 1874, and published in Report[7] of Progress H the following scheme of Coal Measures and underlying formations:

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[1] Roy, Andrew: The Mahoning Valley coal regions. Trans. Amer. Inst. Mining Eng., vol. 4, 1876, pp. 188–190.

[2] Geol. Survey of Pennsylvania, Rep. of Progress. Report A: A history of the first Geological Survey of Pennsylvania from 1836 to 1858, by J. P. Lesley; pp. 226. 1876.

[3] Pp. 3–28.

[4] Pp. 29–52.

[5] Pp. 53–197.

[6] Pp. 198–200.

[7] Second Geol. Survey of Pennsylvania, 1874. Report of Progress in the Clearfield and Jefferson district of the bituminous coal fields of western Pennsylvania, by Franklin Platt, Harrisburg, 1875.

THE COLUMN OF PALEOZOIC FORMATIONS.

Series.			
Monongahela	Upper Barren Measures.		
	(M) Brownsville (Washington) coal bed.		
	(L) Waynesburg coal bed.		
	(K) Sewickley coal bed.		
	(J) Redstone coal bed.		
	(I) Pittsburg coal bed.		
Conemaugh	Middle Barren Measures.		
	Mahoning sandstone.		
Alleghany	(E) Upper Freeport coal bed.		
	(D′) Middle Freeport coal bed.		
	Freeport limestone.		
	(D) Lower Freeport coal bed (Reynoldsville).		
	Freeport sandstone.		
	(C) Kittanning coal bed.		
	(B′) Ferriferous coal bed.		
	Ferriferous limestone.		
	(B) Clarion coal bed.		
	(A) Brookville coal bed.		
	Conglomerate	No. XII	(Seral.)
Shenango	Sharon coal beds	No. XI	(Umbral.)
	Red shale		
Catskill	New River coal beds	No. X	(Vespertine.)
	White sandstone		
Chemung	Olive shales		
Portage	Olive sandstone		(Vergent.)
Hamilton	Juniata coal beds	No. VIII	
	Black shales		(Cadent.)
Upper Helderberg	Corniferous limestone		(Postmeridial.)
Oriskany	White sandstone	No. VII	(Meridial.)
Lower Helderberg	Lewistown limestone	No. VI	(Premeridial.)
Waterlime	Cement layers		(Scalent.)
Clinton	Red shales and fossil ore	No. V	(Surgent.)
Medina	Red sandstone	No. IV	(Levant.)
Oneida	White sandstone		
Hudson River	Slates	No. III	(Matinal.)
Trenton	Limestone	No. II	
Calciferous	Dolomites	No. II	(Auroral.)
Potsdam	Sandstone	No. I	(Primal.)

In the first column the names below Shenango are those adopted by the New York geologists previous to 1843. The numbers in the third column are those adopted by the geologists of the first survey of Pennsylvania in the annual reports previous to 1842. The names in the fourth column are those of the final report of the first geological survey, by H. D. and W. B. Rogers, published in 1858. The letters A, B, C, D, E, applied to the coal beds of the Alleghany series are those adopted by Hodge and Lesley.[1]

In 1876 Franklin Platt described the geological column at Connellsville.[2]

The section is as follows, viz:

(1) The Upper (Monongahela) Coal Measures, including about 280 feet of slates, sandstones, shales, and limestones, and the "Great limestone" with the "Pittsburg coal bed" at the base.

(2) The Lower Barren Measures, including, besides shales and sandstones, the Pittsburg limestone, about 26 feet below the coal; Connellsville sandstones, 76 feet below the coal; and the Mahoning sandstone, 421 feet below the coal.

[1] Fifth Annual Report, 1841; Lesley's Manual of Coal, 1856; and H. D. Rogers' Annual Report, 1858.

[2] Second Geol. Surv. of Pennsylvania, Rept. of Progress L: Special Report on the coke manufacture of the Youghiogheny River Valley in Fayette and Westmoreland Counties, 1875, pp. 13-39.

(3) Lower or Alleghany River series, consisting of shales, coal beds, limestone, and ores, and down to the Conglomerate, No. XII.
(4) Ore beds of XI; limestones of XI.
(5) Catskill rocks, No. X, or Catskill gray sandstone.
(6) Chemung rocks No. VIII.

The means of correlation and identification were the "Pittsburg coal," distinguishing the base of the Upper Coal Measures, the "Mahoning sandstone," which is described as "the great key rock of the bituminous coal field in Pennsylvania, Ohio, West Virginia, and Kentucky. It was first best studied on the Mahoning River, in Jefferson County, and hence its name."[1]

This marks the base of the "Lower Barren Measures" and it puts on locally a thousand varying aspects, being coarse, pebbly, and massive, and again fine-grained, thin-bedded, and shaly." And at the base of the lower series is the "Conglomerate No. XII," which presents similar variations. It is the "Seral" Conglomerate of the first survey.

In 1877 Mr. Platt[2] published the following "Scheme of the measures" which "would be met with could a well be bored near Waynesburg, or on the highest geological land in Greene County:[3]

1. The Monongahela River system:
   (*a*) Greene County group of Upper Barren Measures.
   (*b*) Washington County group of Upper Barren Measures.
   (*c*) Upper Productive Coal Measures.
2. The Alleghany River system:
   (*a*) Lower Barren Measures.
   (*b*) Mahoning sandstone.
   (*c*) Lower Productive Coal Measures.
3. The Kanawha River system:
   (*a*) Pottsville Conglomerate. } XII.
   (*b*) Kanawha Coal Measures. }
   (*c*) Mauch Chunk red shale.. } XI.
   (*d*) Mountain limestone ..... }
4. The New River system (of Lesley, not of Fontaine):
   (*a*) New River Coal Measures..... } X.
   (*b*) Pocono (Upper Catskill) sandstone. }
4. The Devonian system:
   (*a*) Catskill Old Red sandstone, IX.
   (*b*) Chemung sand and shales..... }
   (*c*) Portage shales and sands..... }
   (*d*) Hamilton { Genesee black shales... } VIII.
   { Juniata Coal Measures. }
   { Marcellus black shales. }
   (*e*) Upper Helderberg limestone... .... }
5. Upper Silurian system:
   (*a*) Oriskany sandstone, etc., to the Archean.

Four new names are noted in this list, "proposed by the present State geologist of Pennsylvania," viz:

Pottsville Conglomerate, for Rogers' "Seral," No. XII.
Mauch Chunk Red shale, for Rogers' "Umbral," No. IX.
Kanawha Coal Measures, for Fontaine's "New River" series.
Pocono sandstone, for Rogers' "Vespertine," No. X.

[1] Second Geol. Surv. of Pennsylvania, Rept. of Progress L. Special Report on the coke manufacture of the Youghiogheny River Valley in Fayette and Westmoreland Counties, 1875, 22.
[2] Geol. Survey of Pennsylvania, Rept. of Progress II^2: Report on Cambria County, by F. and W. G. Platt, pp. 194, 1877.
[3] Ibid., p. XXIII.

The scheme of formations published in Report of Progress HH., 1875, is repeated, but with change in names, in Report HHH, 1877. In the preface of this report,[1] by J. P. Lesley, the following scheme of formations is given:

I. The Carboniferous system:
  1. Monongahela River coal series:
    Upper Barren Measures.
      (*a*) Greene County group.
      (*b*) Washington County group.
    Upper Productive Coal Measures.
  2. Alleghany River coal series:
    Lower Barren Measures.
    Lower Productive Coal Measures.
      (*a*) Freeport coal group.
      (*b*) Kittanning coal group.
      (*c*) Clarion coal group.
    Pottsville Conglomerate (Seral) XII
      (*d*) Sharon and Quinnemont coal group.
    Mauch Chunk red shale ..... } XI
    Mountain limestone ..... }
      (*e*) New River coal group.. }
    Pocono sandstone (Vespertine) (mountain sands) X
II. The Devonian system:
  1. Catskill sandstone (Old Red) (? Oil Sand group) IX
  2. Chemung sands and shales .....
  3. Portage shales and sands .....
  4. Hamilton formation .....
    Genesee black shales .....
    Hamilton sandstones XIII
      Juniata River coal group .....
    Marcellus black shales .....
  5. Upper Helderberg limestones .....
  6. Oriskany sandstone VII
III. The Silurian system.
  1. Lower Helderberg limestone VI

The name "Quinnemont beds" is here substituted for the name "Kanawha River system" of the former reports, because the latter name was found inapplicable.[2]

In the report on Indiana County[3] Mr. Platt notes the discovery of fossils in an exposure of the Mountain limestone on the bank of the Dunbar Creek, three of which were identified with species of the Chester group.[4]

This correlates the series XI, Mauch Chunk of Lesley, with the upper division of the Lower Carboniferous limestone series of the Mississippi Valley.

[1] Geol. Survey of Pennsylvania, Rept. of Progress H³. Report on Somerset County, by F. and W. G. Platt, pp. 348, 1877.

[2] See p. xxii.

[3] Geol. Survey of Pennsylvania, Rept. of Progress H⁴: Report on Indiana County, by W. G. Platt, pp. 316. 1878.

[4] Ibid., p. 60.

In 1876[1] Mr. Stevenson classified the formations of Greene and Washington Counties. In his classification the Waynesburg sandstone is made the base of the Upper Barren series.

This is divided into two groups, called the Washington County group and the Greene County group.

The first, or lower, includes the rocks from the Waynesburg sandstone to the Upper Washington limestone, inclusive. The second, or Greene County group, extends from the top of the Upper Washington limestone to the top of the series.

The second distinguishing horizon is the Pittsburg Coal Bed, and the series between it and the Waynesburg sandstone is the Upper Productive Coal series.

Below this the Lower Barren series is the name applied to all the rocks down to the Mahoning sandstone.

The rocks below the Mahoning sandstone are the Lower Productive Coal series, the bottom of which is not seen in the counties under examination.

Several local names are applied to the various strata presenting conspicuous exposures in these counties. These are not of importance for the purpose of this paper.

In 1877[2] the same author reported upon the rocks of Fayette and Westmoreland Counties.

In this classification the Waynesburg sandstone, the Pittsburg coal bed, the Mahoning sandstone, and the Pottsville (Seral) conglomerate form the conspicuous landmarks in the sections by means of which the four divisions of the coal measures are separated.

Below the Pottsville conglomerate the Umbral series of Rogers are recognized, and the author reports the probable identification of fossils from the limestones of this series in West Virginia with fossils of the Chester limestones of the Mississippi Valley.[3]

The Sharon coal group is placed in this series below the Pottsville conglomerate.[4]

The Pocono (Vespertine) rocks include the rocks of the district below the Umbral limestone.[5]

In the following year (1878) Mr. Stevenson's third report[6] was published. In this report are particularly discussed the rocks of the section in the Ligonier Valley, Fayette and Westmoreland Counties. As in his previous reports, Mr. Stevenson adopts in general the nomenclature and classification proposed in the first geoogical survey. In this and

[1] Geol. Survey of Pennsylvania, Rept. of Progress K: Report on Greene and Washington Counties, by J. J. Stevenson, pp. 419, 1876.

[2] Geol. Survey of Pennsylvania, Rept. of Progress K²: Report of progress in the Fayette and Westmoreland district of the bituminous coal fields of Western Pennsylvania. By J. J. Stevenson, pp. 437. 1876.

[3] Ibid., pp. 102, 103.

[4] Ibid., p. 103.

[5] Ibid., p. 105.

[6] Geol. Survey of Pennsylvania, Rept. of Progress K³: Report of progress in the Fayette and Westmoreland district of the bituminous coal fields of Western Pennsylvania. By J. J. Stevenson, pp. 331, 1877.

the second volume he adapts this nomenclature to that proposed by Mr. Lesley, as where he uses Pottsville Conglomerate for "Seral," Mauch Chunk Red Shale for "Umbral," Pocono sandstone for "Vespertine," etc.

Regarding the rocks underlying the Pocono sandstone, in the Fayette County sections, the author refers them to the Catskill "by direction of Prof. Lesley," but under protest.[1] In a paper in the American Journal of Science[2] he explained his reasons for this correlation. The outcrops in question in the river gaps through Laurel and Chestnut Ridges, Fayette County, are separated by many miles from other outcrops of the lower series, and the stratigraphic and lithologic characters do not furnish satisfactory means for determining the precise age of the lower beds. Fossils, however, found in the rocks below the characteristic Pocono sandstone were Devonian marine forms, the majority of them identical with species of the Chemung rocks of New York, two or three Hamilton species, and no species characteristic of typical Catskill rocks of New York. The author therefore concluded that the rocks were of Chemung age and "probably belong to the Lower Chemung."

In the closing chapter (XXII) of the report Mr. Stevenson gives some valuable "Notes on the Paleontology of Southwest Pennsylvania," giving a list of 55 Coal Measure fossils, 26 Lower Carboniferous, and 15 Devonian forms. In most of the rocks of the district the fossils are rare, but occasionally in the limestones and shaly beds sufficient fossils are obtained to satisfactorily determine the correlations.

Mr. Persifor Frazer,[3] in 1877, reported that a specimen of coal was given to him from a locality 18 miles east of Bath, West Virginia, and later another specimen from Bath, by Mr. Pendleton. Mr. Frazer thinks there are some reasons for ascribing the coal to an horizon below the Carboniferous series.

Mr. S. Fisher Morris[4] reported that the New River coal field has only two seams that are workable. Their position is "in the Conglomerate, No. XII, and hence they are called by Fontaine "Interconglomerate." The thickness of the Conglomerate series is about 1,450 feet.

In the report[5] on Lycoming and Sullivan counties, Messrs. Sherwood and Platt follow the established nomenclature, identifying the various stata from outcrop to outcrop mainly by stratigraphic methods.

In the sections traced by Mr. Sherwood "provisional limits" are recorded between the Catskill red sandstone and the Pocono gray sandstone, and between the latter and "Mauch Chunk red shale."

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[1] Geol. Survey of Pennsylvania, Rept. of Progress K, p. 13.

[2] 3d ser., vol. 15, pp. 423–430.

[3] Frazer, jr., Persifor: Anthracite from "Third Hill Mountain," West Virginia. Phila. Acad. Sci., Proc., vol. 29, 1877, pp. 16, 17, ½ p.

[4] Morris, S. Fisher: "The New River coal field of West Virginia." Trans. Amer. Inst. Min. Eng., vol. 8, 1879–1880, pp. 261–269.

[5] Geol. Survey of Pennsylvania, Rept. of Progress G². Geology of Lycoming and Sullivan Counties. I. Field notes, by Andrew Sherwood. II. Coal Basins, by Franklin Platt. 1880, pp. 266.

In this series no fossils appeared to help the correlations. The correlation of Chemung Measures was based upon the appearance of Devonian fossils, and in the strata where the fossiliferous beds were few and the red rock similar to those above was prominent the designation "Transition beds of Chemung into Catskill" is given.[1]

The report[2] on Potter County by the same authors, adds no new features to the general problem of correlation—the report consisting of detailed identification of the formations already classified and named.

In the report[3] on Jefferson County the main part of the volume is occupied with details of the township surveys. On pages XXVIII to XXXIV the author, Mr. W. G. Platt, attempted a grouping of the formations that had previously gone under local names. The Lower Productive Coal Measures, aggregating about 300 feet in this county, he divided into the *Freeport group*, the *Kittanning group*, and the *Clarion group*.

The Pottsville Conglomerate No. XII, 300 feet thick, is subdivided into

Homewood sandstones.
Mercer group of coals and sandstones.
Conoquenessing Upper sandstones.
Quakertown coal.
Conoquenessing Lower sandstones.
Sharon coal and shales.
Sharon conglomerate.

H. M. Chance,[4] in 1881, compared the Millstone grit of Pennsylvania with that of England. He said a survey of the Conglomerate No. XII (Millstone grit) in Pennsylvania by Messrs. Chance, Carll, and White, and of the same rock in Yorkshire, England, by Prof. Green and colleagues, led to the discovery of a striking similarity in the structure of the rock in the two regions.

A comparison of the nomenclature adopted by the two parties of geologists is given, from the Sharon through the Conoquenessing sandstones to the Homewood sandstone of Pennsylvania, and the Kinder Scout grit, coal, and Rough Rock of Yorkshire. Afterward, as the middle members in both localities were sometimes represented by a single rock and sometimes by several, a generalization was adopted by each party, the second and third grits of the Yorkshire formation being called the Middle grits, and the upper and lower Conoquenessing sandstones of Pennsylvania, the Conoquenessing group. In the modified nomenclature the Ohio or Sharon Conglomerate of Pennsylvania corresponds to the Kinder Scout or Lower grits of Yorkshire, and the Rough Rock or Topmost grits of the latter to the Homewood sandstone of the former.

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[1] Geol. Survey of Pennsylvania, Rept. of Progress G^2, p. 50.

[2] Geol. Survey of Pennsylvania, Rept. of Progress, G^3. The Geology of Potter County, by Andrew Sherwood. Report on the Coal Fields, by Franklin Platt.

[3] Geol. Survey of Pennsylvania, Rept. of Progress H^6: Report of Progress in Jefferson County, by W. G. Platt. 1880.

[4] Chance, H. Martyn: The Millstone grit in England and Pennsylvania; in Am. Jour. Sci., 3d ser., vol. 21, 1881, pp. 134–135.

The first report written by Mr. White was published in 1878.[1] He recognized the following formations in the district reported on, viz, Beaver, Alleghany, and part of Butler Counties.

Upper Productive Coal series, Pittsburg coal bed (only).

Lower Barren Measure series, including the measures from the base of the Pittsburg coal to and inclusive of the Mahoning (Lower Mahoning) Sandstone, an average of 600 feet.[2]

Lower Productive Coal series. From the base of the Barren Measures to the "Piedmont Sandstone" of Prof. Lesley, which the author regards the upper member of the Pottsville Conglomerate No. XII.[3] This is subdivided into Freeport group, Kittanning group, and Clarion group, 325 feet.

Beaver River series (J. P. Lesley). This was called by the author in MSS "Conglomerate series," thus identifying it with the series so called by Fontaine in West Virginia.[4]

In the typical section of the series along the Beaver River and the Conoquenessing Creek the series is as follows:

	Feet.
1. Piedmont [?], Upper Homewood Sandstone	75–155
2. Shales, inclosing sometimes a coal bed, iron ore, ? Mercer ? limestone, and coal	20– 80
3. [Pottsville Conglomerate] Conoquenessing sandstone; Massillon sandstone of Ohio:	
(*a*) Upper members	40– 50
(*b*) Middle members	35– 40
(*c*) Lower members	20– 25
4. Sharon shales; sometimes thin layers of coal	7

The name "Conoquenessing sandstone" was introduced for the first time in this report. It is regarded by the author as equivalent to the "Lower Pottsville Conglomerate."

Mr. Lesley, in a note in the chapter on the Beaver River group,[5] remarks that he foresees—

> The probability that the whole group of Pottsville (seral) Conglomerate rocks, containing as it does large and valuable beds of coal, will some day be considered as included in the series of the Lower Productive Coal Measures, as it certainly is in the Alleghany River series, and finally as the Conglomerate No. XII (whether called Seral Conglomerate, Pottsville Conglomerate, Piedmont sandstone and Pottsville Conglomerate, Upper and Lower Homewood sandstone, Homewood sandstone and Conoquenessing sandstone, Massillon sandstone, for by all these names has one or both of its principal members been designated) may be considered the base or bottom member of the Lower Productive Coal Measures as justly as the Mahoning sandstone is considered the bottom member of the Lower Barren Measures, the Connellsville sandstone the bottom member of the Upper Productive Coal Series, and the Waynesburgh sandstone the bottom member of the Upper Barren Measures.

In the Ohio correlations the classification of the Coal Measures was substantially that originally proposed by the Rogers brothers and elaborated by the second survey of Pennsylvania. So far as the correla-

[1] Geol. Survey of Pennsylvania, Rept. of Progress Q.: Report on Beaver, NW. Allegheny, and S. Butler Counties, by I. C. White, pp. 337. 1878.

[2] Ibid., p. 23, et seq.

[3] Ibid, p. 39, et seq.

[4] The conglomerate series of West Virginia, Am. Jour. Sci., vol. 11, 1876, pp. 276–284, 374–384.

[5] Ibid., pp. 65–66.

tions, strictly speaking, are concerned, this was the case down to details which were variable in the different counties of Pennsylvania. As to the classification, the separation of the Conglomerate series from the Lower Coal Measures was not found to express an actual change in nature of the formations in eastern Ohio; and as late as 1884 Mr. Orton, then State geologist, united these two, calling them both Lower Coal Measures.[1]

In the sixth volume[2] the Coal Measures are classified as Carboniferous, thus:[3]

		Feet.
Carboniferous	17. Upper Barren Coal Measures	500
	16. Upper Productive Coal Measures	200
	15. Lower Barren Coal Measures	500
	14. Lower Productive Coal Measures	250
	13. Conglomerate group	250

This is practically the Pennsylvanian classification.

In the results already discussed, coal beds, as lithologic formations, have been the chief means used in the classifying and correlating the Coal Measures.

Fossil plants served to distinguish the Carboniferous from the Triassic and the Cretaceous Coal Measures, but have not heretofore been of much use in subdividing the beds into groups.

In Virginia and West Virginia the character of the plants found in the Upper Barren Measures led Mr. Fontaine to correlate them with the Permian formations of Europe.

The report of his study of the plants and of Mr. White's study of the structure is given in Report PP of the Second Pennsylvania Survey.[4]

A brief account is given of the floras of the Vespertine group (Pocono formation), Conglomerate group (Pottsville formation), Lower Productive Coal Measures, particularly the Kittanning Coal and the Upper Freeport horizons, Lower Barren Measures, Upper Productive Coal Measures, including the Waynesburg coal beds and the Upper Barren Measures. The flora of the last formation, including the roof shales of the Waynesburg coal beds, is discussed at length, and the species described and figured, the authors reaching the conclusion that the "Upper Barrens of the Appalachian coal field are of Permian age."[5]

Most of the species described are from the roof of the Waynesburg coal, and the authors suggest that "perhaps it might be best to separate the roof shales of the Waynesburg coal and Waynesburg sandstone and consider them transition beds, and the strata overlying and including the great limestone below the Sewickley coal are to be considered strictly Permian."[6]

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[1] Geol. Survey of Ohio, vol. 5, p. 10.

[2] Ibid., Economic Geology, vol. 6, 1888. By Edward Orton.

[3] Ibid., p. 3.

[4] The Permian or Upper Carboniferous Flora of West Virginia and SW. Pennsylvania, by Wm. M. Fontaine and I. C. White, 1880, pp. 143, Pls. XXXVIII.

[5] Ibid., p. 119.

[6] Ibid., p. 120.

The authors recognize as of Pocono age coal beds in numerous localities in Pennsylvania, Virginia, and West Virginia, and they correlate the Mauch Chunk formation, or "Subconglomerate," with the Chester and St. Louis limestone group of Illinois, Indiana, and Kentucky, the Waverly group of southern Ohio, and the Cuyahoga shale and Berea grit, of northern Ohio.[1]

It is not proposed here to discuss the value of fossil plants as a means of correlation. The whole subject of the classification, distribution, range and association of fossil plants is under investigation by an expert botanist.

Several interesting problems of correlation depend much upon the evidence of fossil plants: as the determination of the true relations of the arenaceous deposits between the marine Devonian and the Carboniferous formations of the Appalachian province, the correlation of the Upper Paleozoic formations of the Acadian province, and the differentiation of the Permian from the Upper Coal Measures of the Appalachian areas. One work, however, may be cited as an illustration of the kind of modifications in classification suggested by fossil botany. In the year 1880 the results of Mr. Leo Lesquereux's work on the fossil plants of the Coal Measures of Pennsylvania were published in Report P.[2] Several of the chapters, particularly those on stratigraphy, were edited by the State Geologist, J. P. Lesley.

The greater part of the work is devoted to descriptions of the plants. At the close of the volume of text a list is given of the "Literature of the United States Coal Flora" (including Devonian), with 145 titles. Under "General remarks," chapter 2 is entitled "On the geographical and stratigraphical distribution of the plants of Carboniferous age;"[3] and at its close a "Table of distribution" gives the vertical range and geographical distribution of 599 species of plants. The arrangement of the columns expressing vertical range and classification presents in a concise form the results of Mr. Lesquereux's long, exhaustive and most careful study of the paleozoic plants of the United States.

The following is the classification:[4]

I. PRE-CARBONIFEROUS.

1. *Devonian.*
   Chemung (top division of No. VIII)=Middle Devonian.
   Catskill (No. IX), Upper Devonian.

2. *Pocono Sandstone* (No. X), including, in Pennsylvania, Sideling Hill Tunnel, Huntingdon County; Red shale, below Pottsville (Mount Carbon); Lehigh Gap, below Mauch Chunk; banks of the Susquehanna, above Pittston; (Lewis Tunnel and New River group, West Virginia.)

[1] The Permian or Upper Carboniferous Flora of West Virginia and Southwestern Pennsylvania, pp. 626-627.

[2] Description of the Coal Flora of the Carboniferous formation in Pennsylvania and throughout the United States. Vol. 1, cellular cryptogamous plants, Fungi Thalassophytes. Vol. 2, vascular cryptogamous plants, Calamaria, Filicacea (Ferns). By Leo Lesquereux, pp. 694, and atlas, 87 plates.

[3] Edited by J. P. L., pp. 617-635.

[4] Pp. 636-657.

3. *Subconglomerate:* Mauch Chunk, No. XI, including Fontaine's conglomerate series of West Virginia, and localities in Alabama, Tennessee, Arkansas, Illinois, Chester Group; Indiana, Chester Group; and *Megalopteris* beds of Ohio and Illinois.

4. *Interconglomerate,* No. XII, Campbell's Ledge, near Pittston, east Pennsylvania; Shamokin Gap, east Pennsylvania; Jackson Shaft bed, Ohio; Cuyahoga bed, Talmadge Summit beds, Ohio; Youngstown, Ohio.

II. COAL MEASURES PROPER.

1. *Anthracite fields.*

5. Beds A, B, and C, at Archibald, Carbondale, etc.
6. Beds D, E, F, at Pittston, Wilkes-Barre, Scranton, etc.
7. Bed G, Wilkes-Barre, etc.
8. Upper Anthracite (Salem, etc.).
9. Rhode Island, etc.

2. *Bituminous fields.*

10. Coal A, B, above the Conglomerate (both beds often united), at Murphysborough, Neeleyville, Marseilles, Colchester, Morris, Mazon Creek, Centralia Shaft, Vandalia, Illinois; at Burnt Branch of Caney, etc., Kentucky; at Massillon, Ohio.

11. Coal C (which is sometimes united to B), at Clinton, Missouri; Cannelton, west Pennsylvania.

12. Fourth Coal (under the Barren Measures), at Duquoin, St. John, Illinois; Nelsonville, Ohio; Coshocton, Ohio; Sullivan County, Indiana.

13. Upper Coal (top of the Barren Measures), at Pittsburg, Pennsylvania; Pomeroy, St. Clairsville, Barnsville, Ohio; Carmi, Illinois; Grayville and New Harmony, Indiana.

In this classification the base of the Pocono is regarded as the lowest formation of the Carboniferous system, although the line separating it from the Catskill below is stated to be "purely empirical."[1]

The Kinderhook Group of Illinois "is probably referable to the Pocono."[2]

J. P. Lesley, 1886, gave some valuable statistics regarding the Pittsburg coal region.[3]

The Pittsburg Coal Measures have an aggregate thickness of 2,000 feet, containing 15 persistent workable coal seams. Their outcrop lies in a northwest and southeast direction across the State, forming a series of concentric curves, due to the peculiar way in which the surface has been eroded. The Pittsburg seam is the fifth in descending order. It has been preserved from eroding effects in the southern part of the region only. The author sees no reason for disbelieving that this seam with its companions once extended into New York and northern Ohio, and even crossed Lake Erie and Lake Ontario into Canada, and he is firmly convinced that "they once had a quasi-continental outspread."

The Pittsburg seam has a thickness of 12 feet at Connellsville, Penn-

[1] Lesq., Desc. Coal Flora, p. 622.

[2] Ibid., p. 624.

[3] Lesley, J. P.: The Geology of the Pittsburg coal region. Am. Inst. Mining Eng., Trans., Vol. 14, 1886, pp. 618-656, plate.

sylvania, and 15 feet at George's Creek, in Maryland. At Pittsburg it is 8 feet thick, and its outcrop 350 feet above water level.

The Washington bed, also in the Upper Coal Measures, 150 feet above the Pittsburg seam, has a thickness in places of 11 feet, its average being only 3½ or 4 feet.

In the Lower Productive Measures occur the Freeport bed, having an average thickness of 4½ feet, and the Kittanning and Clarion beds.

The Upper Barren Measures are characterized by the absence of workable coal beds. They contain 17 different limestone beds. The most persistent is the Upper Washington limestone, which has an average thickness of 30 feet. These Measures also contain a number of sandstone strata, varying from 50 to 100 feet in thickness, and situated in the upper part of the series. They are not as persistent as the limestones already referred to. The thickness of this series is estimated at about 1,100 feet.

The Upper Productive Measures are also characterized by the predominance of limestone rocks, which form nearly one-fourth of the whole series. There is a great development of sandstones at the top, forming the cliffs along the river at Waynesburg. In this division occurs the Pittsburg coal bed.

The Pittsburg Barren Measures have an average thickness of 600 feet, and include four beds of massive sandstone: The Connellsville sandstone; the Morgantown sandstone, which is oil-bearing and 150 feet beneath the Pittsburg seam, and 50 feet thick; the Saltsburg sandstone; the Mahoning sandstone.

The limestones occur mainly under the Pittsburg coal seam and above the Connellsville sandstone. Two hundred and fifty feet below the former is the Crinoidal limestone, and 100 feet above the Mahoning sandstone is found the Black limestone. The coal of this division is of no commercial value.

In the Alleghany series the first geological survey recognized but six divisions, but the second geological survey found it necessary to subdivide each of the series into three parts. A curious feature of this series is that it contains cannel coal beds.

But one persistent limestone is recognized in this group, designated as the Ferriferous limestone, which has been used as a key for the location of the oil-sand deposits beneath. This is followed by the Pottsville Conglomerate (No. XII), composed chiefly of three massive sandstone subdivisons, small coal seams, and fossiliferous limestones; next lower is the Mauch Chunk Red shale (No. XI), containing the iron ores of Uniontown and the siliceous limestone so well developed at Blairsville and Trough Creek, Huntingdon County, Pennsylvania, and which to the south develops into the great Subcarboniferous limestone. It also appears in Ohio and Kentucky, and in the Mississippi Valley is known as the "Archimedes limestone."

The Mountain sandstone group (No. X), occurs about 760 feet below

the Pittsburg bed, where it has a thickness of 860 feet, and in Venango County of 650 feet. Its equivalent in Ohio and Kentucky is known as the "Knobstone formation."

Underlying these rocks is the oil-sand group, having a total thickness of 350 feet. The first oil-sand, known as the Gantz rock, was struck at Pittsburg, at 1,435 feet below low-water river level, and has a thickness of 112 feet. The second oil-sand is called the Fifty-foot rock, and the third (the Gordon rock) is 260 feet below the Gantz rock.

Concerning the Devonian rocks below the oil-sands little definite knowledge has been attained.

Frank A. Hill,[1] in 1887, made the following remarks about the correlation of the formation of the northern coal fields of Pennsylvania:

> The Northern coal fields are situated chiefly in Luzerne, Lackawanna, Susquehanna, and part of Wayne counties. "The Northern coal field" consists of a single curved, crescent-shaped basin, with its concave side facing northwest, and "locally divided into the Wyoming and Lackawanna valleys." The rock series consists, besides the coal beds, of shales, slates, sandstones, and conglomerates. The Pottsville conglomerate above the coal seams has an average thickness of 200 feet. The coal beds are so split up that in many parts of the valleys they bear different local names, suggesting no relationship whatever. In fact, so little is known concerning the coal beds, that it is at present impossible to make any definite statement concerning their identification and equivalency.

In 1888 Mr. J. J. Stevenson, as a member of the American committee, prepared a "Report on the Upper Paleozoic (Carbonic)," for the International Congress of Geologists, which contains the following classification of the Upper Carbonic:[2]

UPPER COAL MEASURES.

Synonyms and local subdivisions.

Pennsylvania, XIII in part, Monongahela series.	XVI	Upper Barren group	Greene group ..... Washington group — Permian.
	XV	Upper Productive group; Upper Productive Coal group.	
Virginia and West Virginia.	XVI, XV	Upper Coal Measures.	
Ohio		Upper Coal Measures.	
Indiana		Merome Sandstone. Upper Coal Measures.	
Illinois, Iowa, Kansas, Missouri		Upper Coal Measures.	
		Permo-Carbonic and Coal Measures in part.	
Western region		Permo-Carbonic and Upper Carbonic in part.	
Nova Scotia		Permo-Carbonic.	
New Brunswick		Upper Coal Measures.	

[1] Hill, Frank A.: Geology and mining in the Northern coal field of Pennsylvania. Am. Inst. Mining Eng., Trans., Vol., 15; 1887 pp. 699–707.

[2] International Congress of Geologists, London session. Reports of the subcommittees appointed by the American committee from its own members, assisted by associates, for the fourth session of the Congress to be held in London, September 17, 1888. D. Report of the subcommittee on the Upper Paleozoic (Carbonic). J. J. Stevenson, reporter. Pp. D4–D7.

MIDDLE COAL MEASURES.

Synonyms.

Pennsylvania, XIII in part, Alleghany River series { Lower Barren group ... } XIV. / { Lower Productive group } XIII.

Virginia { XIV / XIII } Middle Coal Measures.

Ohio ... { Barren Measures. / Lower Coal Measures in part.

Indiana ... / Illinois ... { Lower Coal Measures.

Iowa ... { Middle Coal Measures. / Lower Coal Measures in part.

Michigan ... Coal Measures.

Mississippi ... / Alabama ... / Tennessee ... / Missouri ... { Coal Measures in part.

Western region ... Upper Carbonic in part, Carbonic in part.

Nova Scotia ... / New Brunswick ... / Newfoundland ... { Middle Coal formation.

LOWER COAL MEASURES.

Synonyms and local subdivisions.

Pennsylvania, XII, Seral Conglomerate, Pottsville Conglomerate, Umbral in part.

Virginia and West Virginia, XII, Quinnimont group Lower Coal Measures.

Ohio ... Lower Coal Measures in part.

Indiana ... / Illinois ... { Conglomerate or Millstone grit.

Michigan ... Parma Conglomerate.

Alabama ... / Mississippi ... / Tennessee ... / Missouri ... { Coal Measures in part.

Nova Scotia ... / New Brunswick ... / Newfoundland ... { Millstone grit formation.

CHAPTER V.

THE CONGLOMERATES AND LOWER CARBONIFEROUS FORMATIONS OF THE APPALACHIAN PROVINCE.

Below the Pennsylvania Coal Measure series there are several thousand feet of Conglomerates, sandstones and shales, with occasional beds of limestones, and in localities showing thin beds of coal, which have been referred to the Lower Carboniferous. They present such differences in their stratigraphy in different localities that considerable difficulty has been experienced in correlating their several members. In general they represent the Mississippian series of the interior, and in some of the limestones fossils have been found establishing closer correlation. But they rarely show any marine fossils and their classification has been made almost entirely upon lithologic and stratigraphic grounds. The Conglomerate at the top has been correlated with the Millstone grit and classified as the base of the Coal Measures. The lower formations were called "Umbral" and "Vespertine" by the early geologists of the Appalachian province, "Mauch Chunk" and "Pocono" by the Second Geological Survey of Pennsylvania, and "Greenbrier" and "Pocono," by Stevenson in 1888.

The Second Geological Survey of Pennsylvania, besides the elaboration of the Pennsylvania series of Coal Measures, did good service in differentiating the formations immediately below, which were called in H. D. Rogers's nomenclature, "Umbral and Vespertine (Nos. XI and X)."

Mr. I. C. White also took a conspicuous part in this work. He was the author of the volumes on Lawrence County,[1] on Mercer County,[2] and on Susquehanna and Wayne Counties,[3] on Pike and Monroe Counties,[4] and on "The Geology of the Susquehanna River region, in the six counties of Wyoming, Lackawanna, Luzerne, Columbia, Montour, and Northumberland."[5] In these volumes, besides the detailed correlations of the outcrops of the several townships, constituting the bulk of the reports, there is the development of a systematic classification and nomenclature for the geological formations of the regions surveyed, which were chiefly of Lower Carboniferous and Upper Devonian age.

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[1] Second Geol. Surv. of Pennsylvania, Rept. of Progress. Q^2. Report on Lawrence County, and special report on correlation of the Pennsylvania and Ohio coal beds. By I. C. White, 1879, pp. 336.

[2] Q^3. Report on Mercer County. By I. C. White, 1880, pp. 233.

[3] G^5. Report on Susquehanna and Wayne Counties. By I. C. White, pp. 243. 1881.

[4] G^6. Report on Pike and Monroe Counties. By I. C. White. Report on the Delaware and Lehigh Water gaps. By H. M. Chance, pp. 407. 1882.

[5] G^7. Report on Wyoming, Lackawanna, Luzerne, Columbia, Montour, and Northumberland Counties, (i. e., the parts lying outside of the anthracite coal fields). By I. C. White, pp. 464. 1883.

In Report QQQ, 1880, the following are the chief members of the Conglomerate Measures (chapter V) as they appear in Mercer County:

Homewood sandstone.
Upper Mercer Iron Ore shales.
Mercer upper limestone (= "*Mahoning sandstone*," Rogers, 1858).
Mercer upper coal (= *Tionesta coal* of Lawrence County).
Mercer shales.
Mercer lower iron ore.
Mercer lower limestone.
Mercer lower coal.
Mercer lower ore shales.
Connoquenessing upper sandstone.
Quakertown over-shales and ore.
Quakertown coal bed.
Quakertown under-shales and ore.[1]
Connoquenessing lower sandstone.
Sharon coal riders.
Sharon upper shales and iron ore.
Sharon plant shales.
Sharon coal.
Sharon Conglomerate.[2]

In Report Q[4], 1881, the Sharon Conglomerate is said to be,

For the western and northern counties, the accepted representative of the whole or of the lower part of the "Ohio Conglomerate." In Warren and Venango Counties it is known under the name of "Garland Conglomerate." In McKean, Forest, Elk, Cameron, Clinton, and Potter Counties it is known as the "Olean Conglomerate." In Clarion, Butler, Mercer, Lawrence, and Beaver reports it is called the "Sharon Conglomerate." In the nomenclature of the oil drillers it is the "Second mountain sand."[3]

The formations next below the Sharon Conglomerate are called by Mr. White the "Subconglomerate formations."[4]

The name is applied to a series of deposits underlying the Sharon Conglomerate in Crawford and Erie Counties, and resting on the Venango oil sand group.

The Subconglomerate is subdivided into the following, viz:

	Feet.
Shenango group	75
Meadville group	205
Oil Lake group	162

The Shenango group consists of the following members:

Shenango shale.
Shenango sandstone.[5]

[1] "The Mountain limestone (Umbral, Mauch Chunk No. XI) or Maxville limestone, of southern Ohio, should be found here." p. 49.

[2] Called "Ohio Conglomerate" in QQ.

[3] Report Q[4], pp. 62, 63.

[4] These are well defined in chapters VII to XI, Report Q[4] 1881.

[5] This is the Ferriferous sandstone, Report QQ, p. 95, sub-Garland conglomerate of the oil region reports; sub-Olean conglomerate of McKean, etc., reports; upper Pocono sandstone (Vespertine) *No.* X; and it is the flat-pebble conglomerate first recognized as such by Mr. Carll (see p. 81)

The Meadville group consists of—

Meadville upper shales.
Meadville upper limestone.[1]
Meadville lower shales.
Sharpsville upper sandstone.
Meadville lower limestone.
Sharpsville lower sandstone.
Orangeville shales.

The Oil Lake group is correlated with the Berea grit of Ohio, the Pithole Grit of Venango, and the Pocono sandstone, No. X, of more eastern sections in Pennsylvania.[2] It is composed of the—

Corry sandstone (=Third Mountain sand of Venango).
Cussewago limestone.
Cussewago shales (=Bedford red shale formation of Ohio).
Cussewago sandstone.

Regarding the formations below this there was still (1881) considerable difference of opinion among the several members of the Second Survey of Pennsylvania. Mr. White, in Report QQQQ, correlated the outcrops of Erie and Crawford Counties as follows:

Venango oil sand group:
Venango upper sand (first oil sand).
Venango upper shale.
Venango middle sandstone (second oil sand).
Venango lower shales.
Venango lower sandstone.... { Le Bœuf conglomerate. / Panama conglomerate. / Third oil sand.

The author reported Chemung fossils from the Venango upper sand, the lower shales, and the lower sandstone.

The author correlated the Venango as "at least in part of Chemung age." He had identified Chemung fossils in the higher Riceville shales.[3] In a foot-note[4] he stated that he was "disposed to look upon the *Venango group* as Upper Chemung," and "on account of the fossils, I should prefer to call these [called Chemung in the text] Lower Chemung." The State geologist, however, objected to this interpretation and in the prefatory letter stated his objections. The substance of this objection is expressed in the following clause:

> Thus the matter stands at present. Geologists who insist on fossil forms will call the Venango group *Upper Chemung*, and will explain the McKean sections by a total disappearance of the oil sand in an increased mass of red beds. Geologists who insist upon lithological data will call the Venango group Catskill, or even Pocono, in spite of Chemung fossils.[5]

The latter course appears to have been Mr. White's preference. Below

[1] Containing fossils which the author concludes indicate correlation with the Lower Keokuk or Upper Burlington.
[2] See Q^4 chapter x, pp. 91–96. [3] Q^4, p. 97. [4] Q^4, p. 117. [5] Q^4, p. xi.

the Venango group in this report are the "Middle Devonian rocks (Chemung, Girard, Portage, No. VIII.)" They are composed of—

	Feet.
Chemung	325
Girard shales	225
Portage flags	475

Mr. White considered the interpretation of the Venango group in Erie and Crawford Counties as of great importance. He said:

> This identification [of the third Venango oil-sand with the LeBœuf conglomerate] I account the most important discovery to which my survey of the district has given rise.[1]

The importance of the correlation is further testified to by the State geologist, J. P. Lesley, who in his letter of transmission wrote:

> The cost of this survey has been justified merely by one result (setting aside the rest), namely, the determination by sufficient evidence that the *third oil sand* of Venango County is the quarry rock of Erie County, and that this deposit in crossing Erie County changes its character from a muddy sandstone in the western townships to a coarse gravel rock east of Le Bœuf Creek, becoming the Panama conglomerate in the State of New York; everywhere charged with a peculiar group of fossil shells and seaweed, and with petroleum, which has evidently resulted from their decomposition.[2]

The method of this determination was in the first place physical and not by fossils. The average dip and direction of dip were ascertained by the comparison of altitudes of the third oil sand in the numerous wells. With this assumed rate of rise on going northward, outcrops were identified by their altitude; these were followed from ravine to ravine or quarry, and the rocks in the quarries were then defined, their fossils identified, and thus their position in the chronologic scale determined. Although the same method was practically used by both Mr. White and Mr. Carll, when their tracings of correlation had reached Chautauqua County the result was that Mr. White correlated the Panama conglomerate with the third oil sand of Venango County, while Mr. Carll placed it entirely below his Venango oil group.

The fact seems to be, as we review the records of the survey, that the data of lithologic character of rocks and of thickness of the deposits were so constantly variable that the "theory of persistent parallelism of strata" was little more than a theory, the exceptions to which were as numerous as the illustrations. It was a cut-and-try system of matching together innumerable sections, made up of irregular combinations of shales, sandstones, conglomerates, and limestone of various color, thickness, and texture. Whenever the gaps were over a mile or two long the adjustment of the theoretical dip, a few feet more or less to the mile, would enable the parallelism to fit any particular stratum in a given section. The fact that those who showed evidence of having noted the fossils, although they may not have identified them, were

[1] Q⁴, p. 101. [2] Q⁴, p. VII.

invariably nearer right than those who neglected them, strengthens the belief that the fossils, even in this case, were the most valuable means of correlation.

William M. Fontaine,[1] in 1877, published some notes on the Vesper tine of the Virginias. The area occupied by the Vespertine in the two Virginias is limited by the main Alleghany in the northern and middle portions, and by Peter's and East River Mountains in the southern portion. The Vespertine rocks compose the middle portion of the main Alleghany from the Potomac to Pocahontas County. The author gives an account of the structure of the country and the geographical distribution of the Vespertine strata, as well as that of the underlying rocks, showing great distortion of the rocks and numerous faults. Two of the detached belts of Vespertine east of the limit mentioned are spoken of in detail, the first occurring on the east flank of the Alleghany Mountains, near White Sulphur Springs, containing coal strata and plant impressions, and showing the strata lying immediately above the Chemung, with the junction of this last with the lower portion of the Vespertine; the second belt more important and extended, about thirty miles east of the last, commencing in the northern part of Virginia, in Berkeley County, and extending south through the State. In the northern and middle portions the coal-bearing member of the Vespertine lies under the inverted massive sandstones of the lower member, and is found on the west side of the mountain, while in the southern part of the State, where the Vespertine strata are not inverted, the coal-bearing member lies on the southeastern face of the mountain. As all the strata, including the coals, thicken to the eastward, the Vespertine coal field must have extended much further in that direction than any remnant now to be seen, the belt of country over which well defined coal beds were formed being more than 300 miles long and 50 wide.

The author considers the most natural upper boundary of the Vespertine in the Virginias to be the base of the "Lewisburg limestone" (p. 43), which he correlates with the St. Louis and Chester groups (p. 44).

The Vespertine strata on Greenbrier River are described, the red upper member attaining a thickness of 250 feet, but thinning out to the north; the middle member, 290 feet thick, having about 70 feet at the top of bluish gray sandstone overlying 40 feet of thinly bedded gray flags, with fully 50 thin strings of carbonaceous matter distributed through them, but with a considerable coal bed a little farther north. Above this carbonaceous portion are 120 feet of firm gray and brownish sandstones, and then 40 feet of very flaggy, gray, soft sandstones and shales, with some layers of fissile black shale containing indistinct vegetable impressions, mostly leaves of *Lepidodendra*. At the base are 20 feet of dark gray, compact, fine-grained sandstone.

At Lewis tunnel the base of the Vespertine shows a rock not brought up at Greenbrier River; a white, pebbly, highly siliceous sandstone, 60

[1] Fontaine, William M. Notes on the Vespertine strata of Virginia and West Virginia. Am. Jour. Sci., 3d ser., 1877, vol. 13, pp. 37-48, 115-123.

feet in thickness, and one of the most persistent and characteristic members of the Vespertine. With this should probably be counted 500 feet of underlying, more argillaceous flags, giving a total of 560 feet for the lower member of the strata in this section. The middle member, 350 feet thick, is characterized by the predominance of gray sandstones containing coal. The upper member consists almost entirely of red marlites, with a thickness of about 250 feet, giving the group a total thickness of 1,160 feet. Although the author does not altogether agree with Prof. Rogers in his measurements, he thinks that they show a considerable thickening of the red overlying strata to the south.

In Augusta County there is great contortion and disturbance of the strata. To the west of this they have suffered much from erosion, and show only the lower and middle members. The Vespertine of Montgomery County is treated at great length. The two areas of Brush Mountain and Price's Mountain, separated from each other by a narrow belt of Lower Silurian limestone, are described, and a detailed section of the lower and middle members of the series exposed at Brush Mountain is given. The lower member shows a thickness of 930 feet, and the middle member is 670 feet thick, but the upper red member is much better displayed at Price's Mountain, where it has a thickness of 1,090 feet.

The conclusion drawn by the author from the facts stated is "that there has been a very marked thickening of the Vespertine as we proceed from north to south through the State, accompanied by an increase in the amount of coal contained in it. This increase seems to be largely at the expense of the supposed Catskill beds. It is in conformity with a law of increase which holds good for all the strata from the Devonian to, and including, the Lower Barren Measures of the Upper Coals."[1]

But few species of plants were found, but these were marked by the great number of individuals exhibited. The most important were forms of *Lepidodendron*, *Pataeopteris*, and *Triphyllopteris*, and one specimen of *Neuropteris*.

In 1878,[2] C. A. Ashburner, reported the following section across southern Huntingdon County.[3]

	Feet.
XIII. Carboniferous, Lower Productive Co al Measures, Alleghany River series	256
XII. Pottsville Conglomerate (= Seral Conglomerate)	280
XI. Mauch Chunk (Umbral) red shale and Mountain limestone	
XIc. Upper Mauch Chunk shales and sandstones	910
XI*b*. Mountain limestone	49
("Lewisburg limestone" of the Greenbrier region in Virginia; St. Louis and Chester limestone of the Mississippi Valley.)	
XI*a*. Lower shales and sandstones	141

[1] P. 122.

[2] Geol. Survey of Pennsylvania, Report of Progress, F: Report on the Juniata River district in Mifflin, Snyder, and Huntingdon Counties, by J. H. Dewees; and on the Aughwick Valley and East Broad Top region, in Huntingdon County, by C. A. Ashburner, 1878, pp. 305.

[3] Report of Progress, F, pp. 184–260,

X. Pocono (Vespertine) sandstone.			
	Xd. Upper gray sandstone group	610	2,133
	Xc. New River coal series	313	
	Xb. Middle Conglomerate group	380	
	Xa. Lower green sandstone group	830	
IX. Catskill (Ponent) Old Red sandstone.			
VIII. Lower Devonian series.			
VIII. D. Chemung	b Transition beds	90	
	a Olive (Vergent) shales	860	
VIII. C. Portage (Vergent flags)		1,450	
VIII. B. Hamilton	c Genessee (Cadent, upper) slates	325	
	b Hamilton's Cadent shale	635	
	a Marcellus (Cadent, lower) black slate	875	
VIII. A. Upper Helderberg Corniferous (Postmeridian) limestone		60	
VII. Oriskany (Meridian) sandstone		58	

Etc. through the Lower Paleozoic.

In 1880 Mr. Ashburner completed and published his report[1] on the geology of McKean County. During the reconnoissance survey in 1876 he had collected a large number of fossil specimens. He was unable to arrive at any "satisfactory conclusions as to a systematic division of the strata." He "finally decided to group the strata by a study of their lithology, and on this basis to seek to make a connection with sections in those portions of the State where the structure had been clearly defined."[2] As a result of his studies he published, as one of the sheets, Plate XI.[3]

During the construction of this sheet he indicated the groups of rocks by letters "A, B, C." After it was finished he determined, by comparison with the sections of adjoining counties, the correlations, and the highest, A, he called "Pocono," B "Catskill," and C "Chemung."

In this report the Olean Conglomerate formed the conspicuous base of the Pottsville Conglomerate series, or No. XII of the old classification. This was, for Ashburner, the base of the Coal Measures and was the equivalent of the Ohio Conglomerate.[4]

Below this conglomerate he reported a series of 500 to 800 feet of rocks which he was obliged to correlate with the Mauch Chunk shales (XI), Pocono sandstone (X), and Red Catskill (IX) of other parts of the State; but the few fossils obtained appeared to him so mingled and to range so throughout the whole series that he could not subdivide them satisfactorily. Eighteen species, he reported, "are identical with characteristic Waverly species," "seven with Chemung species," and he says:

> I am thoroughly convinced that these rocks hold a fauna which is essentially a unit incapable of subdivision, and that this fauna is decidedly of a Subcarboniferous age.[5]

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[1] Geol. Survey of Pennsylvania, Report of Progress R: Report on McKean County, and its geological connections with Cameron, Elk, and Forest Counties, by C. A. Ashburner; pp. 371, 1880.

[2] Report of Progress R., page 29; also see page 292.

[3] A series of columnar sections constructed from surface observations and the records of eleven oil wells situated between Bradford, in McKean County, and Ridgeway, in Elk County, showing the relation of the Lower Carboniferous coal beds to the Bradford oil-producing sand and the thickening of the subconglomerate rocks. J. P. Lesley, State geologist; Chas. A. Ashburner, assistant geologist; A. W. Sheafer, aid.

[4] Report of Progress R, pp. 56, 62.

[5] Ibid., p. 30.

In western Pennsylvania the development of the oil industry furnished a means of geological correlation not before accessible. The great number of oil wells distributed over large areas in western Pennsylvania (and since then wells have been drilled in almost every State in the Union), where the records were preserved and studied, furnished data of levels attained by particular formations under the surface.

Mr. John F. Carll, one of the geologists of the second geological survey of Pennsylvania, collected these data, coordinated them, and elaborated from the records a classification of the formations. His results are contained in Reports of Progress I, II, III, and IIII.[1] In the first of these reports (I) the origin of the name *oil sands* is explained. In the early drilling for oil in Venango County, the drillers, recognizing these sands in their wells in Oil Creek, distinguished them by the term *oil sands*. When the higher ground was perforated the sandstone layers supposed to lie above the horizon of the three oil sands of Oil Creek were called "mountain sands."

Thus it came about that the series of shales and sandstones, about 350 or 400 feet thick, containing the three petroleum-bearing sands of Oil Creek, Venango County, were named the "Petroleum Measures of Venango, or Division of the Three Sands or Oil-sand group," and the rocks above, up to the base of the Conglomerate No. XII, were called the "Mountain sand group or Barren oil measures."

In this report the following equivalences were proposed:

First mountain sand = Upper Berea grit, No. X.
Second mountain sand = Lower Berea grit?

The fact of the conspicuous development of the three sand layers in the wells of Venango County suggested the name "Venango oil-sand group," which was definitely proposed and defended by Mr. Carll in his third report.[2]

Prof. Lesley, in his letter of transmission, says of this report:

The main feature of the report is the settlement of the true character of the Venango oil-sand group as a distinct and separate deposit, with characteristic marks distinguishing it from the Paleozoic formations of a preceding and a succeeding age; the differentiation of the group into three principal and other subordinate layers of gravelly sand, holding more or less oil and gas; the local variability of these sands; their singular persistency beneath long and narrow belts of country; their change into barren shales elsewhere, and their independence of other oil-bearing sands and shales of an earlier and of a later date.[3]

Mr. Carll proposed the name "Garland Conglomerate" for the lowest member of the Carboniferous Conglomerate series in the part of the

[1] I. Geol. Survey of Pennsylvania, Rept. of Progress: I. Report on Venango County, by J. F. Carll; the geology around Warren, by F. A. Randall; notes on the comparative geology of northeastern Ohio, northwestern Pennsylvania, and western New York, by J. P. Lesley, 1875, pp. 127.

II. Report of oil well records and levels in Venango, Warren, Crawford, Clarion, Armstrong, Butler, etc., by J. F. Carll, 1877, pp. 398.

III. Report on the Venango, Warren, Clarion, and Butler oil regions, by J. F. Carll, pp. 482. 1880.

IIII. Report on Warren County, by J. F. Carll, pp. 439. 1883.

[2] I[3], p. 130.

[3] Rept. of Progress, I[3], pp. vi, vii.

State studied by him.[1] He correlated it with the Olean Conglomerate of McKean County, the Sharon Conglomerate of Mercer County, the Ohio Conglomerate of Ohio, and the Second Mountain sand of the oil wells.

"Sub-Garland sandstone" was used for Mr. Ashburner's "Sub-olean" and Mr. White's "Shenango sandstone." In chapter VI the author, by the application of the methods of correlation suggested by his experience with oil well records, determined the Panama Conglomerate of Chautauqua County, New York, first, to be older than the Olean or Garland Conglomerate; second, to be neither of the Venango oil sands; and third, to be of Chemung age by lying below the horizon of the Venango oil sand group.[2]

He pointed out the important distinction that the pebbles of the Panama Conglomerates are almost always lentiform or flat in shape, while the pebbles of the higher Carboniferous Conglomerates are irregularly spheroidal.[3]

By the same methods he argued that the place of the Salamanca Conglomerate is above the Panama Conglomerate.[4] Again, he correlated the "First Mountain sand" with the Conoquenessing sandstone of Butler County and the Kinzua Creek sandstone of McKean County; the "Second Mountain sand" is a synonym for the Garland Conglomerate; for the "Third Mountain sand" of the earlier reports of the oil men, he proposed the name "Pithole grit," which he considered equivalent to the Berea grit of Ohio.[5]

The author prepared the following generalized section of the formation from the Upper Barren Coal series of Greene County, Pennsylvania, down to the Corniferous limestone, which will show his interpretation of the series as the result of a detailed study of oil well records:[6]

		Feet.
1.	Upper Barren Coal Measures, B. Greene County group, from top to Washington upper limestone... Upper Barren Coal Measures, A. Washington County group, extending to Waynesburg sandstone..	600 350
2.	Upper Productive Coal Measures, to base of Pittsburg coal	475
3.	Lower Barren Coal Measures, to top of Mahoning sandstone	500
4.	Lower Productive Coal Measures, to top of Conglomerate No. XII	400
5.	Mountain Sand series, to base of Olean-Garland-Ohio Conglomerate	∓375
6.	Crawford shales, to top of Venango Oil group	∓450
7.	Venango Oil group, from top of "First Oil Sand" to bottom of the "Third Oil Sand"	∓350
8.	Interval between the Venango Oil group and the Warren Oil group	±300
9.	Warren Oil group	300
10.	Interval	400
11.	"Bradford Third Sand"	20 to 80
12.	Interval between the Bradford "Third Sand" and the Corniferous lime stone, commencing in the Chemung and including the Portage and Hamilton groups of the New York Geological Survey	1,600
13.	Corniferous limestone	

[1] Rept. of Progress, I[3], p. 13. [2] Ibid., p. 77. [3] Ibid., p. 60. [4] Ibid., p. 79.
[5] Ibid., p. 82, and chapter 8, p. 91. [6] Rept. of Progress, III, pp. 156–164.

Mr. Carll further discussed the Conglomerates in his report on Warren County.[1]

The Pottsville Conglomerate No. 12 was subdivided into upper, middle, and lower beds, called "Johnson's Run rocks," "Kinzua Creek sandstone," and "Olean Conglomerate."

He correlated these with "Homewood sandstone," "Conoquenessing sandstone," and "Sharon Conglomerate" of the reports Q, Q^2, Q^3, and Q^4. And he proposed to drop the name "Garland Conglomerate" as a synonym for the Olean Conglomerate of Mr. Ashburner's report on McKean County.[2]

In the chapter on the Panama Conglomerate Mr. Carll defended his former opinion that the Panama Conglomerate is not equivalent to any member of the Venango group but stratigraphically is below it, against the view published by Mr. White in Q^4, that the Panama represents the Third oil sand of the Venango oil group. Mr. White claimed the equivalency upon evidence of fossils. Mr. Carll objected to the recognition of the Venango group as Chemung, on account of the absence of any Chemung fossils in any of the members of that group as seen in the Venango County sections.[3] Mr. Carll's method was based upon the theory of the persistent parallelism of strata. While for short distances and in certain directions no doubt the dominant character of the strata could be traced, often this theory utterly failed him, as he confessed in a foot-note on page 205, where, discussing the relations of the sub-Olean and Salamanca Conglomerate across Warren County, he says:[4]

> Sometimes no trace of the particular sand rock sought for could be found in *proper place*, and instead of it other massive pebbly strata would obtrude themselves, 100 feet too high or 100 feet too low to fit into the places where, according to our theory of persistent parallelism of strata, they ought to belong.

In report V[5] Mr. Chance discusses the "geology of northern Butler and parts of Beaver, Lawrence, and Mercer Counties." Aside from the detailed geology the most important contribution toward the development of the classification of the Pennsylvania rocks was his analysis of the Coal Measure Conglomerate, No. XII. The following table exhibits it:[6]

Coal Measure Conglomerate, No. XII. =Beaver River series.	Homewood Sandstone. Mercer group, coals. Conoquenessing group, sandstone. Sharon group, coal and shales. Ohio Conglomerate.

[1] Rept. of Progress I^4, 1883.

[2] Ibid., p. 185.

[3] Ibid., p. 195, et seq.

[4] Ibid., p. 205, foot-note.

[5] Geol. Survey of Pennsylvania, Report of Progress V. Report on northern Butler County; and (Part 2) special report on the Beaver and Shenango River Coal Measures, by H. M. Chance, 1879, pp. 248.

[6] Ibid., p. 188.

Another table shows the difference between his interpretation and that of Mr. Carll:

	Feet.		
Homewood Sandstone	30	No. XII, according to Mr. Chance.	
Mercer group	30	Feet.	
Connoquenessing group	155	265	
Sharon group	10		435 feet. No. XII, according to Mr. Carll.
Sharon Conglomerate (Ohio Conglomerate)	40		
Sharon upper shales	30		
Sharon upper sandstone	15	170	
Sharon middle shales	75		
Sharon lower sandstone	50		

	Feet.
Crawford upper (Cuyahoga) shales	135
Berea grit (Third Mountain sand of oil men, Carll)	75
Crawford lower (Bedford red) shales	--

The last three members of this table, classed together, were called "Crawford shale group" by J. P. Lesley.[1]

In the Report of Progress, G⁴,[2] Mr. H. Martin Chance published as Part Second, "A Special Study of the Carboniferous and Devonian strata along the West Branch of the Susquehanna River."[3] At the time this report was written the Coal Measures series had been fairly well studied, the Conglomerate as a base was established, and the eastern section had been particularly well surveyed, classified, and compared with that of Ohio. The northwestern sections of the State had been examined and great difficulties had been found in identifying the various members.

Dr. Newberry, in the third volume of the Geology of Ohio, had reported "that the Vespertine connects throughout this gap with the Waverly, but the Umbral and Catskill do not reach Ohio."

Mr. Chance says that—

> The Mauch Chunk red shale, No. XI, and the Red Catskill, No. IX, diminish in thickness rapidly from the Alleghany Mountains westward, so that in a few miles the latter entirely disappears; whereas the Pocono (Vespertine, No. X) thins gradually for a few miles, then maintains a nearly constant thickness for 90 miles, when it rapidly loses its lower half by a rise in the Chemung floor at the oil-sand shore line and again stretches away to the west, with a nearly constant thickness, for 100 miles or more.
>
> Among other causes productive of erroneous identifications in the northwestern counties, insufficient paleontological data may be mentioned. The lines of demarkation between Subcarboniferous and Catskill and between Catskill and Chemung fossil horizons are not uniformly drawn by paleontologists, and as—from the conditions essential to the growth of shellfish—it seems certain that there must (at some points) be an overlapping of the fossil fauna of one formation into that above it, the structuralist can not accept unquestioningly an identification supported by paleontological evidence alone.

His correlations are well expressed in detail in a "Table showing the

[1] I⁴. See foot-note, p. 224.

[2] Geol. Survey of Pennsylvania, Report on Clinton County, by H. M. Chance; including a description of the Renovo coal basin, by C. A. Ashburner; and notes on the Tangascootac coal basin, by F. Platt, pp. 183, 1880.

[3] Ibid., pp. 79–174.

proposed nomenclature of the Carboniferous and Devonian rocks of eastern Pennsylvania and Ohio."

		Eastern Pennsylvania.	Western Pennsylvania.	Ohio.
Carb	XIII	Coal Measures	Coal Measures	Coal Measures.
	XII	Conglomerate	Conglomerate series	Sandstone and shale with coals 1, 2, 3.
Subcarb.	XI	Mauch Chunk red shale	Red or dark shales.	
	X	Pocono sandstone	Upper (gray) Pocono	Cuyahoga and Berea grit.
			Lower (red) Pocono=oil-sand group.	Bedford shale. Cleveland shale.
Devonian	IX	Catskill	Absent	Absent.
	VIII	Chemung	Chemung	Erie shales. Huron shales.
		Portage	Portage.	
		Hamilton	Hamilton (?)	
		Corniferous limestone.	Corniferous	Corniferous limestone.

In order to explain the difficulties in correlating the deposits below the great Conglomerate, No. XII, Mr. Chance assumed that there was a basin during the deposition of the Catskill rocks, the western limits of which swept approximately through Potter, Cameron, Elk, Jefferson, Armstrong, and Westmoreland Counties; that along this line, or somewhat westward of it, a sudden rising into shallow water, or to shore line conditions, prevailed in the Catskill and Pocono time. This explains, as he thinks, the accumulation of oil-sands along such a shallow bottom, while further out the Catskill deposits were forming.[1]

Mr. Stevenson,[2] in 1887, presented some new views regarding the correlation of the Umbral and Vespertine in the southern extension of the Appalachian province. He stated that Prof. Roger's division of the Lower Carboniferous into Umbral and Vespertine, seems correct for the eastern side of the Appalachian area, but in southern Pennsylvania and Virginia there are variations worthy of study.

The Umbral deposits in Pennsylvania consist of red shales and shaly sandstones, and were afterward called by Prof. Lesley the "Mauch Chunk."

The limestones first noticed in Maryland increase rapidly in thickness westwardly.

The Vespertine consists of sandstone and shales, with occasional coal seams, and varies in thickness from 1,300 feet in Huntingdon County to 400 feet in Fayette County.

Owing to the faulted condition of the rocks in southwest Virginia, good sections of Lower Carboniferous rocks are shown from the Tennessee line to Giles County. The rocks do not change materially until we come within 75 miles of the Tennessee line. In this direction the Vespertine thins out more rapidly than the Umbral rocks, which in Pulaski and Bland Counties contain streaks of coal. In Smyth County,

[1] A diagram is given illustrating this view on p. 114 of the Report.

[2] Stevenson, J. J.: Notes on the Lower Carboniferous groups along the easterly side of the Appalachian area in Pennsylvania and the Virginias. Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 37-44.

the Umbral, as well as the Vespertine, is scarcely noticeable, while the increasing limestones form the most important feature.

The Umbral of Pennsylvania, Maryland, and the Virginias is equivalent to the Chester and St. Louis groups of the Mississippi Valley, and it may include the Keokuk; while in the Vespertine must be sought the equivalents of the Burlington, and possibly of the Kinderhook.

In 1888 Mr. Stevenson, as one of the members of the American committee, prepared a report on the Upper Paleozoic (Carbonic) for the International Congress of Geologists. In this report the classification and synonomy of the Lower Carbonic is given as follows:[1]

GREENBRIER.

Synonyms and local subdivisions.

Pennsylvania XI, Umbral, most of; Mauch Chunk, most of; Shenango shale?
Ohio ... { Maxville limestone.. / Logan series ..... } Waverly group, in part.
Virginia XI ..... Greenbrier group.
Tennessee.. / Alabama... } ..... { Mountain limestone. / Siliceous group.
Indiana ..... Mountain limestone.
Michigan.. / Illinois.... / Iowa..... / Missouri .. } ..... { Chester group. / St. Louis group. / Keokuk group.
Nova Scotia..... / New Brunswick.. / Newfoundland ... } Windsor group.

POCONO.

Synonyms and local subdivisions.

Pennsylvania X, Vespertine, Pocono ..... { Shenango group. / Meadville group. / Oil Creek group, in part.
Virginia X ..... New River series.
Ohio: Waverly group, in part ..... { Cuyahoga shale. / Berea shale and grit. / Bedford shale. / Cleveland shale.
Tennessee / Alabama. } .....Absent, or represented by the lowest beds of the Siliceous group.
Indiana ..... Knobstone group, in part.
Illinois ..... Burlington group.
Iowa ..... Kinderhook group.
Michigan ..... { Michigan salt group. / Marshall group.
New York ..... Upper part of the Catskill gray sandstones.
Nova Scotia ..... Horton series.
Eastern Quebec ..... Bonaventure series.

[1] See Report, D, pp. 7, 8.

CHAPTER VI.

THE CHEMUNG-CATSKILL PROBLEM: THE HISTORY OF THE DISCUSSIONS CONCERNING THE CORRELATION OF THE CHEMUNG AND CATSKILL FORMATIONS IN THE NORTHERN PART OF THE APPALACHIAN PROVINCE.

In the year 1862 the discovery by Mr. J. M. Way, in the rocks of Franklin, Delaware County, New York, of fish bones, in association with Chemung fossils, raised doubt as to the validity of the correlation of the deposits. The rocks had previously been considered as Catskill, or Old Red sandstone. The fish remains discovered were regarded as characteristic fossils of the Catskill group. The marine fossils found in the same rocks had been regarded as typical Chemung fossils.

Col. E. Jewett, then curator of the State Museum at Albany, announced that "From my investigations I believe there is no Old Red sandstone in this State."[1] The letter communicating this determination was dated "Albany, September 20, 1862."

The same facts led Mr. James Hall to the following judgment:

> Late investigations, combined with those heretofore made, have forced upon me the conviction that the greater part of the area colored on the geological map of New York as *Catskill group*, is in fact occupied by the Portage and Chemung.[2]

Again—

> Until we ascend the slopes of the Catskill Mountains and rise to an elevation of at least 2,000 feet above tide water, we find no rocks of newer age than the Chemung.[3]

And again—

> It now becomes necessary to restrict the term *Catskill group* to the beds formerly known as x and xi of the Pennsylvania survey.[4]

This announcement, as Alexander Winchell wrote[5] in a letter to James D. Dana, dated December 10, 1862, produced "a sensation among geologists," and led to discussions extending over a number of years.

In this letter Winchell spoke of Jewett's announcement[6] of disbelief in the existence of the Catskill group in the State of New York, and recalled his own disbelief in its existence as a distinct group, and his

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[1] Am. Jour. Sci., 2d ser., vol. 34, p. 418. Also 15th Ann. Rep. State Cabinet of Nat. Hist., Albany, 1862, p. 198.

[2] On the Catskill group of New York, by Prof. James Hall. A letter addressed to Principal Dawson, dated Albany, October, 1862. Canadian Nat. and Jour. of Sci., new series, vol. 7, p. 377.

[3] Ibid., p. 380.

[4] Ibid., p. 381.

[5] See also "James Hall. Remarks on absence of Catskill group in New York." Albany Inst. Trans., vol. 4, 1863, pp. 307, 308.

Winchell, Alexander, on the identification of the Catskill Red Sandstone group with the Chemung (in a letter to J. D. Dana). Am. Jour. Sci., vol. 35, 1863, pp. 61, 62.

[6] Am. Jour. Sci., vol. 34, p. 418.

doubts of the Devonian character of the Old Red sandstone of New York when he had previously announced his conviction of the equivalency of the Marshall and Chemung groups, and of their common Carboniferous character. Since that time the confirmation of his doubts led Winchell to include within the Marshall (Chemung) group the Old Red sandstone of New York.

In his researches among the rocks of this age, the writer found an almost universal generic identification, establishing fully the equivalency of the Chemung, Marshall, Ohio, Rockford, Burlington, and Chouteau strata. He gives as evidence that these localities are all of Carboniferous age: "First, the fact that of the 135 species now known from the yellow sandstones of Burlington no less than 40 ascend into the base of the Burlington limestone, while 2 rise to the upper portion of it, and 1 recurs in the Coal Measures; second, the fact that of the known species of this horizon, at least 9 occur in the Coal Measures, or upper part of the Carboniferous limestone; while third, multitudes of species are clearly the local representatives of European and American Carboniferous types." Mr. Hall's declaration in the Canadian Naturalist "that large areas of the rocks of New York hitherto regarded as Chemung, do really fall within the limits of the Hamilton group," is said to account for the Devonian aspect of *some portions* of the Chemung fauna, as heretofore understood, and, Winchell adds, "tends to confirm a broad generalization, and complete the adjustment of American to European Paleozoic formations."[1]

Mr. James Hall[2] in 1870 announced that he had previously regarded the so-called "Montrose sandstone" (of Pennsylvania) and "Oneonta sandstone" of Vanuxem as lying above the Chemung rocks. The same views were held by Mr. Mather, who made the Montrose and Oneonta series equivalent to the upper part of the Catskill rocks. Further examination proved this conception of their relations to be erroneous and brought out the following parallelism of the groups in the eastern and western parts of the State:

Old Red sandstone of Tioga, etc.:	Catskill Mountain sandstone:
Chemung group.	Chemung group.
Portage group.	Oneonta group.
Hamilton group.	Hamilton group.

The Oneonta sandstone does not occur in the central part of the State, and its western extension has not been traced beyond Chenango County.

In 1875 Mr. Hall[3] again referred to the age of the Catskill formation.

In 1870 it was the prevalent opinion that, contrary to the author's statements, the Old Red sandstone did not exist in New York State.

[1] Regarding the development of Winchell's views on the correlations here announced, see the chapter on the Waverly Problem.

[2] Hall, James: On the relations of the Oneonta Sandstone and Montrose Sandstone of Vanuxem with the Hamilton and Chemung groups. Am. Nat., vol. 4, 1870, pp. 563-565.

[3] On the geology of the southern counties of New York and adjacent parts of Pennsylvania; especially with reference to the age and structure of the Catskill Mountain Range. Am. Assoc., Proc., vol. 24, pt. 2, pp. 80-84; Am. Jour. Sci., 3d ser., vol. 12, 1876, pp. 300-304.

Further examination proved its existence, as well as the occurrence of higher formations. From these additional facts a map was constructed, colored to represent the different formations. The Catskills consist of a series of nearly parallel synclinals and anticlinals, with a southwest and northeast strike, running from the base of the Catskill range "to the western limit" of the red rocks in Chenango County. This continues to the western part of the State, but before reaching the boundary of western New York and Pennsylvania, it probably thins out entirely. In the southern part of New York State the synclinals show traces of the Coal Measures, while others are cut down to the Chemung.

The author states the difficulties that have arisen in determining the relation of the Chemung and typical Catskill. In some localities the Chemung fauna runs above its apparent horizon, and even mingles with Carboniferous forms. This fact is especially important when we attempt to determine the limit between the Devonian and Carboniferous formations. In the section exhibited which runs across the Catskill range from Schenevus to Glasco, the Portage and Chemung rocks have a thickness of over 2,000 feet, the Red Rocks of the Catskill about 3,000 feet, and the Vespertine beds about 800 feet.

He stated in 1880[1] that he found long ago that the Catskill Mountains of New York consist of Devonian rocks of Chemung and Catskill epochs, resting unconformably on Silurian rocks. Mr. Arnold Guyot in his observations found that the highest points of this region were on Slide Mountain, 4,205 feet, and the Panther, 3,828 feet above tide level. "As to structure, the beds show weak plications whose axes are parallel with those of the Alleghany system, but the mountain ranges were at right angles to the system, or from northwest to southeast." This anomaly is explained by erosion. "The general level descends westward."

The work of the Second Pennsylvania Survey had been conducted, up to 1880, or up to the time of preparing the reports published in 1880, on the plan that correlations could best be made by lithologic and stratigraphic means. Frequently one meets with expressions of lack of confidence in the evidence offered by the fossils.

In the correlation of the Coal Measures and as far down as the Catskill the fossils were not discovered frequently enough to serve as satisfactory means of correlation. In this case lithologic character, thickness, and stratigraphic order were the data which by aid of actual altitude of the strata in individual sections enabled the geologist to trace dominant formations from one township to another and from county to county. But as the work progressed, different geologists having charge of groups of two or three counties, the correlations at the edges of contiguous counties were constantly presenting disagreements.

The formations, where fossils were not present stubbornly to resist

[1] Hall, James: The geology and topography of the Catskill Mountains. Am. Nat., vol. 14, 1880, pp. 612-613. ½ p.

false conclusions, could be adjusted by compromise or by readjustment of nomenclature. In the case of fossiliferous zones the real difficulties became more apparent as the final adjustments were attempted.

Mr. Stevenson,[1] in 1878, said that the Upper Devonian rocks of southwest Pennsylvania, underlying the Vespertine or Pocono sandstone, are well exposed in the gaps of the Conemaugh River through Laurel and Chestnut Ridges. He gave a general section of these rocks as observed in the gaps, as follows:

	Feet.
1. Shales and thin gray sandstones	80
2. White to reddish-gray sandstones with some shale	70
3. Reddish-gray micaceous sandstones with red to gray and olive shales	150
4. Red to gray shaly sandstones with variegated clays and shales	200
	500

After a description of the rocks, and a discussion of their relations, he concluded by saying, that, "as the lithological characters of these rocks are much like those of the Chemung, and their fossils, both animal and vegetable, are unquestionably of Chemung age, the rocks themselves must be Chemung, probably representing the Lower Chemung;" and that "the great Catskill group has so far thinned out that it is represented only by its upper or gray member, the Vespertine of Pennsylvania."

The Pennsylvania reports published in 1880 gave little indication of the true nature of the errors of correlation of the Upper Devonian. In the Report of Progress G[7],[2] the imperfection of the theory of "persistent parallelism of strata" became evident. The author classified the deposits examined as follows:

Pottsville Conglomerate, with 8 feet of slate and sandstone below it in a section at Susquehanna Gap.

Mauch Chunk Shale, No. XI, 150 feet.

Pocono group, No. X, 353 feet.

The Pocono-Catskill group, 400 feet thick near Loretto.

Catskill, No. IX, varying in thickness from 1,800 to 4,500 feet. The base of the Catskill is fixed as the lowest horizon at which the scales, teeth, and bones of *Holoptychius* occur.

The Catskill-Chemung group, section between Rupert and Catawissa, 1,077 feet. The base of this group was the lowest red bed.

Chemung, near Rupert, 2,443 feet thick.

Hamilton, at Little Fishing Creek, made up as follows:

	Feet.
Genesee slate	275
Tully limestone	50
Hamilton	400
Marcellus shale	410

This is called the "Northern type."

[1] Stevenson, J. J.: The Upper Devonian rocks of southwest Pennsylvania. Am. Jour. Sci., 3d ser., vol. 15, 1878, pp. 423-430.

[2] The geology of the Susquehanna River region in the six counties of Wyoming, Lackawanna, Luzerne, Columbia, Moptour, and Northumberland, by I. C. White, 1883.

The section below Selin's Grove is as follows:

	Feet.
Genesee slate	264
Hamilton group	2,022
Marcellus slate	300
Selin's Grove lower limestone	65
Selin's Grove shale	140
	505

This is the "Middle type."

The third or "Southern type" is exhibited at a railroad cut two miles below Georgetown.

	Feet.
Concealed	400
Selin's Grove upper sandstone	300
Selin's Grove shales	325
Selin's Grove lower sandstone	100 to 50
Marcellus?	25
Selin's Grove lower limestone	75
Gray shales	50

Oriskany sandstone, VII, placed in the Silurian by Mr. White, varying from 40 to 0 in thickness.

In the Campbell's Ledge black slate, immediately below the Pottsville Conglomerate, sixty-three species of plants and six fossil insects were obtained, a few of them suggesting "Subcarboniferous types," but the great majority were of the coal flora, known only from the Pottsville Conglomerate.[1]

High up in the rocks called Catskill, fossils of Chemung species were reported, as *Spirifera disjuncta* and *S. mesostrialis*.[2] This was some three hundred feet above *Holoptychius* remains.

Several species regarded as of characteristic Chemung age in New York were reported from several horizons in the Chemung-Catskill group. These, too, are well above red shales which had been regarded as at least as high as Catskill formations. In the Chemung, typical Chemung species were reported, but in combinations not precisely those commonly seen in the typical New York sections. The "Tully" was not recognized by its fauna, but on account of resemblance lithologically to the Tully limestone of New York.[3] The "Hamilton" is identified by typical Hamilton species. Thus is the "Oriskany" also distinguished. The identification of species is credited to Prof. E. W. Claypole.

The report called out sharp criticism, first in the letter of transmission by the State geologist who wrote:

> The paleontology of this report requires the closest consideration, and presents some difficulties of considerable magnitude, I have, therefore, submitted the proof sheets to our highest authority, Prof. James Hall, of Albany.[4] * * *

Prof. Hall objected to considering the *Holoptychius* bed as the base of the Catskill, because of the occurrence of Chemung species higher up.

[1] Rep. of Prog. G⁷, p. 39. [2] Ibid., p. 57. [3] Ibid., p. 76. [4] Ibid., p. XIX.

To "the topsyturvy appearance of the three species of *Spirifera* which outside of Pennsylvania have been found (1) never in any but Chemung rocks; (2) confined each to its own horizon; and (3) always in a fixed order from above downwards;"[1] and also to the high reported range of several species. The objections were so pointed that the State geologist, J. P. Lesley, closed his letter with the statement that "the startling fossil species of this report will therefore be regarded by the paleontological reader as only *provisionally verified*," etc.[2]

Two things about the report were out of the ordinary and expected line of opinion. The author, though partly recognizing the lithology as worthy of consideration, based his classification of these "subconglomerate" rocks on the evidence of the fossils and secondly he classified the rocks according to the evidence and not according to the standards as they existed in New York State. He was forced to recognize two "transition" groups in order to suit both kinds of evidence. This satisfied neither the lithologic nor the paleontologic schools of geologists.

The identification of fossils may not have been accurate in all cases, but the result of later studies has clearly shown that the real difficulty was not in the identification but in interpretations which were brought out by the facts. The minute and exhaustive field work of the second Pennsylvania survey had shown beyond the possibility of contradiction that geologic formations vary within wide limits in their lithologic character and in their thickness, and constantly, so that sections a few miles apart may present very little in common, although known to be stratigraphically correlative with each other. This had led to the full adoption of the idea that the parallelism of strata must be made by actual tracing of the strata from place to place, and that identification by lithologic likeness was impracticable over any considerable interval of space. Paleontologists, however, still clung to the theory of the strict uniformity of sequence in faunas.

The "canonical" opinion of the "highest authorities" in paleontology was that the order of sequence in species of fossils, established by the facts in one well authenticated section of deposits, furnished a standard that could be implicitly relied upon in the correlation of other sections. When it was reported that this established order was not preserved, doubt was naturally cast upon the identification of the fossils.

The Pennsylvania geologists did not seem to be aware of the importance of the facts, but they were correct and the error lay in the theory of the paleontologists.

Mr. Claypole,[3] in defense of his statements embodied in the Pennsylvania report, and criticised by Mr. Hall in the preface of the same volume, quoted from an article of Mr. Williams's, in which are recorded observations confirming his statements in Report G[7].

[1] Rept. of Prog. G[7], p. xx. [2] Ibid., p. xxvi.

[3] Claypole, E. W.: On the vertical range of certain fossil species in Pennsylvania and New York. Am. Naturalist, vol. 19, pp. 644–654.

The principle underlying the new interpretation of this problem was suggested several years earlier in a paper read before the American Association in 1881.[1]

In this paper announcement was made of the discovery of a distinctly Hamilton fauna, all the species of which had been heretofore considered as strictly Hamilton species, in arenaceous shales several hundred feet above the Genesee shales, at Ithaca, New York. It is separated from the typical Hamilton fauna by four distinct faunas; those of the Tully limestone, the Genesee shale, the *Spirifera lævis* fauna, called Portage in the State reports, and a fauna described in this paper from shales overlying the last, called "Ithaca shales," resembling the Genesee shale fauna, but evidently a later stage of it. This black shale was regarded by the author as "a single continuous fauna." He says:

Its appearance in the rocks of central New York in three separate zones, called the Marcellus shales, the Genesee slate, and the Ithaca shales is regarded as evidence of interrupted incursion eastward of the conditions which were continuous over some portions of the interior of the Devonian intercontinental sea, where the three New York zones were represented by one continuous series of Black shales.

The hypothesis is also advanced that (*a*) the Hamilton and Chemung faunas were probably coexistent with this Black-shale fauna; and (*b*) were respectively the northern and southern faunas of a western coast line of the open ocean on the eastward of this continent; and (*c*) the appearance of the Chemung fauna, displacing the Hamilton faunas, in the latitude of New York and Pennsylvania, was the resultant of some grand changes in the relations of the ocean and continental borders, by which tropical conditions of the ocean were advanced northward, occasioning the shifting of the Hamilton faunas toward the North pole; so that (we may suppose) at the time when the Chemung fauna was dominant over the northeastern United States, rocks being deposited in the arctic latitudes received a Hamilton fauna; and (*d*) finally, these changes were gradual, the shifting of the faunas northward beginning as early as the beginning of the Portage epoch, and continuing far into, and perhaps after the close of the Chemung epoch, with some oscillation of the conditions, causing traces of the Hamilton to recur at the base, and possibly a second time higher up in the midst of Chemung rocks and faunas.

The fundamental idea inspiring the paper was an application of conditions of modern biology to the interpretation of the fossil faunas. As in the present seas many faunas are known to coexist in the same ocean basin, their particular constitution and characteristics being determined in great measure by differences of environment, bathymetrical conditions, temperature, purity of water, etc., so in the past, it is supposed, similar differences in the faunas will be found to mark deposits which were made at the same time, but under different conditions. And in the second place since oscillations are known to have occurred and currents are supposed to have existed in the ancient as in the modern oceans, according to the theory it is reasonable to expect a more or less constant change of the conditions of environment at any particular geographical position, and consequently a shifting backward and forward over it of the faunas during the accumulation of the sedi-

[1] The Recurrence of Faunas in the Devonian Rocks of New York, by H. S. Williams. Proc. Am. Ass. Adv. Sci., vol. 30, pp. 186–191.

ments. With this as a working hypothesis the paper on "Recurrence of faunas" was the announcement of the first confirmatory evidence actually seen. Barrande's theory of "Colonies" considered the laws concerned as exceptional; the theory of the recurrence of faunas was set forth as the formulation of a general law.

Investigations in the same line were extended by the author westward from the meridian of Cayuga Lake, New York State, across the State, northwestern Pennsylvania, and the eastern part of Ohio. The rocks studied were of Devonian and Lower Carboniferous age, and the problems were the same over which the Pennsylvania geologists were struggling.

In 1883, Mr. Claypole[1] reported that the Catskill group of New York had hitherto been considered as non-fossiliferous, and as separating the characteristic Devonian and Carboniferous faunas. Further examination, however, proved that these rocks contained a scattered fauna consisting of fish and plant remains. From a study of these deposits in central Pennsylvania, the author reached the following conclusions:

(1) That the lower portion of the Ponent Red sandstone and shale (Catskill) is less barren of organic remains than has been supposed. (2) That Holoptychius and Bothriolepis are not exclusively Catskill fauna, and (3) That the Ponent group differs from what it is generally understood to be, the contained fossils indicating that there are Chemung and also Carboniferous faunas included in rocks called Ponent.[2]

Mr. Claypole,[3] during the same year, communicated several other papers bearing more or less upon the general discussion.

In the same year (1883) in which Report G[7] of the second geological survey of Pennsylvania appeared, the manuscript of Bulletin 3 of the U. S. Geological Survey [4] was furnished, though not published till the following year.

The bulletin is a report upon the constitution, the order, and relative position of the fossil faunas in a continuous section of the rocks, from the Genesee shales through the Upper Devonian to the first appearance of a coal bed at the Barclay coal mines in southern Bradford County, Pennsylvania.

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[1] Claypole, E. W.: On the occurence of fossiliferous strata in the Lower Ponent (Catskill) group of middle Pennsylvania. Am. Nat., vol. 17, 1883, pp. 274-282.

[2] Ibid., p. 282.

[3] Claypole, E. W.: Note on the occurrence of Holoptychius about 500 feet below the recognized top of the Chemung group, in Bradford County. Proc. Am. Phil. Soc., vol. 20, 1883, p. 531.

On a mass of Catskill rocks, supposed to exist on the north bank of Towanda Creek, near Franklin. Proc. Am. Phil. Soc., vol. 20, 1883, pp. 531-533, 535.

On two small patches of Catskill, represented near Leroy, on the map in report G, of the second geol. survey of Pennsylvania. Proc. Am. Phil. Soc., vol. 20, 1883, pp 533-534.

On the Kingsmill white sandstone. Am. Phil. Soc., Proc., vol. 20, 1883, pp. 666-677.

On the equivalent of the New York Portage, in Perry County, middle Pennsylvania. Am. Phil. Soc. Proc., vol. 21, 1883, pp. 250-255.

On a large crustacean from the Catskill group of Pennsylvania. Am. Ass. Proc., vol. 32, 1883, p. 265.

[4] On the fossil faunas of the Upper Devonian along the meridian of 76° 30′, from Tompkins County, New York, to Bradford County, Pennsylvania, by Henry S. Williams.

A notice of the general results, embodied in the bulletin, appeared in Science, December 28, 1883. (Comparative Paleontology of the Devonian formations, Science, vol. 2, p. 836.)

The consecutive faunas were also examined particularly as to conditions of environment with which they were originally associated, as indicated by the lithologic character of the deposits. The scope of the work may be indicated by the following quotations:

The aggregation of species into faunas, the blending of one fauna with another, the rarity or abundance of particular species, variation in form or size or modification of specific characters, the extinction of old and the initiation of new forms—all these become the most delicate tests of change in the physical conditions, the record of which constitutes the geological history of the earth.

For the correct solution of this problem the laws of geographical distribution form as important an element as geological sequence. The attempt to apply such principles to the study of the Devonian and Subcarboniferous deposits is no simple task, but the very fact that their faunas offer so great variation and difference in their combinations makes this series particularly attractive for the purpose.[1]

* * * * * * *

These facts make it plain that over any particular area the faunas shifted back and forth with the advance of geological time. Hence I was led to the simple conception of a fauna as continuing on intact as long as the favorable conditions for its life continued, as shifting its habitat with the elevation or depression of the land, with the advance or retrocession of the coast line. In such shifting and change of conditions, one species after another may drop out and become extinct; others may suffer varietal modification, and, what is still more important, the sudden appearance of new forms may take place in the midst of the normal fauna—forms new to the locality only, or entirely new, so far as our knowledge of the fossils can tell us. Merely from the initiation of the new forms in the fauna we can gain no clew of its origin, but the study of its relations to allied forms of other faunas may enable us to decide whether it is a modification of some older form or the forerunner of a new type, marking a later geological stage.[2]

* * * * * * *

The following is a summary of the order and general relative position of the faunas from the Genesee slate to the Barclay coal, which my present knowledge leads me to believe is true for the meridian passing through Ithaca, New York, running southward.

(1) Genesee slate fauna,

(2) Portage group fauna, distributed through approximately 1,300 feet of strata, but interrupted by the intrusion of the Ithaca faunas and several sub-faunas.

(3) Chemung fauna, occupying at least 1,200 feet of strata, with perhaps two subfaunas, and driven out or destroyed by the presence of the conditions marked by the deposit of red and gray Catskill rocks.

Within the limits assigned to the Portage group in the western part of New York State, I believe should be included for this meridian all those deposits lying between the Genesee shale and the lowest yellow-brown shale and sandstones which carry the true Chemung group fauna.

This series, as a whole, may be described as arenaceous, dark-colored shales with the *Cardiola speciosa* fauna, toward the top running into wave-marked, tough, arenaceous deposits, almost totally barren, so far as known.

The passage between this series and the true Chemung is stratigraphically indistinct, but in a general way it may be recognized by the clearer separation of the argillaceous from the arenaceous deposits after passing the line, and the appearance of lighter-colored sandstones in the midst of softer argillaceous shales, in which iron nodules and iron stains become more conspicuous than below.

The shales of the Portage below are thinner and of more greenish tint, and its

[1] U. S. Geol. Surv., Bull. No. 3, p. 6. [2] Ibid., p. 8.

sandstones are darker in color and thin, tough, and wave-marked or flaggy. Paleontologically, however, the transition is more marked.

The upper part of the Portage appears to be utterly barren except in an occasional thin stratum of green shale, a *Cardiola speciosa*, or a small *Palæoneilo*, or *Leda* may appear.

As soon, however, as we reach the true Chemung rocks we meet large *Productella lachrymosa*, *Ambocœlias* and *Spirifers* of the Chemung types. * * *

To the author of this bulletin the facts reported by Mr. White in the Report of Progress G[7] were not startling, but what he was ready to expect from his studies in New York. He expressed his agreement thus:

In regard to the identification of these Upper Devonian faunas of Columbia County, Pennsylvania, in the association of species and the relative order of the sub-faunas, the record agrees in general with that of the series exposed along the same meridian farther north in New York State.[1]

The following year, 1884, the same author read a paper before the American Association on "Geographical and physical conditions as modifying fossil faunas."[2] In this paper application of the principles above described is made in the study of sections of the Devonian rocks east and west of those described in the Bulletin No. 3. By dissecting the faunas of each section and comparing them consecutively across the State, is it shown that there are changes in the composition of the faunas coordinate with changes in the deposits. Among other examples the occurrence of Castkill type of fossils with Catskill character of rocks in Chenango and Otsego Counties, New York, is reported entirely below genuine Chemung fossils, in the Oneonta formation.

In the discussion which followed, Mr. Hall, to whom the objectionable identifications of the Pennsylvania Report G[7] had previously been referred, again objected to the report that *Spirifera mesostrialis* and *S. disjuncta* were found together, on the ground that they represent different zones and should not occur together; also, he objected to the interpretation of strata as "Chemung-Catskill," claiming that these are two distinct formations with distinct faunas, and it was not reasonable to expect the two to be blended. At the same meeting, in a paper read by Mr. Hall, this opinion is further illustrated by his interpretation of a section in Warren County, Pennsylvania.[3] In the section described about 1,500 feet of Chemung rocks are reported with Chemung fossils, followed immediately, and without sign of unconformity, by Waverly sandstone rocks with Waverly fossils. Between the two is marked "*the place of the Catskill*," where, it is stated, "there is a hiatus which in eastern New York and Pennsylvania is marked by the presence of measures having a thickness of from 3,000 to 5,000 feet."

The interpretation of the facts is "that there has been a long interval of time between the final deposition of the barren Chemung shales and the fossiliferous Waverly sandstones, or that the deposition of the

[1] See "The Spirifers of the Upper Devonian," by H. S. Williams, Science, vol. 3, p. 374.

[2] Proc. Am. Assoc. Adv. Sci., vol. 33, p. 422, et. seq.

[3] On the intimate relations of the Chemung group and the Waverly sandstone in northwestern Pennsylvania and southwestern New York, by James Hall, Proc. Am. Assoc. Adv. Sci. vol. 33, p. 416.

estuary Catskill sediments has been going on simultaneously with the open sea deposits of the Waverly formation."[1]

The true objection to such terms as "Chemung-Catskill" and "Catskill-Pocono" did not come to light in this controversy. The names do not misrepresent the facts they were intended to represent, i. e., that in Pennsylvania there are formations which by their fossils indicate not only transition, but a blending of two distinct formations of New York, but it may be urged that these names do not clearly express the facts. The truth is that sedimentation did not change synchronously for even very limited areas, and to attempt by the use of nomenclature to make the division lines of the chronological scale precisely coincide for the sections of adjoining States will often unnaturally strain the facts.

In 1885 Report of Progress F^2 was published.[2] In this report the classification adopted in Mr. White's Report G^7 was more fully elaborated. Mr. Claypole's classification is as follows:

No. XI. Mauch Chunk red shale.
No. X. Pocono sandstone.
No. IX. Catskill formation, including—
Upper beds.
Dellville sandstone.
King's Mill shales.
King's Mill sandstone.
Fish beds.
No. VIII (*f*). Chemung group.
No. VIII (*e*). Portage group.
No. VIII (*d*). Genesee group.
No. VIII (*c*). Hamilton group, including—
Hamilton Upper shale, 200 to 300 feet.
Hamilton (Montebello) sandstone, 500 to 800 feet.
Hamilton Lower shale, 400 to 500 feet.
No. VIII (*b*). Marcellus limestone and black shale, including
Marcellus black shale, 100 feet.
Marcellus upper iron ore, 2 feet.
Marcellus limestone, 50 feet.
Marcellus lime shales, 50 feet.
Marcellus lower iron ore, 2 feet.
No. VIII (*a*). Upper Helderberg (Corniferous) group. (Absent.)
No. VII. Oriskany sandstone group.

The division line between the Chemung group and the Catskill is not clear. Occasional red beds occur below the line he sets, and Chemung fossils occur above the "Fish beds," which he regards as the base of the Catskill.[3]

In 1885 Williams read a paper on the classification of the Upper Devonian.[4]

[1] On the intimate relations of the Chemung group and the Waverly sandstone in northwestern Pennsylvania and southwestern New York, by James Hall, Proc. Am. Assoc. Adv. Sci., vol. 33, p. 418.

[2] Second Geol. Survey of Pennsylvania, Report of Progress F^2. A preliminary Report on the Palaeontology of Perry County, describing the order and thickness of its formations and its folded and faulted tructure, by E. W. Claypole. Harrisburg, 1885.

[3] Ibid., pp. 72, 73.

[4] On the classification of the Upper Devonian, by Henry Shaler Williams, Am. Ass. Adv. Sci. Proc., vol. 34, 1885, pp. 222–234.

A number of sections across the same series of deposits, about 50 miles apart, are compared. The sections are called: I Cuyahoga, II Painesville, III Girard, IV Chautauqua, V Genesee, VI Canandaigua, VII Cayuga, VIII Tioughnioga, IX Chenango, X Unadilla, making a series reaching from Cleveland, Ohio, to the Unadilla Valley, Otsego County, New York.

The individual faunas were studied in their stratigraphic order in the various sections, and their relative positions in the sections were shown to exhibit a shifting back and forth of the faunas during the deposition of the sediments. The faunas were classified and the recurrent stages of each were given names from the dominant fossils, characterizing them as follows:[1]

A is the Hamilton fauna and its immediate successors.

The middle Devonian fauna (A) was traced above the horizon of the Genesee shale in the following successive stages:

A 1, the *Paracyclas lirata* stage.
A 2, the *Spirifera lævis* stage.
A 3, the *Strophodonta mucronata* stage.
A 4, the *Atrypa reticularis* stage.
A 5, the *Leiorhynchus globuliformis* stage.
A 6, the *Tropidoleptus carinatus* stage.
A 7, the *Spirifera mesostrialis* stage.
A^6+ is a second recurrence of the *Tropidoleptus* stage, found above the Chemung fauna and distinguished by the variety *Owegoensis* of *Spirifera marcyi*, a characteristic variety of the *granulifera* type of *Spiriferas*.
B is the black shale fauna, beginning in the typical or first stage of the Genesee shale.

In the fauna of the black shales:

B, the Genesee stage of *Lingula spatulata*.
B 1, the second *Lingula spatulata* stage, in Portage shales.
B 2, the *Lingula complanata* stage of the "Ithaca group."
B 3, *Lingula spatulata*, third variety, in the Cleveland shale.
B 4, *Lingula complanata*, second stage, in Chemung shales.
C is the fauna of the green shales of the typical Portage group.
C 1 is the Cephalopod stage, with *Goniatites* and large *Cardiadæ*.
C 2, the Lamellibranch stage, with *Cardiola speciosa*, etc.
C 3 is the Portage sandstone, generally barren.
D is the Chemung fauna associated with brown argillaceous shales, flags, or calcareous sandstones.

The faunas of the brown shales and sandstones of the Chemung deposits were classified into the following stages:

D 1, the stage of *Orthis tioga*.
D 2, the stage of *Strophodonta cayuta*.
D 3, the stage of *Athyris angelica*.
D 4, the stage of *Rhynchonella contracta*.
D 5, the stage of *Spirifera alta*.

All of these stages, except the first (D 1) are characterized by the presence of some variety of *Spirifera disjuncta*) = *Sp. Verneuili*).

E is the fauna of the flat pebble conglomerate.
F is the fauna and flora of the Catskill grays and reds.

In the Catskill rocks the fossils are very rare, but there are two stages (F 1) of the

[1] On the classification of the Upper Devonian, by Henry Shaler Williams, Am. Ass. Adv. Sci. Proc., vol. 34, 1885, pp. 225-227.

Oneonta reds and grays and (F 2) of the typical Catskill. So far as fossils have been found there is difficulty in defining them.

It is probable that *Holoptychius* and several allied fish, Conrad's *Cypricardia angusta* and several plants, are found in both alike, but further investigation will be necessary to establish any clearly distinctive characters in the fossils.

The Waverly fauna G appears to be distinguished into three stages in other parts of Ohio. But in the region comprised in these sections the stages are recognized more by their lithologic than by their paleontologic characters. The general fauna may be called the *Syringothyris* fauna,

With G 1, the Bedford shale stage,
With G 2, the Berea grit and sandstone,
With G 3, the Cuyahoga shale and sandstone.
H is the conglomerate (Olean and equivalent).
J is the Barclay coal beds.

From these studies the following principles of correlation were deduced:[1]

First. The complications arising from both geological and geographical modifications of fossil faunas are so great that the attempt to determine horizons by single or by roughly identified fossils will certainly lead to erroneous results.

Second. In classifying deposits in geologic surveys, it is of the greatest importance that the actual altitude and the geographic position of rock strata should be precisely defined, as well as the lithologic character of the strata themselves. And for this purpose some systematic and uniform nomenclature for the various kinds of rocks should be made and adopted by all geologists in the country.

Third. The fact that species composing the faunas and the total faunas themselves are subject to constant modification, both geographical in the same horizon and geological in the same area, is an element that paleontologists can not safely ignore. These modifications, though they may be slight, can be easily recognized in the passage of 50 miles.

Fourth. The actual order of faunas met with in a vertical section is not necessarily expressive of biologic sequence, but signifies the sequence of the occupants of that particular area.

The change in the species from one stratum to the next may express the shifting for miles of the actual inhabitants, and if the change, within a few feet of strata, is to an entirely distinct group of species, the evidence should be taken as pointing to a considerable shifting of condition of the bottom. If in such case each fauna is kept distinct, the means of tracing the geographical distribution and modification are at hand. If mingled, then the collection, though made at the same locality, will only confuse. Two such faunas meet at Owego, Tioga County, in distinct strata, but in rocks which are of similar lithologic character. One is a remnant of a prevailing western fauna, the other is an eastern and late stage of a new fauna.

Fifth. The classification of the rocks may receive local geographic names; the classification of the biologic series should receive names derived from the names of species; ages defined by families, periods by genera, and epochs by species, or something of that kind, and these periods or ages will always adjust themselves to future discoveries.

Regarding the classification of the particular formations the following conclusions were reached, viz:

(1) The Devonian black shales occur in the strata from the Genesee shales upward, alternating with the normal deposits of the Portage and Cleveland shales and sandstones, and possibly higher, with modifications of the faunas, but run out at the eastern extremity of the area.

[1] On the classification of the Upper Devonian, by Henry Shaler Williams, Am. Ass. Adv. Sci. Proc., vol. 34, 1885, pp. 232.

(2) The Portage rocks and faunas are local, the characteristics of each being unrecognizable east of the Cayuga section.

(3) The typical Portage formations of the Genesee section have quite a different set of species from the rocks occupying the same interval in the Cayuga section, while farther east the same interval is filled by rocks like the Catskill, called the Oneonta sandstones, etc.

(4) The "Ithaca group" contains a *modified* Hamilton fauna, which differs from the Chemung fauna in the absence of some of its most characteristic species.

(5) The modified stages of the Hamilton fauna appearing above the Genesee shale are confined to sections east of the Canandaigua meridian.

(6) The Catskill deposits of Chenango and Otsego Counties are intrinsically not distinguishable from those of the higher stage called Catskill, but appear at a lower position, stratigraphically, in the interval occupied by the "Ithaca group" of the Cayuga section, and by the middle part of the Portage group of the Genesee section; but paleontologically they are immediately preceded by stages of the same general fauna.

(7) The dominant and most characteristic species of the Chemung fauna appear stratigraphically earliest in the more western sections (D 4 of Girard and Chautauqua). This stage of the fauna appears in the upper part of the Chemung group in the eastern sections; and in the extreme part of the area this stage of the fauna is all that appears, and it is there represented by only a few specimens in the very upper strata just before the final incursion of the Catskill deposits.[1]

[1] Op. cit., p. 234.

CHAPTER VII.

THE LOWER CARBONIFEROUS OR MISSISSIPPIAN SERIES: THE DEVELOPMENT OF THE NOMENCLATURE, AND CLASSIFICATION OF THE LOWER CARBONIFEROUS FORMATIONS OF THE MISSISSIPPIAN PROVINCE.

The presence of the Carboniferous system in America was early recognized by finding coal beds containing plants similar to those of the Coal Measures of Europe; but the determination of the lower and upper limits and the classification of the Carboniferous formations were matters of gradual development.

In the northern and central portions of the Appalachian province the interval between the marine Devonian formations and the Coal Measures is mainly filled by arenaceous deposits with few distinguishing fossils, and here the more interesting correlation problems were concerning the termination of the Devonian.

In the Mississippian province the sedimentation introducing the Carboniferous was strikingly different. A considerable series of limestones and calcareous shales, and a few sandstones intervene between the termination of the Silurian and the base of the coal-bearing strata above. These rocks contain rich and varied fossil faunas, and their correlation and classification constitute one of the most important chapters in American geology. Rocks containing Devonian faunas are found at the base of the series in some parts of the province, but in other sections they are missing. The formations resting upon the Devonian where these occur, and in other places upon the Silurian, are characterized by fossils of Carboniferous age, and have heretofore gone under the names "Mountain limestone," "Carboniferous limestone," "Subcarboniferous," and "Lower Carboniferous." No one of these names is satisfactory, and as these formations are bound together by a common general fauna and constitute a conspicuous feature in the geology of this region, it is proposed to call them the *Mississippian series*. This series may be defined stratigraphically as that series of rocks, prevailingly calcareous, which occupies the interval between the Devonian system and the Coal Measures, and is typically developed in the States forming the upper part of the valley of the Mississippi River, viz, Missouri, Illinois, and Iowa. The name is a slight modification in form and usage of a name proposed by Alexander Winchell in 1870.[1]

[1] The Marshall group, etc., Am. Phil. Soc., Proc., vol. 11, p. 79.

He proposed "the use of the name" "Mississippi limestone series or Mississippi group" "as a geographical designation for the Carboniferous limestones of the United States which are so largely developed in the valley of the Mississippi River."

At the time this was written the Chouteau group of Broadhead was correlated with the Chemung group of the New York geologists, and one of the important results of Winchell's paper was the demonstration that the Chouteau group of Missouri, the Kinderhook group of Illinois, the Waverly group of Ohio, and the Marshall group of Michigan were different types of a single formation of more recent age than the Chemung group of New York.

As the Carboniferous age of the Chouteau and Kinderhook faunas is fully established, it appears entirely appropriate to extend the limits of the Mississippian series so as to include all the formations containing Carboniferous faunas from the top of the Devonian to the base of the Coal Measuses. I have already proposed the use of the name in this sense in recent reports to the State geologists of Arkansas and Missouri.

As the nature of sedimentation is greatly determined by the geographical relations of ocean to shore lines, a brief description of the geographical conditions of the region during the upper Paleozoic is here appended.

At the opening of the Devonian period the Archean continental nucleus of the Northeast had been increased by a considerable border of Silurian formations. The borders of this land mass roughly defined extended from near the mouth of the Mackenzie River southeastward to Lake Winnipeg, and as the line approached Lake Superior it was diverted westward, to what extent we do not know, as the more recent deposits cover the record. The shore line appears again running across the northeast corner of Iowa, thence eastward across Illinois, and there suddenly bends northward, forming a great bay, taking in the peninsular part of Michigan; thence eastward across Ontario, northern New York, and around the Catskill Mountains into New Jersey; thence with some interruptions southwestward, forming an eastern shore for the Appalachian basin.

The Cincinnati uplift was probably an island for part of the Devonian period, and the Ozark uplift of southeastern Missouri formed another large island, which probably remained above water throughout the Carboniferous. Other islands may have furnished shores of erosion farther to the south and west. Thus from the beginning of the Devonian till the time of the general continental elevation which initiated the Coal Measures, the central part of the United States was a vast ocean basin. The sedimentation about the margins of this basin was prevailingly arenaceous and argillaceous, the formations are more varied, and it is in these margins that we find the best development of the Devonian system, both stratigraphically and faunally considered. As we approach the central portion of the basin the sedimentation is prevail-

ingly calcareous; and the strata representing the Devonian system become reduced in amount, and less varied in composition, and contain a limited fauna; and, finally, in Alabama, Tennessee, Arkansas, and southern Missouri, a black shale only a few feet in thickness, with Lingulas and rarely other fossils, is all that represents the complex stratigraphy and paleontology of the Devonian of New York. The "Black shale" has consequently assumed an important role in the correlations of the Mississippian series.

The upper termination of the series is marked by the more or less rapid change from calcareous to coarse arenaceous deposits, indicative of elevation and shore line sedimentation.

In the Appalachian province, Rogers's "Seral Conglomerate" has been adopted as the base of the Pennsylvania series of Coal Measures, but in the Mississippian province, although the coal beds are preceded by a greater or less thickness of arenaceous sediments, the delimitation between the Mississippian and the Coal Measures, as we shall see, is not yet drawn with any great degree of precision.

Thomas Nuttall, in the year 1821, in the article referred to on p. 25, made the first allusion discovered in our literature to the limestone rocks of the Mississippi Valley as a formation possessing common characteristics. These limestones he rightly interpreted by recognizing in them the fossils of Martin's Petrifacta Derbiensis. It is not probable that he, any more than many geologists who immediately followed him, recognized the distinction between the true Carboniferous limestones and others of Silurian and of Devonian age. The fact that the limestones which he described as forming the calcareous platform of the Mississippi are conspicuously of Lower Carboniferous age, and that for years they went under the names "Mountain limestone," "Carboniferous limestone," and "Cliff limestone," is sufficient reason for giving special consideration to these Mississippi Carboniferous limestones.

It was D. D. Owen, however, who devoted careful study to the Mississipian series and first described and elaborated the details and proposed a distinct nomenclature and classification. His earlier views on the subject are found in the reports of the geological survey of Indiana. The first and second annual reports were published in 1839.[1]

In the first report Owen gave the general outlines of the system then in use in Europe as expressed in De la Bêche's Manual, and constructed a section representing his interpretation of the rocks "along a line from Terre Haute running southeasterly toward that part of the Alleghany range which divides Tennessee from North Carolina," thus:

Bituminous coal formation.
Mountain limestone.
Grauwacke.
Crystalline and inferior stratified rocks.

[1] Report of a Geological Reconnoissance of the State of Indiana made in the year 1837 in conformity to an order of the legislature. By David Dale Owen, M. D., geologist of the State, pp. 34, 1839.
Second Report of a Geological Survey of the State of Indiana made in the year 1838. By David Dale Owen, 1839.

In the course of the survey a line was run along the Ohio River, and the succession there is interpreted as follows:

Coal formation.	Seams of coal associated with beds of sandstone, shale, clay, and limestone.
Subcarboniferous group.....	1. Oolitic limestone. 2. Encrinital strata, Siliceo-calcareous series with occasional beds of clay. 3. Black bituminous aluminous slate. 4. Fossiliferous and inferior strata of the Subcarboniferous group, consisting of (1) Fossiliferous bed of Ohio Falls. (2) Water-lime and variegated strata. (3) Sand or burr stone. (4) Bluish or brownish limestone.

On page 25 the rocks of the State are classified into three formations:

1. A bituminous coal formation.
2. A limestone formation (similar to the Mountain limestone of European geologists).
3. A diluvium.

In this report the Carboniferous group is restricted to the coal-bearing rocks, or what is now called the Coal Measures.

All the fossiliferous rocks below the Coal Measures were called "Subcarboniferous." The author said:

To this group may with propriety be applied the name Subcarboniferous, as indicating its position immediately beneath the coal, or Carboniferous group of Indiana; [and in a foot note], "The fossils generally coincide closely with those of the Carboniferous or Mountain limestone of Europe; but as no perfect seams of coal have ever yet been observed alternating with these deposits in this country, and as most of its fossils differ decidedly from those of the coal formation, it would seem to preclude the possibility of including it, here at least, as some European geologists do their Mountain limestone, in the Carboniferous group. * * * I prefer designating it by the term "Subcarboniferous," which merely indicates its position beneath the Carboniferous group without involving any theory.[1]

In the second report, published the same year, Owen briefly reported details for various counties of the State. The "Encrinital strata of Harrison County" are said to "correspond to the 'incrinital' of Dr. Troost" of the "well known iron region of Tennessee." The rocks below the fossiliferous strata of the Falls of Ohio were correlated with the "Cliff strata" of Dr. Locke, of Ohio, and "most of the rapids and falls in the State are produced by these cliff rocks."[2] And in the discussion of the rocks near Lockport and near Delphi, the author remarks:

The whole of the rock formation which I have just been describing I consider as belonging to the strata inferior to the black bituminous aluminous slate, including part, if not the whole, of the Cliff strata.

In the latter part of the report a comparison is made between the geological formations of Indiana and those of Ohio.

[1] Report of a Geological Reconnoissance of the State of Indiana made in the year 1837 in conformity to an order of the legislature. By David Dale Owen, M. D., geologist of the State, 1839, pp. 12, 13.

[2] Second Report of a Geological Survey of the State of Indiana made in the year 1838. By David Dale Owen, 1839, p. 17.

The bituminous coal formation of Indiana is correlated with the coal fields of lower Missouri, northwestern Kentucky, and Ohio, thus:[1]

INDIANA.	OHIO.
Oolitic limestone (of Troost)	= "Conglomerate" of Locke.
The soft freestone of the Knobs.....	= Waverly sandstone rock, which caps the hills bordering on the Scioto Valley, Ohio.
The black slate at the base of the Knobs	= The shale stratum in "the base of the hills capped with sandstone, bordering on the Scioto Valley."
Arenaceous and argillaceous limestone, forming falls and cliffs in Madison County, on the Ohio River, and on the Upper Wabash, etc.	= Cliff rocks.
Blue fossiliferous limestone.....	= Blue fossiliferous limestone.

The whole of the series above described, from the bottom of the coal formation downward, that is, the Subcarboniferous group, has received the name of "Galeniferous limestone" from some geologists, because it has yielded in a few of the Western States an abundant supply of galena.

The next contribution Owen made was his report on the mineral lands of the United States, which first appeared as a Presidential message to the House of Representatives in 1840.[2]

As we glance over the introduction to this document we find that Owen regarded all the stratified rocks, from the Coal Measures downward, including the "Blue Fossiliferous limestone" (Cincinnati limestone), as belonging to the Mountain limestone of the English geologists. For the States of Ohio, Indiana, Kentucky, and Tennessee this Mountain limestone was represented by him under the following subdivisions:[3]

Pentremital limestone, light-colored limestone, sometimes oolitic.
Fine-grained sandstone in Knobs.
Black bituminous shale.
Thick beds of yellowish limestone, Cliff limestone of the West.
Blue fossiliferous shell limestone in thin beds with marlite.

Of these the Cliff limestone was dominant in Iowa and Wisconsin, and the other members were absent or greatly diminished, as in the case of the Blue limestone, so that in Iowa and Wisconsin the following subdivisions were observed:[4]

Pentremital limestone.
Cliff limestone.
Blue limestone.

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[1] Geol. Surv. Ind., 2d Report, pp. 39-45.

[2] "Mineral Lands of the United States. Message from the President of the United States in reply to a resolution of the House of Representatives, February 6, 1840. House of Representatives, Executive Document No. 239, Twenty-sixth Congress, first session."

Report on a geological exploration of part of Iowa, Wisconsin, and Illinois, made under instructions from the Secretary of the Treasury of the United States, in the autumn of the year 1839, by D. D. Owen, M. D., principal agent to explore the mineral lands of the United States, pp. 9-160.

[3] Ibid., diagram 4, op. p. 14.

[4] Ibid., diagram 5.

The sandstones below the blue limestone were regarded as equivalents of the Old Red sandstone.

Another table exhibits the following classification of the rocks of Iowa and Wisconsin:

Coal formation	Coal, shale, grit, and slaty clays with ironstone.
Carboniferous or Mountain limestone formation	Cliff limestone. Blue fossiliferous limestone.
Old Red formation(?)	Alternations of red and white sandstone and Magnesian limestone. Red sandstone.(?)

John Locke, in a report accompanying Owen's report, stated that he had used the term "Cliff limestone" in the Ohio report (1858), adopting it as a provisional name "from the inhabitants on the Miami above Dayton, Ohio." He gave a list of synonyms:[1]

Galeniferous limestone, Featherstonhaugh.
Cornutiferous limestone, Eaton.
Magnesian limestone, Keating and Shepherd.
Mountain limestone, Ohio Reports.
Cliff limestone.

The name "Cliff limestone" is adopted in this paper as a synonymous term for the "Scar limestone" of Phillips's Geology as it appeared in the seventh edition of the Encyclopedia Britannica.

This report was printed on the 4th of June, 1840, without the accompanying charts, sections, and illustrations, and transmitted to the House of Representatives. It was revised, and the public edition was ordered by the Senate to be printed June 1, 1844. The executive document of the House (No. 239) appears to be the first edition unrevised, and there were ordered printed (February 25, 1843) 5,000 extra copies for the use of the House.

Some important revisions first appearing in the Senate document are as follows:

First, a modification of the classification, expressed in a table giving a comparative view of the correspondence between the New York and English surveys, modified from Hall's table of formations in the Final Report on the Fourth District of New York, published in 1843. In the table of the 1844 edition the "Blue limestone" is the equivalent of the Trenton limestone, Utica slate, and Hudson River groups of the New York system. The "Cliff limestone" was recognized in part as the equivalent of the Clinton group, Niagara group, the Onondaga, and the Corniferous limestones of the New York system. The "Black slate" of Ohio and Indiana was the equivalent of the Marcellus shale of New York, and the Waverly sandstone and "fine-grained sandstone of the Knobs" were considered as the equivalents of the Portage and Che-

[1] "Mineral Lands of the United States. Message from the President of the United States in reply to a resolution of the House of Representatives, February 6, 1840. House of Representatives, Ex. Doc. No. 239, Twenty-sixth Congress, first session."

Report on a geological exploration of part of Iowa, Wisconsin, and Illinois, made under instructions from the Secretary of the Treasury of the United States, in the autumn of the year 1839, by D. D. Owen, M. D., principal agent to explore the mineral lands of the United Stares, pp. 116, 117.

mung groups. Owen subsequently changed these last two correlations.

In a footnote[1] Owen mentioned Hall's substitution of the term Niagara for "Cliff limestone," and on page 28 of the same document he stated:

> A review of the fossils of the region under consideration proves, however, that the Cliff formation of Iowa and Wisconsin is, in point of fact, the American equivalent of the Upper and perhaps of part of the Lower Silurian formations of Murchison.[2]

Owen introduced another distinction which is of great importance, but would scarcely be noticed were we not watching for it. In the House edition of the report, the table giving the rocks of Iowa and Wisconsin has "Carboniferous or Mountain limestone" for the rocks below the Coal Measures,[3] and the revised edition[4] has "Subcarboniferous limestone or Protozoic rocks" in its place, and on page 32 is added a clause describing the "Carboniferous limestone of Iowa." Under this heading the author included the reddish limestones of Rockingham, Iowa,[5] and some dark encrinital layers near Stevenson, Illinois.

The "white limestones" of the same part of the State the author reported as contemporaneous with the "shell beds" on the Falls of the Ohio, and as representing by their fossils the Onondaga, Corniferous, Marcellus, and Hamilton groups of New York.

The geological chart[6] has a legend which gives the following classification for the part of the scale here under consideration:

Northwest margin of Great Illinois coal field.
Subcarboniferous limestone.
Shell stratum.
Cliff rocks of the West ..... } { Coralline beds.
Upper Magnesian limestone ..... } { Lead-bearing beds.
Blue Fossiliferous limestone.
Etc.

On comparing the two editions of the report it becomes evident that a study of Hall's report of the Fourth District of New York, in which a comparison is made with Murchison's Silurian system, convinced Owen that his "Cliff limestone and Blue limestone" were representatives of Silurian rocks.

In the Senate edition of the report as published in 1844, Owen stated:

> A review of the fossils of the region under consideration proves that the Cliff formation of Iowa and Wisconsin is, in point of fact, the American equivalent of the Upper, and perhaps of part of the Lower, Silurian formation of Murchison.

It will be remembered that at this time the Lower Devonian, as far up as the Hamilton formation inclusive, was identified with the Silurian

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[1] Senate Document 407, page 23.
[2] He had just remarked upon the identity of the Cliff limestone of America with the Scar limestone of England.
[3] Doc. 239, p. 22.
[4] Senate Doc. 407, XXVIIIth Congress, first session. pp. 27–32.
[5] Previously called Archimedes beds.
[6] Pl. 3 of the Senate document.

of Murchison.[1] And the identification of the fossils of the Cliff limestone in Iowa, Falls of Ohio, and Illinois, with species of the Onondaga, Corniferous limestones, Marcellus shale, and Hamilton group of New York, was strictly in accordance with the statement above quoted.

I find no evidence in this report of the recognition of the Black shale.

The name "Subcarboniferous limestone," thus introduced by Owen in the Indiana reports of 1839, was again used in the second edition of the "Mineral Lands," and in his final report of 1852 was adopted as the name for the lower division of the Carboniferous rocks of Iowa. Owen considered it the equivalent of the Yoredale series and the Lower Scar limestone of the English geologists.

As we shall see elaborated beyond, Swallow retained the old name "Carboniferous or Mountain limestone" in the Missouri reports of 1855. Hall in the Iowa reports of 1858 retained "Carboniferous limestone." In 1859, in volume 3 of the Paleontology of New York, "Great Carboniferous limestone of the Mississippi Valley" is used. Owen in the Kentucky report of 1856 continued to use "Subcarboniferous limestone," and Worthen in the Illinois reports of 1866 and later used Owen's name "Subcarboniferous." Thus the name became established in American literature. Not only is it inappropriate for the purpose to which it is applied, but it is evident that it was introduced as an expression of confusion and dissatisfaction with the correlation attempted. It probably never would have appeared except for the erroneous correlation of the "Cliff limestone" of the Mississippi Valley with the "Scar limestone" of England. "Scar limestone" was Sedgwick's name for the Carboniferous limestone of the Lake district and Yorkshire; "Cliff" was the American name for "Scar," but the "Cliff limestone" of the Mississippi Valley was found to be, some of it certainly, not Carboniferous, and all of it below the coal-bearing strata, and the prefix "sub" was attached to indicate these facts.

Although we have come thoroughly to understand the application of the name, the substitution of the Mississippian series for it will not, it is believed, do violence to the honor of the early geologists or to the rights of the present and future geologists who will adopt the nomenclature best suiting their purposes.

In 1847 D. D. Owen and J. G. Norwood published a paper entitled "Researches among the Protozoic and Carboniferous rocks of Central Kentucky, made during the summer of 1846." This was noticed in the American Journal of Science.

The reviewer remarked:[2]

> Most if not all of the groups of rocks which occur in New York, from the Genesee slate to the top of the Catskill range, are deficient or obscurely marked in the west, and the Carboniferous rocks rest almost immediately on the schistose beds which represent the Genesee slate; whilst our black slate, and the underlying shell beds of

[1] See Geol., Fourth Dist. New York, p. 20.

[2] Am. Jour. Sci., 2d ser., vol. 5, 1847, p. 269.

the Falls of Ohio, with the Goniatite limestone of Rockford, Jackson County, Indiana, as well as the upper shales of Perry County, Tennessee, are the representatives of the Devonian system of Europe.

The reviewer further states: "The *Knob* region, Indiana, Kentucky, Tennessee, Illinois, and Ohio, above the black slate, they show to correspond to the Carboniferous rocks."[1]

In 1847, M. de Verneuil called attention to the necessity of changing the limits of the Cliff limestone and Blue limestone of the Ohio reports. He regarded the upper part of the Cliff limestone as equivalent to the Devonian system of Europe. He announced (in this paper,[2] for the first time, I believe), that "le grand étage des psammites, situé au-dessous du grès houiller et du calcaire de montagne, là où il existe, et que l'on appelait Dévonien, devait être rangé dans le système carbonifère."[3]

Later in the same year, in his paper entitled "Note sur le parallélisme, etc.," he elaborated the same idea.[4]

In the same year, after a visit to this country, M. Verneuil published his important paper in the Bulletin of the Société géologique de France,[5] on the parallelism of Paleozoic rocks. This paper is discussed in a previous chapter (see p. 68). M. de Verneuil's most important contributions to the correlation of the Mississippian series were his positive recognition of the Waverly group of Ohio as Carboniferous, and his demonstration that all the formations from the top of the Black shales upward, and inclusive of the so-called "Carboniferous limestone," for Indiana, Kentucky, Tennessee, and the corresponding beds in the Mississippi Valley, were of Carboniferous age.

Owen's final report did not appear till 1852, but he presented an abstract of its contents before the American Association in 1851.[6] After outlining the lower and "metalliferous rocks" of these States, he mentioned the occurrence in Red River Valley of a "Magnesian limestone," followed by a calcareous formation which he called "Devonian." This was traced westward to Iowa City, thence southeast to the Mississippi River. Between Johnson and Iowa Counties is found an uplift of "Carboniferous sandstone," and "Carboniferous limestone" occurs along the Iowa River, which runs on the extreme eastern margin of the coal field. From Iowa River the Carboniferous rocks bear south through Washington, Henry, and Lee Counties, crossing the Des Moines River and Iowa into Missouri.

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[1] The original article reviewed I have not seen.—H. S. W.

[2] Lettre sur la géologie des États-Unis. By M. Ed. de Verneuil. Soc. géol. France, Bull., II, vol. 4, pp. 12, 13,

[3] Page 12.

[4] Pages 646-687.

[5] "Note sur le parallélisme des roches des dépôts paléozoïques de l'Amérique Septentrionale avec ceux de l'Europe, suivi d'un tableau des espèces fossiles communes aux deux continents, avec l'indication des étages où elles se rencontrent et terminé par un examen critique de chacune de ces espèces."—Soc. géol. France, Bull., II, vol. 4, pp. 646-709.

[6] Owen, D. D.: Abstract of an introduction to the final report on the Geological Surveys made in Wisconsin, Iowa, and Minnesota, in the years 1847-1850, containing a synopsis of the geologic features of the country. Proc. Amer. Assoc., vol. 5, 1851, pp. 119-131.

The coal field of Missouri and Iowa covers about 35,000 square miles. This western field is very shallow, consisting of three well marked divisions—(1) an upper siliceous, 100 feet; (2) middle argillaceous, 75 feet; (3) lower calcareous, 100 feet. The middle division carries the coal, the coal layers having a thickness of four or five feet.

Passing from the mouth of Iowa River to that of the Des Moines, the "Subcarboniferous limestone" occurs "*with no coal seams.*" There the Mississippi passes through a corner of the Illinois coal field. The limestone thins out here and the Coal Measures rest on "the limestones of Devonian age." At the junction of the Missouri and Mississippi, "Carboniferous limestone" is found which just underlies the lowest workable seam of the Illinois field.

In the same year, in association with B. F. Shumard, Owen published some statistics regarding the fossils obtained during the survey.[1]

The authors found in the Devonian rocks of these States 49 species, included in 26 genera, and in the Carboniferous 120 species, included in 49 genera.

"Of the above genera 5 are peculiar to the Devonian and 36 to the Carboniferous." * * * "Eight genera are common to the Silurian and Devonian, 10 to the Silurian and Carboniferous, 10 to the Devonian and Carboniferous, and 9 are common to the three systems."

Two-thirds of the 39 species from the Devonian rocks between Parkhurst and New Buffalo, on the Upper Mississippi, are identical with those found in the coralline beds of the falls of the Ohio at Louisville and Charleston Landing, Indiana. "Thirteen species are identical with European forms."

Twenty-four of the 120 Carboniferous species found mainly in Iowa, are identical with European species. While over one-half of the Brachiopoda are identical with ("can be referred to") European species, only two out of 52 Crinoids are common to the two countries.

Polyparia are most abundant in the Devonian, while Acephala are most numerous in Carboniferous rocks.

Mr. H. King,[2] in 1851, published a paper in which he commented upon a section running from St. Louis southwest to Iron Mountain and Pilot Knob. He observed that above the so-called "Mountain limestone" or "Yoredale limestone," upon which St. Louis stands, occurs a coal bed having an average thickness of 4 feet. This coal deposit is not an outliner of the Illinois coal basin, but a continuation of it. Passing over the southern point of this basin, we meet again the "Mountain limestone" which the author for convenience named "St. Louis limestone;" he considered it, both from its position and fossils, as strictly Carboniferous. Its thickness was estimated to be between 500 and 600 feet.

[1] Owen, D. D., and B. F. Shumard: On the number and distribution of fossil species in the Paleozoic rocks of Iowa, Wisconsin, and Minnesota. Am. Assoc. Proc., vol. 5, 1851, pp. 235–239.

[2] King, H.: Some remarks on the geology of the State of Missouri. Am. Assoc., Proc., vol. 5, 1851, pp. 182–199.

Below this limestone occurs a siliceous sandstone, from 40 to 100 feet thick, which rests upon the second important coal deposit of Missouri, consisting of two beds, sometimes thinning out to a single bed, resembling very much the upper deposit near St. Louis. This is again underlaid by another limestone, some two or three hundred feet thick, and "of Devonian aspect," but with the majority of its fossils Carboniferous. All that portion of the State lying northwest, north, and east of the line starting on the western boundary of the State, near the headwaters of Sac River; thence northeasterly to the junction of the Sac and Osage Rivers; thence to Warsaw and northeasterly to the Missouri River, a few miles west of Jefferson City to Salt River, is classified as "Carboniferous." From thence the line runs south to the Missouri River, to a point opposite our starting place.

Mr. D. Christy,[1] in 1851, gave account of the Goniatite limestone of Rockford, Indiana. The author, having sent a few Goniatites from Rockford to M. de Verneuil, was informed by him that they were "Carboniferous fossils," identical in age with the supposed Mountain limestone of Belgium and England. Dr. D. D. Owen, who had also presented him with some Goniatites from this locality, had reported that they came from the Black slate beneath the Cliff limestone. But further examination proved, as was suggested by M. de Verneuil, that they came from the "Goniatite limestone."

In the vicinity of Queensville unmistakable evidence was found that it was "central in the Black slate" and "above the Cliff limestone." Hence "should the European classification be adopted, this would require us to bring down our range of Carboniferous rocks to within 30 feet of the Cliff limestone."

In a note which appeared in the Proceedings of the American Association[2] Mr. Christy reported that "M. de Verneuil had remarked in one of his letters that these Goniatites, in the structure of their septa, present a curious blending of the forms of the Carboniferous and Devonian Goniatites, which makes them exceedingly interesting; hence his anxiety to ascertain their true geological position."

This note reveals to us the method applied at this early date by de Verneuil in the correlation of geological formations. He already appreciated the historical (or perhaps chronological will more accurately express it) relations of the morphological characters of fossils.

Fossils were not merely "medals of creation" to him, they were remains of organisms which had lived; similarity suggested genetic relationship.

In 1852, Owen published his final report.[3]

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[1] Christy D.: On the Goniatite limestone of Rockford, Jackson County, Indiana. Am. Assoc., Proc., vol. 5, 1851, pp. 76–80.

[2] Am. Assoc. Adv. Sci., Proc., vol. 5, p. 180.

[3] Report of a geological survey of Wisconsin, Iowa, and Minnesota, and incidentally of a portion of Nebraska and Tennessee, by D. D. Owen, United States geologist.

The following generalized section of the "Subcarboniferous limestones of Iowa" appears in this report.[1]

			Feet.
Subcarboniferous limestones.	Upper series.	*f'*. Upper concretionary limestone	25
		e'. Gritstones—contains *Lepidodendra, Calamites*, etc	5
		d'. Lower concretionary limestone—*Lithostrontian*, etc., compact white, usually concretionary, magnesian in places, including the more evenly bedded limestones of St. Louis, with *Melonites*, etc	30
		c'. Gritstone	10
		b'. Magnesian limestone—reticulate corals and *Terebratula Royssii*	10
		a'. Geodiferous bed	30
	Lower series.	*f*. Archimedes limestone, a thin bedded, light gray limestone—*Spirifers, Terebratula Royssii, Orthis*, etc	50
		e. Shell beds—gray crystalline limestone, *Spirifer striatus, cuspidatus, rotundus, Productus punctatus*, and *semireticulatus*, etc	15
		d. Keokuk cherty limestone	15
		c. Reddish brown Encrinital group of Hannibal, Mo., alternating with bands of chert, at base white, crystalline, and semi-oolitic—*Productus cora, Spirifer cuspidatus*, etc.	70
		b. Encrinital group of Burlington, top brown and flesh colored encrinital limestone, with *Pentremites* and *Crinoids*, various beds of limestone, argillaceous and magnesian	60
		a. Argillo-calcareous group, Evans's Falls, at the top a fine-grained buff siliceous rock, containing casts of *Chonetes, Posidonomya, Allorisma, Spirifer*, and *Phillipsia*; Middle, ash-colored, earthy marlites	70

The author described under the name "Cedar River limestone formation" the limestones of Red Cedar and Iowa River Valleys, Iowa, and referred them to the Devonian age.[2]

On the map the legend classifies this "formation of Cedar Valley" as follows:

Hamilton and Onondaga limestone.....	*c*. Upper Coralloid limestone.
	b. Middle shell beds.
	a. Lower Coralline beds.

The author recorded no evidence of the Black shale in the States reported upon.

In the fall of 1855 G. C. Swallow, as State Geologist, published the "first and second annual reports of the Geological Survey of Missouri." The first annual report was made in 1853, but was merely a short report of progress.

In the Survey work, F. Hawn, G. C. Pratt, G. C. Broadhead, B. F. Shumard, and F. B. Meek assisted. Dr. Litton furnished a chemical report on some of the principal mines. The maps and charts were drawn by R. B. Price. Messrs. Meek, Hawn, and Shumard each furnished reports on the special work assigned him, and the classification in the main report is in some cases at least suggested by the studies of these assistants. In the generalized section, opposite page 60, the following classification of the Upper Paleozoic is given:

[1] Report of a geological survey of Wisconsin, Iowa, and Minnesota, and incidentally of a portion of Nebraska and Tennessee, by D. D. Owen, United States geologist.

[2] Ibid., p. 77.

				Feet.
System III. Carboniferous	Coal Measures, *e*.	Upper Coal series		275
		Middle Coal series		225
		Lower Coal series		140
	Carboniferous or Mountain limestone	*f*. Ferruginous sandstone		195
		g. St. Louis limestone		200
		h. Archimedes limestone		200
		i. Encrinital limestone		500
System IV. Devonian	Chemung	*j*. Chouteau limestone		70
		k. Vermicular sandstone and shales		75
		l. Lithographic limestone		60
		p. Hamilton group		50
		m. Onondaga limestone		75

The Coal Measures is overlaid by *d*, Drift, and the Onondaga limestone is underlaid by Delthyris shaly limestone. The term "Ferruginous sandstone" appears to have been first applied here in a technical sense and defined by Prof. Swallow[1] and first applied to the rocks in the bluff near Salt Creek, Sulphur Springs, near Osceola. St. Louis limestone had been used as a general term, and was technically applied by Dr. Owen as a discovery of Dr. Shumard in 1849. Archimedes limestone had been used already by Dr. D. D. Owen in 1852. The name Encrinital limestone was also suggested by Owen in 1852, who spoke of the Encrinital group of Hannibal, Missouri, which was also Swallow's typical locality.[2] Prof. Swallow applied the name "Chemung" to the group of strata including the Chouteau limestone, Vermicular sandstone and shales, and Lithographic limestone. It is placed stratigraphically at the base of the Carboniferous system. In a foot-note he says:[3]

There is some difference of opinion respecting the system to which this group belongs, but if we make a division of the Missouri rocks into Devonian and Carboniferous, the line of separation most distinctly marked is between the Encrinital and Chouteau limestones.

Six pages later a new section begins with the following:

System IV, Devonian.—Two formations of this system exist in Missouri: *Hamilton group, Onondaga limestone.*

Mr. Meek stated in his report that the stratigraphical position of *j*, *k*, and *l*, "taken in connection with their organic remains, leaves little room to doubt that they represent the Chemung group of New York," and "I am far from considering it a settled question that we should not carry up the Devonian so as to take in the Chouteau limestone."[4]

As well as the fact can be determined by the literature, Prof. Swallow was the first to correlate these rocks with the Chemung group of New York. The rocks themselves had been included in the Carboniferous by Owen in 1852, under the name "Argillo-calcareous group of Evans Falls." Neither Messrs. Swallow nor Meek was fully satisfied in placing them in the Devonian. But it was James Hall who settled the correlation by identifying Owen's "Argillaceous group" of Iowa with the Chemung (Devonian) of New York, and recognized the same formation in the section at Hannibal, Mo. This was in harmony with his correla-

[1] Owen's Report, pt. 1, pp. 91, 92. [2] Ibid. pt. 1, p. 101. [3] Ibid., pt. 1, p. 101. [4] Ibid., pt. 2, p. 103.

tion of the Waverly with the Chemung.[1] Later, when Mr. Meek had become better acquainted with fossils, he corrected the mistake.

"Chouteau group," the name proposed later by Mr. Broadhead in 1879, is a proper designation for the rocks in question, and had Swallow proposed it in 1855, the name Kinderhook group would have been superfluous.

In the report of the Geological Survey in Kentucky,[2] made in 1854 and 1855, by D. D. Owen, principal geologist, and printed in 1856, the "Anvil Rock" is named and defined.

The name is applied to a massive sandstone separating the Lower Coal Measures from the Upper Coal Measures of southwestern Kentucky. The title is a popular one originally applied to an immense mass of the sandstone, which has somewhat the form of an anvil, in Union County, Kentucky, a figure of which is given.[3] The name was extended to the sandstone formation of which this rock was a part.

In this volume the term "Subcarboniferous" is applied to the limestone below, separated from the Coal Measures by sandstones, shales, and conglomerates, which together are regarded as representing the "Millstone grit." The "Subcarboniferous" includes "Archimedes limestone" of the Dismal Creek section and "limestones with Pentremites and Archimedes" of other sections.

The author[4] subdivides the "Subcarboniferous" into—

1. Archimedes and Pentremital limestone.
2. Lithostrontion or Barren limestone group.
3. The lower part of this is more argillaceous and may constitute a third division.
4. Subcarboniferous sandstone (Jefferson and Bullitt Counties). This is the Knob formation. Under this lies the "Black Lingula shale," "Coralline Falls limestone," "Chain Coral and Magnesian limestone," and "Blue Shell limestone marl."

In 1856,[5] in the Subcarboniferous limestones near Warsaw, A. H. Worthen discovered the remains of fish in considerable abundance, and later two other beds were found lower down in the series.

The upper fish bed is situated in the Lower Archimedes limestone, the fossil remains consisting entirely of palate teeth. At the base of this limestone is the middle bed, in which the more abundant remains are mostly jaw teeth, with a few palate teeth and spines.

The lower bed was first observed in Quincy, Illinois, near the top of the Burlington Crinoidal limestone, and subsequently in Henderson County, Illinois, and at Augusta, Iowa. As the fossil remains in this bed are much smaller than those mentioned above, the author inferred

[1] See Geol. of Iowa, vol 1.

[2] Report of the geological survey in Kentucky, made in 1854 and 1855. By D. D. Owen, principal geologist, Frankfort, Kentucky, 1856.

[3] Ibid., Pl. III, opp. p. 45.

[4] Ibid., pp. 81, 82, 89, 90, 91, 95, 97, 98.

[5] Worthen, A. H.: On the occurrence of fish remains in the carboniferous limestone of Illinois. Am. Assoc., Proc., vol. 10, pt. 2, 1856, pp. 189–192.

that the Subcarboniferous fish increased greatly in size during this period. In the southern extension of the Pentremital and Archimedes limestone into Tennessee and Alabama, these remains are exceedingly rare.

In 1856 James Hall[1] read a paper before the American Association, an abstract of which was published in the American Journal of Science. His object was "to show that there are certain well marked subdivisions in the Carboniferous limestone of the Mississippi Valley."

The article appears to be a preliminary account of chapters which appeared later in his Report on the Geology of Iowa.

In the following table are expressed the correlations which he proposed, showing the "true order of superposition among the different members of the limestone series:"

VII.	Coal Measures.		
VI.	Kaskaskia limestone, or Upper Archimedes limestone.	of	Kaskaskia and Chester, St. Mary's, Missouri.
V.	Gray, brown, or ferruginous sandstone, overlying the limestones of Alton and St. Louis.	of	Below St. Genevieve, Missouri. Between Prairie du Rocher and Kaskaskia, Illinois.
IV.	"St. Louis limestone," or "Concretionary limestone."	of	St. Louis; highest beds below Keokuk. Alton; St. Genevieve.
III.	"Arenaceous bed," Warsaw or Second Archimedes limestone.	of	Warsaw and above Alton, Illinois; Keokuk, Iowa.
	"Magnesian limestone,"—Spergen Hill, Bloomington, Iowa.		
	Beds of passage, soft shaly or marly bed with geodes of quartz, chalcedony, etc.		
II.	Keokuk limestone, or Lower Archimedes limestone.	of	Keokuk, Quincy, Illinois, etc.
	Beds of passage, cherty beds 60 to 100 feet. Rapids above Keokuk.		
I.	Burlington limestone	of	Burlington, Iowa; Quincy, Illinois; Hannibal, etc., Missouri.

The formations I to VI, inclusive, constituted the "Carboniferous limestone;" next below them he reported the

Oolitic limestone and argillaceous sandstone of the age of the Chemung group of New York.	of	Burlington, Iowa; Evans Falls, and Hannibal, Missouri.

He correlated the "Argillo-calcareous group" of Owen and the "Chouteau limestone" of Shumard and Swallow with the "Chemung group" of New York, stating that "the higher beds contain the same fossils as the Chemung group of New York and elsewhere, and have been carefully traced throughout the intermediate space."[2]

He thought the "green shale" of the Burlington section and the "ash-colored earthy marlites" of Evans Falls "should be referred to the Portage group. * * * It is likewise probable that the lithographic limestone of Prof. Swallow will be found more closely allied to the Hamilton than to the Chemung group."

The name "Burlington limestone" was proposed to include what Owen had called the "encrinital group of Burlington," and "reddish-

[1] Hall, James: On the Carboniferous limestones of the Mississippi Valley. (Abstract.) Am. Jour. Sci., vol. 23, 1857, pp. 187-203.

[2] Ibid., p. 189.

brown encrinital group of Hannibal," and what Swallow and Shumard had called the "encrinal limestone" in Missouri.

Owen's name "Keokuk cherty limestone," with "cherty" omitted, is adopted for the next division, and the author writes, "the so-called siliceous formations of Tennessee and Alabama are of the same strata."[1] This division includes the three divisions *d*, *e*, and *f* of Owen's classification, viz, the "Keokuk cherty limestone," the "shell beds," and the "Archimedes limestone."

Omitting the "Geodiferous bed" of Owen as "beds of passage,"[2] Hall applied the name "Warsaw or Second Archimedes limestone" to the "Magnesian limestone" and "Gritstone" of Owen. The next higher division is called the "St. Louis limestone."

D. D. Owen, in a letter[3] to M. de Verneuil, referred to the discovery by Shumard of the "St. Louis limestone" which, Owen thought, "belonged in the lower part of the Carboniferous limestone." This appears to be the earliest announcement of the St. Louis limestone in the scientific sense. The name was definitely proposed and defined by Dr. H. King of St. Louis in 1851,[4] and in Owen's table the "lower concretionary limestone" includes the "limestone of St. Louis."

Above the St. Louis limestone is reported the "Ferruginous sandstone" of Missouri. Owen did not report such a member, but for the overlying limestone series (composed of heavy-bedded limestones, and generally alternating with marl, shale, limestones, and a few beds of sandstone), Hall proposed the name "Kaskaskia limestone or Upper Archimedes limestone." This formation was found both at Kaskaskia and at Chester, Illinois, and below St. Genevieve in Missouri, and according to A. H. Worthen had been examined, its position clearly determined, and reported upon under the name "Chester limestone"[5] by himself in 1853. It is probable that Owen did not recognize this higher limestone, and that his "*f'*, upper concretionary limestone," may be only a continuation of the "lower concretionary," *d'*, separated from it by a more or less local sandstone, *e'*.

Evidence was given of extensive denudation previous to the coal period, and the author mentioned as consequences of this ancient denudation, the coal deposits in depressions among the inclined strata of the Silurian rocks; also rounded masses of clay found in the limestones of the Hamilton and Upper Helderberg groups, and he concluded from examination that these masses of clay and coal deposits were made subsequently to the deposition of the limestone, filling cavities caused by denudation.

In conclusion, a few words express the general features of the series

[1] Hall, James: On the Carboniferous limestones of the Mississippi Valley. (Abstract.) Am. Jour. Sci., vol. 23, 1857, p. 190.

[2] In the final Report on the Geology of Iowa, 1858, this bed is included with the Keokuk limestone, p. 96,

[3] Dated January 14, 1849, and published in the Bull. Soc. géol. France, II, vol. 6, pp. 419-441.

[4] Proc. Am. Assoc. Adv. Sci., vol. 5, p. 185.

[5] See Geol. of Illinois, vol. 1, p. 41.

of limestones on the south of the Ohio River. All the members of these limestones thin out, with the exception of the "Kaskaskia limestone," which predominates over the whole country, and is there the great "Carboniferous limestone."

In 1857 Owen[1] recognized the following classification at the Falls of Ohio:[2]

1. Black bituminous shale.
2. Upper Crinoidal, shell, and coralline limestones above.
3. Hydraulic limestone.
4. Lower Crinoidal, shell, and coralline limestones.
5. Olivanites bed.
6. *Spirifera gregaria* and shell and coralline beds.
7. Main beds of coral limestone, resting upon the "chain coral limestone" (Niagara).

In the base of No. 2, on Conn Island, fish remains were found, and this stratum is called the "Upper Fish bed." A lower fish bed was seen at the base of No. 6, called the "Turbo bed" in general, the subdivisions of which are given as follows of Nos. 6 and 7.:

6.	Shell beds	A. *Conocardium bed.*	inches..	7
		B. *Leptæna bed*	feet..	6
	Parting chert layers		do...	3
	Coral layers		do...	7
	Very hard rock		do...	2
7.	Main *coral beds*	1. Dark gray bed.		
		2. Black coralline layer.		

This rests upon the (Niagara) "chain coral bed."

G. C. Swallow[3] gave a brief description of the formations of Missouri and the contained minerals. He reported that the stratified rocks of Missouri belong to the following divisions, enumerated in descending order:

I. Quaternary.
II. Tertiary.
III. Cretaceous.
IV. Carboniferous.
V. Devonian.
VI. Silurian.

In giving a detailed account of each system, he considered the Carboniferous as presenting the following divisions:

(1) Upper Carboniferous or Coal Measures.
(2) Lower Carboniferous or Mountain Limestone.

The upper series is made up of sandstones, limestones, and shales, amounting to 1,500 feet in thickness, containing numerous beds of iron ore and ten beds of workable coal. The lower series, about 1,745 feet in thickness, includes "Chester limestone," "Ferruginous sandstone," "St. Louis limestone," "Archimedes limestone."

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[1] Geological survey of Kentucky, second annual report, 1857.
[2] Ibid., p. 97.
[3] (Explanations of the geological map of Missouri, and a section of its rocks. Proc. Amer. Assoc., vol. 11, pt. 2, 1857, pp. 1-21.

In the report of the geological survey of Iowa, a systematic study of the fossils of the Mississippian series was applied in the differentiation of the several formations.[1]

The geological formations of the upper Paleozoic were classified in the following manner by James Hall:

Above the Le Claire limestone comes a hydraulic, drab-colored limestone and shales with cavities, called the "Onondaga salt group"; next above this a limestone, gray and ash-colored, subcrystalline, also containing cavities, and with shaly partings, called the "Upper Helderberg;" following this is an argillaceous limestone or calcareous shale called the "Hamilton," which in some places is an alternation of calcareous shales and limestones, but is said to be more calcareous at the bottom. A stratum 10 to 15 feet thick at Rockingham and New Buffalo is called the "Encrinal limestone." Next above are shales and soft sandstones, as at Pine Creek, called the "Chemung." The order observed at this last mentioned place for the Chemung is "shaly limestone, green shale, sandy beds, yellow sandstone." At Davenport, Burlington, etc., the Chemung is described as "gray and yellow sandstone with shaly partings." Sometimes it is underlain by green shales, which are called the "Portage group."[2]

The typical section of this part of the series is at Burlington, Iowa.[3] It is as follows:

(1) Soft green shale. (2) Fine grained siliceous and argillaceous sandstone. (3) Limestone and shale, siliceous. (4) Argillaceous sandstone with Chemung fossils. (5) Oolitic bed. (1-5—"Chemung group".) (6) Calcareous and argillaceous shale, beds of passage. (7) Cherty beds. (8) Burlington limestone, brownish or grayish-brown encrinal limestone, the higher beds more or less white and subcrystalline, and in places 72 feet thick.

This Burlington limestone was regarded by Hall as equivalent to the "Encrinital limestone" of Owen of Missouri. It thickens southward.

Following the "Chemung" occurs a light gray or brownish white crinoidal, subcrystalline limestone called the "Burlington limestone." Upon this comes the "Keokuk limestone," a shaly grayish or bluish crinoidal limestone, which the author regarded as an equivalent of the "Archimedes limestone" of Owen and the "Siliceous group" of Tennessee. The Keokuk is followed by a geode bed and this by the "Warsaw limestone or second Archimedes limestone," which is "a magnesian limestone, shale and shaly limestone, thin-bedded and arenaceous," and after this a "coarse yellow calcareous sandstone and some pebbles of quartz." Next comes the "St. Louis limestone" of Swallow or "Concretionary limestone" of Owen. This is a brecciated, ash colored limestone, and sometimes subcrystalline and granular in texture, becoming more com-

[1] Report on the Geological Survey of the State of Iowa, embracing the results of investigations made during portions of the years 1855, 1856, and 1857, by James Hall and J. D. Whiting, vol. 1, Albany, 1858. 8vo., xv, 724, 4, and 30 pp., 29 plates, plate of section, and 2 maps.

[2] Ibid., p. 89.

[3] Ibid., pp. 89-90.

pact on going southward. Hall speaks of "the brecciated character of the northern exposures of the St. Louis limestone," and of the "more or less diagonally laminated limestone of gray to white color" in the more southern part.[1]

Below St. Louis, along the valley of the Mississippi, from Prairie du Rocher to Chester, the series dipping gradually southward exposes the "St. Louis limestone," with the "Ferruginous sandstone" resting on it, and above this the "Kaskaskia limestone." Hall observed the fact that the limestones thin out toward the north and upon their inclined edges are followed unconformably by the Coal Measures. He drew from this the inference that a contraction of the borders of this sea at the north began with the deposition of the Carboniferous limestone; that this was consequent upon the uplifting of the older rocks at the north.[2]

The limestone of the UpperCoal Measures in Ohio is traced westward, and is regarded as represented by the Carboniferous limestone of the Rocky Mountains. Previously, in the Report on the Mexican Boundary, Mr. Hall had recognized the fact that the Rocky Mountain region must have been an open sea at the time the Coal Measures were being deposited in the Mississippi Valley and farther eastward. The oscillation during the time of the Carboniferous limestone was mainly upward for the Upper Mississippi basin, and during the Coal Measures Worthen shows[3] that the same region was gradually sinking, causing the higher Coal Measures to extend farther northward than those below.

In the classification of the rocks of Iowa it was quite natural that the New York series should take a prominent part in the nomenclature. Although fossils were considered in the correlation, the erroneous interpretations, as well as the reports themselves, show that the lithologic characters of the various rocks were considered of chief importance. As Worthen stated in the First Report on the Geology of Illinois, in regard to the beds in Indiana, Iowa, and Missouri, which had been referred to the "Chemung group" of New York, the identifications were "made purely on lithological grounds."[4] It was this dominant idea, that there should be some similarity in the character of the rocks of the corresponding zones in separate regions, that led to the importance of the "Ferruginous sandstone" of the Missouri and, later, of the Iowa Reports.

Again, the "Siliceous group" in Tennessee and Alabama was regarded as important because probably representing a corresponding Siliceous group in the English classification.

The "Carboniferous or Mountain limestone" was distinctly recognized in the upper Mississippi region, and a "Millstone grit" was needed to fill out the system as interpreted in England. It can not be denied that great masses of limestone or of sandstone can be traced satisfactorily for hundreds and may be thousands of miles along the geological outcrops, but this expresses only the fact that, for long geological periods,

[1] Geol. Surv. Iowa, Rep., p. 105.
[2] Ibid., p. 117.
[3] Geology of Illinois, vol. 1, p. 50.
[4] Ibid., p. 109.

the general relations of oceans and continents remained substantially the same. When, however, the attempt is made to trace the subdivisions and to correlate series and stages and the lesser zones of the geological classifications by lithologic means, then the inadequacy of the method becomes apparent. As we look over the history of the work of geologists in America, we find the majority, and for the field I have specially studied I am inclined to say nearly all, of the erroneous correlations are directly traceable to a too great dependence upon lithology.

The following exhibits the classification of the Carboniferous limestone of Iowa, Illinois, and Missouri as it was understood by Hall in 1858.[1]

COAL MEASURES OF IOWA, ILLINOIS, AND MISSOURI.

VI. Kaskaskia limestone, or Upper Archimedes limestone. Pentremital limestone.	Kaskaskia and Chester, Illinois. St. Mary's, Missouri.
Lower arenaceous beds of passage.	
V. Gray, brown, and ferruginous sandstone overlying limestone of St. Louis and Alton.	Below Ste. Genevieve, Missouri. Below Prairie du Rocher and Kaskaskia, Illinois.
Abrupt passage.	
IV. St. Louis limestone, Concretionary limestone.	Highest beds below Keokuk, Alton, St. Louis, Ste. Genevieve, Prairie du Rocher.
Passage arenaceous or indistinct.	
III. Arenaceous bed, Keokuk and northward. Warsaw limestone or Second Archimedes limestone. Magnesian limestone.	Warsaw and Alton, Illinois. Bloomington and Spurgen Hill, Indiana. Opposite Fort Madison, Mount Pleasant.
Passage soft, marly, geodiferous.	Geode bed, Keokuk, Nashville, Iowa, and Warsaw, Illinois.
II. Keokuk limestone, Lower Archimedes limestone. Archimedes limestone, Owen and Swallow.	Keokuk and Mount Pleasant, Iowa. Quincy, Illinois. Hannibal, Missouri.
Passage cherty limestone, 60 to 100 feet.	Rapids above Keokuk, Iowa. Quincy, Illinois.
I. Burlington limestone	Burlington, Iowa, Quincy, Illinois, Hannibal, Missouri.
Oolitic limestone, sandstone, and shale of Chemung and Portage groups of New York.	Burlington and Evans Falls, Iowa. Hannibal, Missouri, etc.

In 1859 Mr. A. H. Worthen[1] reported the discovery of a terrestrial flora in the Chester limestone group.

While constructing a section of the Ohio Bluffs he discovered, in 1851, in the middle of the Chester limestone of Pope County, a bed of calcareo-argillaceous material containing fossil plants. The flora does not present a single species in common with the Carboniferous. Among the plants he found representatives of the genera *Stigmaria*, *Sigillaria*, *Knorria*, and *Lepidodendra*, but of species quite distinct from those in the Coal Measures.

"This fact seems to indicate the close proximity of an ancient coast line in this direction," and its probability is increased by the fact that "the Subcarboniferous series thins out rapidly to the north and east."

[1] Geology of Iowa, p. 109.

[1] Worthen, A. H: Remarks on the discovery of a terrestrial flora in the Mountain limestone of Illinois. Am. Assoc., Proc., vol. 13, 1859, pp. 312, 313.

In 1859[1] James Hall presented his view of the relation of the strata of the Mississippi Valley to those of the New York section. The interval between the Chemung and the Coal Measures of the Appalachian section is filled, in the West, by the representatives of the Carboniferous limestone. The following table explains this view:[2]

New York and Pennsylvania Coal Measures.		Mississippi Valley Coal Measures.
Red shales Conglomerate Catskill Mountain group	Great Carboniferous limestones of the Mississippi Valley.	Kaskaskia limestone. Ferruginous sandstone. St. Louis limestone. Warsaw limestone. Keokuk limestone. Burlington limestone.
Chemung and Portage groups		Chemung and Portage groups.
Hamilton group		Hamilton group.

Concerning the fauna of the Western rocks, which he regarded as the equivalent of the Chemung and Portage groups, he reported that he had traced the rocks through Ohio, and then from Indiana into Michigan, across Indiana and Illinois to Iowa, and into Missouri. He recognized scarcely a single species identical, but found representative forms.

It will be seen thus that the dominant means of correlation was the strata, probably the black shale and the argillaceous and arenaceous deposits following below the limestone. The suggestion was thrown out that the cause of the great difference in sedimentation is the elevation of the Cincinnati axis, allowing a sea to be depositing calcareous sediments in the Mississippi Valley, while a coarse deposit was being made east of that axis.[3] This is evidently the true explanation.

It was the wide territory which American geologists had to study which led them to recognize the great difference in the conditions which existed at the same geological time in separate regions of the continent, and developed that minute comparative study of fossils which alone has made exact correlation possible.

In the above table it is evident that up to this time Professor Hall still held to the view that the Chemung Group of Iowa, Missouri, and Illinois was, as he called it, "Subcarboniferous," that is, was below the "Carboniferous formations," not one of them.

In 1860 Sydney S. Lyon[4] recognized three divisions, viz: "(1) Coal Measures, (2) Millstone grit series, (3) Subcarboniferous series;" but in the latter, the lower or "Subcarboniferous series," he follows the erroneous usage introduced by Owen, for we find included under this division not only the lower Carboniferous rocks, but all from the "Black slate" to the "Catenipora beds," inclusive. "Subcarboniferous series" applied to the rocks below the Millstone grit is a modification of Dr. Owen's usage. Owen proposed the name "Subcarboniferous limestone," but applied it in about the same sense in which Mr. Lyon applied the name "Subcarboniferous series." Mr. Lyon restricted the use of the

[1] Paleontology of New York, vol. 3. [2] Ibid., p. 53. [3] Ibid., p. 58.
[4] Discussion of the Stratigraphical Arrangement of the Rocks of Kentucky. Trans. St. Louis Acad. Sci., vol. 1, 1860, pp. 612-621.

former term to the limestone which Prof. Hall called "Carboniferous limestone."

Mr. Lyon's classification was as follows:[1]

	Feet.	
a. Coal Measures	1,200	
b. Fifth sandstone	40–100	Millstone grit series.
c. Fourth limestone	10– 40	
d. Beds of colored clays	0– 84	
e. Fourth sandstone	0– 6	
f. Third limestone	25– 50	
g. Aluminous shale	0– 53	
h. Third sandstone	25– 40	
i. Second limestone	25– 50	
k. Second sandstone	75– 90	
l. First limestone	15– 20	
m. First sandstone	10– 30	
n. Cavernous limestone	200–400	Subcarboniferous series.
o. Middle limestone	500–600	
p. Sandstones and shales	205–300	
q. Black slate	50–100	
r. Encrinital limestone	0– 8	
s. Hydraulic limestone	0– 20	
t. Spirifer bed	0– 3	
u. Nucleocrinus bed	0– 2	
v. Turbo bed	6– 10	
w. Coral bed	5– 10	
x. Catenipora beds	15– 40	

The divisions *p*, *o*, *n*, constituted what he called "Subcarboniferous limestone," the synonyms for which were "Barren limestone," "Cavernous limestone," "Carboniferous limestone," and "Mountain limestone" of the Europeans.

Division *o* was the middle member of the Subcarboniferous limestone, and 180 feet above its base is a bed which was regarded as equivalent to Hall's "Spurgen Hill beds," of Washington County, Indiana, which Prof. Hall considered as equivalent to the "Warsaw limestone."

The lower member of the "Subcarboniferous limestone" (*p*) "is frequently distinguished as the *Knobstone beds*."[3] The "Black slate" with *Lingulas* (*q*) the author put in the "Devonian," and he stated that division *p* has been also placed in the Devonian, but that the paleontologic evidence of the Goniatite beds at Rockford, Indiana, would point to its inclusion with the Subcarboniferous limestones, instead of in the Devonian.[4]

The beds *r*, *s*, *t*, *u*, *v*, *w*, *x*, "thin out rapidly and disappear entirely about twenty miles south of Louisville."[4]

This classification was in accord with the general usage of Dr. Owen and those who had assisted him in his surveys in the Mississippi Valley.

James Hall, in the various papers in which he attempted to correlate the Western deposits with his New York system, used the name "Carboniferous limestone" for the calcareous portion of the "Subcarboniferous series" of Owen, and applied "Subcarboniferous" to his so-called "Chemung group," which in New York is of Devonian age. The Western geologists clearly understood the relation of the so-called "Chemung" of the Mississippi Valley to these "Carboniferous limestones,"

[1] Discussion of the Strategraphical Arrangement of the Rocks of Kentucky. Trans. St. Louis Acad. Sci., vol. 1, 1860, p. 641.

[2] Ibid., p. 617. [3] Ibid., 619. [4] Ib., p. 620.

but they were not so well acquainted with the Chemung group of New York. This is shown by the fact that Swallow and Meek, in the Missouri report of 1885, placed the Chemung above the "Devonian,"[1] although in tabulating it they bracketed the Chemung with the Devonian. However, to the State geologist of New York the "Chemung" was unmistakably Devonian, and for him to correlate deposits in the West with the Chemung necessitated placing them below the Carboniferous system; hence he used the term "Subcarboniferous" to separate these deposits from the Carboniferous system above, whereas the Western geologists included the Subcarboniferous limestone in the Carboniferous system to distinguish the lower series, which was under the true carbon-bearing Coal Measures.

Mr. A. Litton[2] in 1860 reported some statistics regarding thickness of deposits derived from a well boring in St. Louis.

A description of the boring is given, beginning in the St. Louis limestone and penetrating to a depth of 2,199 feet, passing through the limestones, cherty rock, and shales of the Carboniferous system, 650 feet, the red marls and the shales of the "Chemung," the limestones, shales, sandstones, etc., of the Hudson River, Trenton, and Black River groups, and finally the magnesian series. The white, soft sandstone found at a depth of 1,505 feet is considered as the Saccharoidal sandstone; from that the main supply of water was obtained, none rising to the surface from below this sandstone.

Mr. C. A. White contributed a paper[3] on the rocks at Burlington, Iowa, in 1860, in which he called attention to the close relationship between the faunas in the "Chemung" rocks in the lower part and those in the upper rocks of the Burlington section. He noticed also that the Brachiopods of the "Chemung" were very similar and possibly of identical species in some cases with those above the Burlington limestone. He suggested (p. 225--6) that although the so-called Chemung rocks of Iowa may be geologically equivalent to the Chemung of New York they are not contemporaneous; migration of the species westward having taken place at the close and after the time of the Upper Chemung of New York.

W. B. Rogers, commenting upon this paper,[4] remarked on the gradual passage from a Devonian to a Carboniferous fauna on passing westward from the Appalachians, previously suggested by James Hall. He suggested that "the mingling of races in successive formations is a natural result of the accumulations of the strata during a long period of comparative repose," and said further:[5]

> The changes of fossil faunas are more gradual in proportion to the degree in which the successive deposits of a given period have been preserved from destruction.

[1] See text of the report (vol. 1-2, Pt. 1, p. 101, and Pt. 2, p. 101.

[2] Litton, A.: Belcher & Brothers' artesian well in St. Louis, Missouri. St. Louis Acad. Sci., Trans., 1857, vol. 1, 1860, pp. 80-86, plate.

[3] Observations upon the geology and paleontology of Burlington, Iowa, and its vicinity, by Charles A. White, Sept., 1860. Boston Journ. of Nat. Hist., vol. 2, pp. 209-235.

[4] Proc. Boston Soc. Nat. Hist., vol. 7, 1861, p. 320.

[5] Ibid., p. 321.

He would correlate the calcareous and associated beds below the Burlington and possibly all below the Keokuk with the Ponent or Catskill and Vespertine, represented by 6,000 feet of deposits in the Appalachian region. He adds:

> But all such attempts at synchronizing distant deposits must be limited to a general and vague result, even when corresponding fossils would seem to mark simultaneous origin, and we must not forget the large agency of migration, and the long lapse of years, which in many cases may have been required for the extension of a living race into distant submarine settlements.

Messrs. C. A. White and R. P. Whitfield, in the introduction to their paper[2] on the Chemung rocks of the Mississippi Valley, which is mainly descriptive of species, state their reasons for recognizing the "Chemung" in Iowa. They say the Hamilton group of New York is recognized in Illinois and Iowa as a reliable Devonian horizon by the fossils; that the Chemung offers changes even in short distances. In northeastern Ohio they hold that there are few if any species common with those of New York, and the fauna in western Ohio and Michigan is still different, but still the Chemung age of each is maintained. It is thus apparent that to these authors the correlations in the West were based upon relative stratigraphic position, the generic relations of the fossils, together with a not unremarkable similarity of lithological characters.

Some species of the "Chemung" of Burlington, Iowa, are said to be the same as those of the "Chemung" of Ohio, "which rocks can be traced continuously to New York."[3]

Notwithstanding an unmistakable resemblance to Carboniferous fauna, they refer them to the Chemung of New York, explaining that "a direct continuity of strata of the Chemung of New York can be traced from that State to those of Ohio." Thus it appears that Messrs. White and Whitfield, relying upon the correctness of the determination of continuity of strata claimed by Hall in 1842 were led to put aside the evidence of fossils, and to explain the differences as due to geographic causes.

Messrs. Meek and Worthen, in their discussion of this question, made the want of specific identity the chief reason for separating the Burlington rocks called "Chemung" from the Chemung of New York,[4] and their reliance upon the Carboniferous aspect of the fossils led them to correctly correlate the formation which had hitherto been called "Chemung."

Messrs. W. H. Niles and Charles Wachsmuth,[5] maintained that the

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[1] Proc. Boston Soc. Nat. Hist., vol. 7, 1861, pp. 321, 322.

[2] Observations on the Rocks of the Mississippi Valley which have been referred to the Chemung group of New York, together with descriptions of new species from the same horizon at Burlington, Iowa. By R. P. Whitfield and C. A. White, Boston Soc. Nat. Hist., vol. 8, 1862, pp. 289–306.

[3] Ibid., p. 290.

[4] Remarks on the age of the Goniatite limestone at Rockford, Indiana, and its relations to the "Black slate" of the Western States, and to some of the succeeding rocks above the latter. By F. B. Meek and A. H. Worthen. 1861. Am. Jour. Sci., 2d ser., vol. 32, pp. 167–177 and 288.

[5] Evidence of two distinct Geological Formations in the Burlington Limestone. Am. Jour. Sci., vol. 42, 1866, pp. 95–99.

Burlington limestone is divided into two distinct formations, which they called the "Lower" and "Upper Burlington limestone." The two sections can be distinguished from each other by their lithologic characters alone, but the distinction chiefly depends upon the different kinds of crinoids found in the two divisions. In the lower section its upper strata become interstratified with beds of chert, and the uppermost stratum of chert forms the division between the two sections. The crinoids below this cherty bed are smaller, less coarse in their general features, and the ridges, spines, etc., are never so prominent as in the species of the upper division. The inference is, that circumstances were not so favorable to the growth of these animals during the deposition of the lower strata. There is a similar marked distinction between the crinoids of the Upper Burlington and those of the Keokuk limestone, the latter being still larger in size and more prominent in feature. A band of chert is also found between the Upper Burlington and the Keokuk, and it appears from these facts that there was something in the presence of siliceous material in the depositing waters during the formation of the upper beds of both the Lower and Upper Burlington divisions which was unfavorable to the growth and life of the inhabiting crinoids, for as the chert appears the crinoids seem to have declined, and finally all species became extinct before the completion of the chert. The same fact is found true of the Mollusca, most of the species of the two divisions being distinct. Lists of some of the better-known species of the crinoids are appended, arranged under the names of the formations to which they are exclusively restricted.

If the view of the authors were found to be correct in fact, it would signify that the cherts had their origin during the original deposition of the rock, but even were it a fact, it may be questioned whether the difference in fauna was not purely local, conditioned upon changed character of the bottom.

The series of Reports of the Geological Survey of Illinois,[1] by Mr. A. H. Worthen as Director, began with vol. I., in 1866.

In the classification of the rocks of Illinois, the New York nomenclature was used for the subdivisions of the Silurian and Devonian

[1] Geological Survey of Illinois, A. H. Worthen, Director.

Vol. I. Geology. 1866.

Vol. II. Paleontology, Descriptions of Vertebrates, by J. S. Newbury and A. H. Worthen. 1866. Descriptions of Invertebrates, by F. B. Meek and A. H. Worthen. Description of Plants, by Leo Lesquereux.

Vol. III. Geology and Paleontology. 1868. Geology, by A. H. Worthen. Paleontology, by F. B. Meek and A. H. Worthen.

Vol. IV. Geology and Paleontology. 1870. Geology, by A. H. Worthen. Paleontology, Vertebrates, by Newberry and Worthen. Plants, by Lesquereux.

Vol. V. Geology and Paleontology. 1873. Geology, by Worthen and James Shaw. Paleontology, by Meek and Worthen.

Vol. VI. Geology and Paleontology. 1875. Geology, by Worthen, G. C. Broadhead, E. T. Cox. Paleontology, by O. St. John, Worthen, and Meek.

Vol. VII. Geology and Paleontology. 1883. Geology, by A. H. Worthen. Paleontology by A. H. Worthen, Orestes St. John, and S. A. Miller, with an addenda by Charles Wachsmuth and W. H. Barris.

systems, and for the Carboniferous system the nomenclature already proposed in the Missouri (1855) and Iowa (1858) Reports was adopted with some modifications.[1]

In classifying the Carboniferous rocks, Worthen included the "Barren Coal Measures" or "Millstone grit" in the Coal Measures. They are seen in the southern part of the State, but not in the more northern part, where the Coal Measures proper or "Upper Coal Measures" outcrop. They are terminated by a sandstone called the "Anvil rock sandstone" (Owen), upon which are some limestones regarded as equivalent to the "Great limestone of Pennsylvania."[2]

Worthen adopted the name "Subcarboniferous limestone" for the rocks between the Black slate and the Coal Measures and Conglomerate.

The following expresses the classification of the upper Paleozoic rocks of Illinois as interpreted by Mr. Worthen in 1866:[3]

Coal Measures and Millstone grit	Coal Measures, 600–1,200 feet and Conglomerate.
Subcarboniferous	Chester group, 500–800 feet.
	St. Louis group, 50–200 feet.
	Keokuk group, 100–150 feet.
	Burlington limestone, 25–200 feet.
	Kinderhook group, 100–150 feet.
Devonian	Black slate, 10–60 feet.
	Devonian limestone, 10–120 feet.
	Oriskany sandstone, 40–60 feet.
Devonian and Silurian	Clear Creek limestone.

Mr. Worthen in the first report considered the "Clear Creek limestone as equivalent, in its upper part, to the base of the Devonian. The name "Chester group" is proposed by Worthen for the "Chester limestone" and the underlying "Ferruginous sandstone" of the Missouri Reports. The "Warsaw limestone" (Hall) of the Iowa Report, Mr. Worthen united with the "St. Louis limestone" of Missouri to form the "St. Louis group." He also united the "Geode bed," the "Keokuk limestone," and the underlying "Cherty beds" of the Iowa Report to constitute his "Keokuk group." The "Siliceous group" of Tennessee and Alabama he regarded as a southern extension of this same "Keokuk group" of Illinois. The author further pointed out the fact that the—

> Subcarboniferous limestone becomes arenaceous on the northeastern border of the coal field, and that all the upper members above the Kinderhook group thin out in that direction, and are replaced by the grit stones forming the lowest member of the series; and in Ohio these grit stones occupy the entire horizon from the Conglomerate to the "Black slate."[4]

The name "Burlington limestone" was adopted with substantially its original meaning as applied by Hall in the typical locality, Burlington, Iowa. It was not recognized outside the States of Iowa, Illinois, and Missouri. It is famous for the great abundance of crinoids, which are found in beautiful preservation about Burlington.

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[1] See Geol. Survey of Ill., vol. 1, p. 40.
[2] Ibid., p. 61, et seq.
[3] Ibid., vol. 1, p. 26.
[4] Ibid., p. 101.

The name "Kinderhook group" was proposed by Messrs. Meek and Worthen in 1861 in the course of a discussion on the geological positions of the Goniatite beds of Rockford, Indiana.[1] Its original application was to the rocks between the top of the Black slate and the base of the Burlington limestone as seen at Kinderhook, Pike County, Illinois. In the present report Mr. Worthen further defined the group, and defended its reference to the Carboniferous.[2] He defined it as including "the Chouteau limestone, the Lithographic limestone. and the Vermicular sandstone and shales of the Missouri Report, the so-called 'Chemung rocks' of the Iowa Report, that part of the 'Waverly sandstone' of Ohio which overlies the Black slate of that region, and the 'Goniatite limestone' of Indiana."[3]

This group, the "Kinderhook," was traced into Indiana, where it is represented by grit stone and arenaceous deposits, and is regarded as the only division of the Subcarboniferous in northwestern Indiana and in northern Ohio, where it constitutes all the so-called "Waverly sandstone." The Kinderhook group of Worthen constituted the lowest member of the Carboniferous system of the upper Mississippi province.

Mr. Worthen correlated "a series of dark blue, green, or chocolate colored shales, passing locally into a black bituminous shale," of western and southern Illinois with the "Black slate" of Tennessee and other States in the interior.[4] Certain Devonian limestones were recognized immediately underlying it, and from this fact and the presence of *Lingula spatulata* he correlated it further with the Genesee slate of New York. In that part of the State it is followed by the Kinderhook group. In the northern part of the State, however, in Rock Island County, the author reported the Black slate and the Subcarboniferous limestone series absent, the Coal Measures resting unconformably upon the Devonian limestones, which were correlated with the Corniferous limestone of New York by their fossils.[5]

In the southern part of the State a sandstone was observed which Mr. Worthen identified with the Oriskany sandstone of New York. This was first observed in the neighborhood of Jonesborough, Union County, Illinois.[6]

In the second volume, published in 1866, slight changes were made in the classification and nomenclature. The introduction was by Messrs. Meek and Worthen.

The classification preferred is as follows:[7]

				Feet.
Carboniferous system	Upper	Carboniferous period.	Coal Measures, Millstone Grit	1,200
	Lower	Mountain limestone or Subcarboniferous period	Chester group	800
			St. Louis beds	200
			Keokuk group	150
			Burlington group	200
			Kinderhook group	150

[1] Am. Jour. Sci., vol. 33, p. 228.
[2] Ibid., pp. 108–118.
[3] Ibid., p. 109.
[4] Ibid., p. 119.
[5] Ibid., p. 121.
[6] Ibid., p. 124.
[7] Geol. Surv. Ill., vol. 2, p. VIII.

			Feet.
Devonian system	Hamilton period	Genesee division ("Black slate" and grayish shale)	100
		Hamilton beds	120
	Upper Helderberg period. Corniferous and Onondaga beds		25
	Oriskany period	Oriskany, upper bed	40
		Oriskany, lower beds or Clear Creek group	200
Silurian system	Lower Helderberg period.		

In this table the use of the term "Subcarboniferous" as meaning below the coal-bearing strata is clear. The recognition of the absence of upper Devonian is to be noticed. In the Oriskany the upper cherty part only of what was originally included in the "Clear Creek group" is placed in the Devonian. The lower part as it arrives at Bailey's landing, Perry County, was correlated by its fossils with the "Shaly limestone of the lower Helderberg group."[1]

The authors, after the proposal of the name "Kinderhook group," examined the rocks in Ohio and concluded that the "Waverly sandstone" or more properly "Waverly group," is of the same age, and suggested that it may be necessary to adopt the earlier name. Still they think it wise to retain the local State names until exact parallelism be established.

The third volume was published in 1868. The authors of the Geology, besides A. H. Worthen, were H. Engelmann, H. C. Freeman, and H. M. Barris. The paleontology was by Meek and Worthen. In this report "Lower Carboniferous" is substituted for "Subcarboniferous" of the earlier reports. In the volume are described a number of invertebrates from the Devonian, Kinderhook, and other deposits of Illinois, and there are descriptions of sections for several of the counties in the western part of the State.

The fourth volume was published in 1870. Bradley and Green took the place of Engelmann and Freeman. The paleontology of vertebrates was by Newberry and Worthen; of plants, by Lesquereux. "Lower Carboniferous" and "Carboniferous system" are used to cover the upper and lower divisions of the Carboniferous.

The fifth volume was published in 1873. A. H. Worthen and James Hall were the geologists, and Messrs. Meek and Worthen the paleontologists. In this report the nomenclature is "Carboniferous system" and "Lower Carboniferous system."

The sixth volume was published in 1875. The geologists were Messrs. Worthen, Broadhead, and Cox; the paleontologists, Messrs. Orestes St. John, Worthen, and Meek.

The seventh volume was published in 1883. Mr. Worthen, the geologist; paleontologists, Messrs. Worthen, St. John, and S. A. Miller. Addenda appear in this volume, written by Messrs. Wachsmuth and Barris.

I have noticed no particular change in the geological nomenclatur

[1] Am. Jour. Sci., vol. 33, pp. XI–XII.

in either of the last two volumes. They are devoted to the elaboration of the details of geology in the counties and to paleontology.

Mr. Henry Englemann,[1] in 1868, described the Lower Carboniferous formations of southern Illinois as follows:

Underlying the Coal Measures in central Illinois, Iowa, and Missouri, were distinguished the following formations:

1. The Ferruginous sandstone.
2. The St. Louis limestone.
3. The Warsaw limestone.
4. The Keokuk limestone.
5. The Encrinital or Burlington limestone.

Farther south the "Kaskaskia or Chester limestone" was found between the Coal Measures and the Ferruginous sandstone; and heavy masses of sandstone ("Millstone grit") were observed next below the Coal Measures, and also beds of sandstone intercalated with the Chester limestone.

The author discovered that in the extreme southern part of Illinois this upper division of the Lower Carboniferous attains a much greater and more varied development, while the lower subdivisions seen farther north are lost or merged into one. He subdivided the series as follows:

A. Coal Measures.

B. Millstone grit, reaching a thickness of 500 feet, with a seam of coal far above the middle dividing it into Upper and Lower Millstone grit.

C. Strata corresponding to the Chester limestone and Ferruginous sandstone, and consisting of alternations of siliceous, Archimedes and Pentremital limestones, of hales, and sandstones, attaining a maximum thickness in Johnson County and adjoining counties of 1,000 feet.

The different layers of limestones and sandstones are described in detail.

D. The St. Louis limestone, with a thickness of 200 feet or more.

Some of the layers have an Oolitic structure. Underneath this are shales, siliceous slates, and some black laminated slate,[2] considered by good authorities as of the age of the Chemung group. Below these are well marked Devonian strata.

The general features of the geology of Tennessee were defined in the various reports of Gerard Troost, and some of the names which have been preserved were proposed by him.

In 1869 appeared Safford's "Geology of Tennessee," which elaborates the work begun by Mr. Troost, and presents a systematic classification

[1] Englemann, Henry: On the Lower Carboniferous system as developed in southern Illinois. St. Louis Acad. Sci., Trans., vol. 2, 1868, pp. 188–190.

[2] This paper was written later than the publication of the first Report of the Geological Survey of Illinois, in which, as is quoted on a previous page, the name "Chester group," was proposed to include the formations which had previously gone under the names "Kaskaskia limestone," "Ferruginous sandstone," and "Chester limestone."

Dr. Englemann, who was at the time of writing this paper (1868) one of the geologists on the survey of Illinois, elaborates the facts as exhibited in southern Illinois.

of the formations in unison with the correlations and nomenclature of neighboring States.

In Mr. Safford's[1] report the upper Paleozoic terrane of Tennessee is sharply defined above and below. It rests, with very slight unconformity, but with unmistakable interval, upon Upper or Lower Silurian rocks, and is capped, with more distinct interval, by the Cretaceous or later rocks. The classification proposed by the author is as follows:

10. Cretaceous.

9. Coal Measures { Upper Coal Measures. Conglomerate. Lower Coal Measures.

8. Lower Carboniferous { Mountain limestone. Siliceous group.

7. Black shale.

Silurian—either "6. Lower Helderberg; 5. Meniscus limestone, Dyestone group; or 4. Nashville," as the case may be, etc.

The lowest member of this upper Paleozoic terrane is the "black shale," a bituminous black shale with grains or nodules of pyrite, which is widely distributed, and, whenever present, is a valuable stratigraphic bench mark. In the eastern part of the State it rests on the "Nashville, or Dyestone, or Meniscus formation;" farther west, on the opposite side of the central basin, the subjacent formation is "Meniscus, Dyestone, or Lower Helderberg." West of the Cumberland tableland it is not solely a black shale; it thins on going westward, and at its top, in a lighter colored shale, is a thin layer of argillaceous fetid concretionary bodies called "Kidneys," and taking the place of the lower layer is a stratum varying from 1 to 15 feet of dark gray fetid sandstone, containing the same *Lingula* seen in the typical black shale. This character of the formation is seen in Wayne and Hardin Counties. The author considered this to be the equivalent of the Devonian, and particularly of the Genesee shale of the Hamilton Period of New York.[2] The highest rocks seen underlying this were referred to the Lower Helderberg division of the Upper Silurian. The black shale throughout the book is spoken of under this name and not as Devonian. The black shale formation is in some places associated with a sandstone layer containing the same *Lingula*, varying from a few inches to 15 feet. (Wayne County.)[3] Above the black shale is also seen in places a layer of "kidney concretions." It is defined as "a thin layer of argillaceous, very fetid, concretionary bodies called 'kidneys.'" They are in a bluish shale and vary in size from an inch or less to 2 feet in diameter. In the more eastern sections this black shale rests on the "Nashville" (Sumner County) "Niagara or Dyestone group" (De Kalb and Maury Counties); farther west, on the "Meniscus limestone" or Helderberg (Wayne and Hardin Counties). Wherever it occurs it is overlain by the "Siliceous group," or else is the top rock. The place of unconformity is thus shown to be below the black shale formation.

[1] Geology of Tennessee, by James M. Safford, State geologist, Nashville, 1869.
[2] Ibid., p. 157.
[3] Ibid., p. 331.

The "Lower Carboniferous," or "Formation VIII," is primarily defined as "the great group of strata intervening between the black shale and the Coal Measures," with a maximum thickness of 1,200 feet.[1] This is subdivided into (8*a*) the "Siliceous group" and (8*b*) the "Mountain limestone." This, as the author remarks, "is the most useful division that can be made, so far at least as the consideration of the topographical and agricultural features of the State are concerned."

The Coal Measures are classified by the author in three divisions: (*a*) the "Lower Coal Measures," varying from a few feet to 300; (*b*) the "Conglomerate;" (*c*) the "Upper Coal Measures," from 200 to 2,000 feet thick.

It is evident that this classification is primarily a natural classification of the rock formations according to their prominent petrographic features. To take them in detail: Safford's "Siliceous group" (8*a*) embraces about the same rocks as were previously defined by Troost under the name Siliceous stratum." The name is suggested by the fact of the predominance of siliceous material in the rocks in the form of "chert, fine sandstone, silicocalcareous rock or siliceous shale." The "Siliceous group" as it appears in Middle Tennessee, is subdivided, into "a lower," the "*Protean member*," and an upper or "Lithostrontion bed." From a study of the characters distinguishing the two it is evident that the presence of the Lithostrontion in the upper member is chiefly relied upon, the lithologic characters not presenting any constant distinction, and the author states that no division is practicable in East Tennessee.[2] Two characters are mentioned as pertaining to the "Lithostrontion bed"—the fossiliferous character of the cherts and the liberation of oxide of iron in the decomposing of the cherts. The author also thinks the two members become one below Huntsville, on the anticlinals of Alabama,[3] being characterized throughout by *Lithostrontion Canadense*. He correlates the "Protean member" in general with the "Lower Carboniferous limestone below the St. Louis limestone" of the Iowa and Illinois and Missouri classification, and the "Lithostrontion bed" he correlates with the "St. Louis limestone." The "Mountain limestone" is "a heavy group of limestones and shales, the latter constituting in the aggregate about one-fourth of the mass," including a sandstone near the base which in the northern part of the State is 40 or 50 feet thick. This formation reaches its maximum thickness in the southern part of the State (720 feet), decreasing going northward until near the Kentucky line it is reduced to 400 feet.[4] The limestones are often argillaceous, sometimes oolitic, but rarely cherty. The fauna is considered equivalent to that of the Kaskaskia limestone (Hall) of the Northwestern States (=the Chester limestone of Worthen). Thus the name "Mountain limestone" is used in a restricted sense.

The author's classification is primarily a lithologic classification of the

[1] Geology of Tennessee, by James M. Safford, State geologist, Nashville, 1869, p. 338.
[2] Ibid., p. 347. [3] Ibid., p. 340. [4] Ibid., p. 352.

strata represented within the State. Above the Silurian they are as follows:

1. Black slate formation, at the base,
2. Siliceous formation, or the series of cherty limestones,
3. The Argillo-limestone formation, called the Mountain limestone,
4. The Lower Coal Measures, separated by
5. The conglomerate from the
6. Upper Coal Measures.

Fossils were reported and were used in correlating the several formations, but the subdivisions were much less finely drawn than in Illinois, Missouri, or Iowa, where fossils were more abundant in the Mississippian series.

The classification of the Lower Carboniferous formations into two groups, the "Siliceous" and the "Mountain limestone," is worthy of attention, but until the faunas are thoroughly studied this can not be considered as final. A comparison of the various faunas reported from the "Subcarboniferous," or "Lower Carboniferous" formations of the interior had already demonstrated considerable difference in the association of species in different parts of the area, but of the marine faunas the line which appears generally more sharply drawn is that between (*a*) the St. Louis (and, where present, the Warsaw,) and (*b*) the fauna next below, as the Keokuk and Burlington.

In the reports of the second survey of Iowa,[1] some modification of the classification proposed by James Hall in 1858 is seen. Mr. White reported in volume 1 the following classification:

			Feet.
Carboniferous	Coal Measures	Upper	200
		Middle	200
		Lower	200
	Subcarboniferous	St. Louis limestone	75
		Keokuk limestone	90
		Burlington limestone	190
		Kinderhook beds	175
Devonian	Hamilton	Hamilton shales and limestone	200
Silurian		Niagara limestone	

Mr. White referred all the Devonian strata of Iowa to a single formation, the Hamilton group of New York, and did not recognize any representative of either Upper Helderberg or Chemung. The Carboniferous system is present in only the two members, which he called "Subcarboniferous" and "Coal Measures." He used "Subcarboniferous group" as synonymous with the old terms "Carboniferous limestone," "Subcarboniferous limestone," and "Mountain limestone." In the subdivision of this group and its nomenclature he evidently follows the first and second Illinois reports.

Mr. F. B. Meek[2] wrote a report on the Spergen Hill fossils in 1873.

[1] Report on the Geological Survey of the State of Iowa to the Thirteenth General Assembly, for 1870, containing results of examinations, etc., made 1866, 1867, 1868, and 1869. By Charles A. White, M. D. Vol. 1, 1870.

[2] Meek, F. B.: Spergen Hill fossils identified among specimens from Idaho. Am. Jour. Sci., 3d ser., vol. 5, 1873, pp. 383, 384.

The Spergen Hill fossils found at Bloomington, Ind., at about the horizon of the Lower Carboniferous series, are miniature representatives of known larger species, belonging for the most part to the genera of Corals, Blastoidea, Brachiopoda, etc. They are crowded together in immense numbers, but finely preserved, in this locality, and a few have been found at the same horizon in Illinois, Iowa, and Missouri, but none in such numbers, or in any locality west of Missouri or Iowa, until Mr. Meek discovered hundreds of these little fossils in a small, dark-gray mass of crumbling limestone, brought by Professor Bradley from Idaho. The fossils belong to about 17 species of the same genera found at Spergen Hill, and of the species about one-half were undistinguishable from the Spergen Hill forms.

In the first annual report of the Survey of Minnesota[1] a chart[2] is presented with some modifications in the classification and correlations of the Missisippian series.

The Carboniferous system is represented on the chart, although nothing representing it is recorded for Minnesota, and is divided into the following groups:

Permian.
Coal Measure.
Carboniferous conglomerate.
Subcarboniferous.

The Subcarboniferous group is made up as follows for North America:

Subcarboniferous.....	Mississippi formation	Chester limestone.	
		St. Louis limestone.	
		Keokuk limestone.	
		Burlington limestone.	
	Marshall formation	Marshall sandstone.	

The "Mississippi formation" is the equivalent of the "Mountain limestone" of Europe and Tennessee.

The "Marshall formation" is the equivalent of the "Kinderhook" of Iowa and Illinois and of the "Old Red sandstone" of Europe.

The Devonian system is made up as follows:

System.	Groups.	Formations.	Strata of North America.
Devonian ..	Hamilton	Hamilton....	Huron shale.
			Hamilton limestone.
	Upper Helderberg	Corniferous..	Corniferous limestone.
			Onondaga limestone.
		Oriskany....	Schoharie grit.
			Cauda-galli grit.
			Oriskany sandstone.

The usage of "Mississippi" as a name for the limestones of the Sub-

[1] The Geological and Natural History Survey of Minnesota, by N. H. Winchell, State Geologist, 1873.

[2] Chart of geological nomenclature, intended to express the relation of Minnesota to the great geological series of the earth, and the probable equivalency of some of the names the formations have received in the various States and in Europe, opp., p. 40.

carboniferous is according to the proposal of Alexander Winchell in 1870, (see ante, p. 135). The "Marshall formation" is also according to the classification proposed by Alexander Winchell. As the whole Carboniferous and all of the Devonian except beds with a very meager fauna are wanting in Minnesota and the author does not explain the reasons for his departures from ordinary usage, it is useless to make further comment.

In 1873 two reports[1] were published upon the geology of Missouri, under the directorship of Mr. Raphael Pumpelly.

In the first of these reports the work consists of material previously unpublished, mainly details of county surveys made before 1861, the maps and charts having been struck off prior to 1861. Pages 1 to 110 are by G. C. Broadhead, 111 to 188 by F. B. Meek, and 189 to 323 by B. F. Shumard. The nomenclature is substantially the same as that of the first and second reports of G. C. Swallow, 1855.

In Mr. Shumard's report on Sainte Genevieve County,[2] a classification is given which deserves attention.

Opposite page 292 is an engraved chart entitled "Vertical section of strata observed in Sainte Genevieve County, by B. F. Shumard."

The part of this chart referring to the present discussion is as follows:

				Feet.
Carboniferous system.		*e.* Coal Measures.	Hard siliceous limestone	10
			Dark purple and drab shale	25–40
			Micaceous sandstone	30
	Archimedes group.	*h.*	Archimedes limestone or Kaskaskia limestone	200
		f.	Sandstone	80
		h'.	Archimedes limestone	50
		g.	St. Louis limestone	150
		h''.	Oolitic limestone	20
			Archimedes limestone or Warsaw limestone	80–100
	i. Encrinital limestone			200–300
Devonian.	Chemung group.	*j.*	Chouteau limestone	90
		k.	Vermicular sandstone and shale	25–30
		l.	Sandstone	25
		p.	Hamilton	25
		m.	Oriskany	

As explained in the text, the upper Archimedes limestone (*h*) is the equivalent of Hall's "Kaskaskia limestone;" the "Sandstone" (*f*) is the "Ferruginous sandstone" of the earlier reports.

[1] Reports on the geological survey of the State of Missouri, 1855-1871, by G. C. Broadhead, F. B. Meek, and B. F. Shumard, published by authority of the legislature, under the direction of the Bureau of Geology and Mines, pp. 323, and index, 1873.

Preliminary report on the iron ores and coal fields from the field work of 1872. Part I, pp. 1-218, part II, pp. 1-402, bound in one volume. Raphael Pumpelly, director. 1873.

Part II. Geology of Northwestern Missouri, by G. C. Broadhead, and of Lincoln County, by Wm. B. Potter.

[2] Pages 292-293.

The name "Ste. Genevieve limestone" is proposed for the second Archimedes limestone (*h'*) of the table (p. 293).

The "third Archimedes limestone" (*h''*) is the "second Archimedes" or "Warsaw limestone" of Hall's section (p. 294).

The classification of the formations between the top of the Encrinital limestone and the base of the Coal Measures into a distinct group under the name "Archimedes group" is worthy of particular notice. Although the author made little account of it, and as far as I have ascertained no further notice has been taken of it, recent studies have convinced me that the primary subdivision of the Mississippian series, based upon affinity and difference in the faunas, calls for a line of demarcation at the place here indicated. The faunas of the Chester, St. Louis, and most of those referred to the Warsaw formations are paleontologically more closely allied than they are to the faunas of the Keokuk and Burlington—i. e., the Encrinital of the Missouri geologists—and considering the variations in the lithologic characters of these formations in different parts of the Mississippi province I believe the division of the Mississippian series into three groups defined upon paleontologic grounds will greatly facilitate the understanding of the relations of the various formations, whose differentiation hitherto has been made upon lithologic character. This will avoid the necessity, as the finer details of the geology are developed, of forced correlation with already named formations, which is the only alternative to proposing new names where the local stratigraphy is dissimilar to that of the typical section.

For the uppermost of these groups, which is that called Archimedes group by Dr. Shumard, I would propose the name Genevieve group, as it was first defined in the county of Ste. Genevieve, by Shumard, and along the eastern border of this county is well represented, as is shown in Shumard's Report.[1]

To apply this classification I propose the following scheme, which expresses the subdivisions into groups indicated by the fossil faunas of the Mississippian series:

Mississippian series.	Genevieve group...	Chester. St. Louis. Warsaw (in part).
	Osage group.....	Keokuk. Burlington.
	Chouteau group....	Chouteau limestone and the "Vermicular" and "Lithographic" formations as proposed by G. C. Broadhead in the following report:

In 1874 Mr. G. C. Broadhead published a detailed report of surveys made by him as State geologist during the years 1873 and 1874.[2]

[1] Geol. Surv. Missouri, 1855–'71, pp. 292–294.

[2] Report of the Geological Survey of the State of Missouri, including field work of 1873–'74, with 91 illustrations and an atlas, by Garland C. Broadhead, State Geologist. Printed by the authority and under the direction of the Bureau of Geology and Mines. Jefferson City, 1874 (pp. 734 and index).

The classification he proposed is slightly different from that given in Mr. Worthen's first report of the Geological Survey of Illinois (1866).[1] It is as follows:

- Carboniferous system.
  - Upper Carboniferous or Coal Measures.
    - Upper coal.
    - Middle coal.
    - Lower coal.
    - Clear Creek sandstone and lower coal.
  - Lower Carboniferous
    - Chester group .. { Chester limestone and Ferruginous sandstone.
    - St. Louis group. { St. Louis limestone and Warsaw limestone.
    - Keokuk group.. { Encrinital and Burlington group.
    - Chouteau group.
      - Chouteau limestone.
      - Vermicular sandstone and shale.
      - Lithographic limestone.
- Devonian system ..... { Hamilton. Onondaga.
- Upper Silurian ..... Oriskany.

In the use of Chester, St. Louis, and Keokuk groups he follows Worthen (1866).

He proposes the name "Chouteau group" to take the place of the "Chemung group" of Swallow's Report of 1855,[2] which included—

1. Chouteau limestone, 100 feet.
2. Vermicular sandstone and shale, 75 feet.
3. Lithographic limestone, 55 feet.

"The Chouteau limestone," he reported, "in the upper part is a coarse gray limestone resembling the lower beds of the Encrinital limestone. In fact it is a bed of passage, as it often contains fossils common to both." "At the base of the group in northeast Missouri a few feet of black slate are occasionally seen." The volume adds very little to the development of the correlations of this region. The "Chouteau group" is a very appropriate addition to the nomenclature. The classification of these formations as a group had been early recognized, but the erroneous correlation fixed upon it a name which no one had heretofore replaced. The "Kinderhook group" of Meek and Worthen is synonymous from a stratigraphic point of view, but the fauna and lithology of the Chouteau group on the western margin of the Ozark uplift present sufficient differences to make the retention of the name desirable.

As we conclude this review of the development of the correlation and classification of the Mississippian series, the problems appear simple, but they were complex and confusing to those who elaborated them.

[1] Report of the Geological Survey of the State of Missouri, including field-work of 1873-'74, with 91 illustrations and an atlas, by Garland C. Broadhead, State Geologist. Printed by the authority and under the direction of the Bureau of Geology and Mines. Jefferson City, 1874, pp. 20, 24.

[2] Ibid., p. 26.

In New York State, which had given the most perfect section of upper Paleozoic formations, there appeared a complete series of deposits distinguished by easily recognized differences in their lithologic characters and in the fossils. The Coal Measures in Pennsylvania formed an easily recognized datum above, and below the Devonian the sections led by regular stages downward.

As the eastern geologists went westward they attempted to correlate the deposits discovered with the familiar standards of the Appalachian province, the New York and Pennsylvania systems. The geologists who began their investigations in the Mississippi Valley and westward correlated the formations with European standards, finding little to help them in the eastern sections, and in the finer subdivisions classified them independently, as the New York geologists had already done with their strata.

On comparing notes, the geologists found that there were unmistakable differences in the rocks which occupied the same general intervals, which were more extreme the more distant the contrasted sections were from each other, and they assumed (a conclusion which was natural at that stage of progress in the science) that like differences might be allowed for the faunas. This error was fatal and delayed for years the acceptance of the correct interpretation which those who depended upon evidence of fossils alone made in the early part of the discussion.

With the recognized variation in the composition of the strata, a black shale which was present in a great number of the sections across the country, and certainly below the Coal Measures and above Silurian rocks, was seized upon as a common horizon by means of which the sections of separate States might be tied together. The problem regarding the black shale consisted in the fact that in the standard sections of New York there were two black shales, the Marcellus and Genesee, with the rich Hamilton fauna between them. When correlations were followed across the States it was seen that no black shale appeared in the northern part of the Mississippi Valley, but a Hamilton fauna was found, and in the more southern sections little or no trace of Hamilton faunas, but a single black shale.

In the solution of this problem a study of the fossils alone finally brought out the truth.

A third problem came up, particularly concerning the sections of Ohio, Michigan, and western Pennsylvania. With slight differences in the characters of the deposits, on passing westward from the typical upper Devonian of New York, there appear slight changes in the character of the faunas. The question was, Is this a geographical modification, or is it a change coordinate with sequence of time? For the Chemung faunas do not extend westward under the Waverly, nor do the Waverly faunas extend eastward over the Chemung. This problem is being gradually settled by a minute study of the fossils, and the discovery of

the characteristics of species coordinate with temporal sequence. It is the light which evolution has thrown upon the history of organisms that is doing more to clear up the correlations involved than all the minute stratigraphy which has been applied to their interpretation. The true position of the fauna in the chronologic scale was, moreover, first clearly discerned in the Mississippian series by Meek and Worthen, who, in 1861, proposed the name "Kinderhook group" for the erroneously identified Chemung rocks of Iowa, Illinois, and Missouri. The fundamental correlation involved had been announced as early as 1847 by M. de Verneuil, but Mr. Meek was the first American palæontologist to insist on the correctness of the interpretation, and to carry it out in the classification of the rocks of the country.

Another problem which chiefly concerns the various members of the Mississippian series is that regarding the subdivision and correlation of the parts of the series as exhibited in separate sections.

So far little advance has been made beyond the interpretation given by Dr. D. D. Owen in 1852, chiefly on structural grounds.

In the geological reports of Iowa and Illinois, and in separate publications elsewhere, the faunas have been largely described, but the materials have not been studied with sufficient attention to their biological character to determine the true relations of the faunas to each other and to chronologic sequence. The evidence now in hand enables us to point out where to draw the paleontologic lines to indicate the three general faunas above named, 1, Chouteau; 2, Osage group; and 3, Genevieve group; but the full content of each fauna and the precise points at which the stratigraphic lines should be drawn in local sections is not in all cases clear.

CHAPTER VIII.

THE WAVERLY PROBLEM: THE HISTORY OF THE DISCUSSION CONCERNING THE CORRELATION OF THE WAVERLY, MARSHALL, GONIATITE LIMESTONE, KINDERHOOK AND CHOUTEAU FORMATIONS.

In the second stage of development in the history of geologic correlations, American geologists did not rely solely upon fossils, but prominent stratigraphic units of each new province surveyed were identified, partly by their petrographic, partly by their paleontologic characters; and local and independent classifications and nomenclatures were constructed, using these stratigraphic units as datum levels. Thus the Coal Measures, with actual coal beds, formed the most conspicuous datum plane for the correlation of the interior; then the limestones below were correlated with the Carboniferous limestones of England. Going still finer, the Black shales (often called "black slates") assumed a prominent rôle in determining the division line between the Carboniferous and Devonian.

The Coal Measure Conglomerates have also played a prominent part in marking the base of the Coal Measures, although in actual age, as represented by the evolutional history of organisms, I am inclined to believe that in different parts of the country the whole length of the Carboniferous limestone period transpired between the times when the lowest Coal Measures of the several regions began, and that, therefore, Conglomerates which mark the elevation preceding such Coal Measures vary greatly in age. The Oriskany sandstone played a similar part in the more eastern sections. The Catskill sandstone, as the supposed equivalent of the Old Red sandstone, formed a conspicuous landmark and division plane between Devonian and Carboniferous in the northern Appalachian province.

The influence of the belief in the continuity of such stratigraphic units was, and is still, one of the stumbling-blocks in the way of a correct interpretation of the relation between the Waverly formations of Ohio, and the more eastern strata of New York and Pennsylvania and those of Indiana and the Mississippi province farther west.

In the more minute application of correlation methods the same influence predominates. In attempting to classify the formations across State boundaries, the prevailing custom has been in the case of each prominent limestone or sandstone to seek the corresponding limestone

or sandstone in the nearest State already surveyed with which to correlate it. This custom is satisfactory in some cases, and in others it fails because of the inconstancy of the conditions of sedimentation; and, using the criterion of fossils, whenever considerable distance intervenes, there is clear indication of difference in the time of beginning and ending of a formation which in its general characters may indicate equivalency of age. Doubtless the same principles of correlation have been applied in the interpretation of the formations below and also of those above the Upper Paleozoic. Of these others may speak. This custom having prevailed during the last fifty years, it is in the discussion regarding the correlation of the dominant stratigraphic units that we find best expressed the methods and usages employed.

During the last half century a large number of papers have been written, having as a common theme some form of the problem regarding the demarkation between the Devonian and Carboniferous systems. These papers and discussions have gathered mainly about the interpretation, taxonomic value and position of the Waverly group, the Kinderhook group, the Marshall group, the Black shale and Goniatite limestone formations, the Catskill, the "Old Red sandstone," and the variously named Conglomerates.

The determination of the demarkation between the Devonian and Carboniferous systems presented itself under different names to each of the State surveys of the States in which the transition is seen. In New York and the States of the Appalachian Basin it appeared in the discussion regarding the Catskill formation and the Conglomerates; in Ohio it was regarding the Waverly formations; in Michigan it was the Marshall group; in Indiana it was about the Goniatite limestone and the Black shale; in Kentucky and Tennessee it was the Black shale and the Siliceous group; in Illinois it was the Kinderhook group; in Iowa and Missouri it appeared first under the name "Chemung group," later as Kinderhook group in Iowa and as Chouteau group in Missouri. In each of these various States the difficulties were similar: the absence of any satisfactory definite standards of delimitation, either in stratigraphic or paleontologic terms, between the Devonian and Carboniferous systems.

In New York State the highest pure marine fauna in the Chemung is equivalent in a general way to the upper Devonian fauna of North Devonshire. But some of the species recorded in the upper Devonian of Europe are more conspicuous in formations stratigraphically above the Chemung horizon in America. Again, the Catskill formations in New York, containing estuarian faunas, carry also plants, which on the one hand indicate close affinities with the Carboniferous, but are stratigraphically well below true Carboniferous deposits of the Appalachian province.

When, however, New York series are taken as the standard, the terminal part of the Devonian presents no parallel, either stratigraphically

or paleontologically, even in Ohio; still less in the States farther west. In each case it is a comparison of allied but dissimilar series.

The Catskill and Conglomerate problems are discussed in a former chapter. Some of the problems associated with the Kinderhook and Chouteau groups have been considered in the chapter on the Mississippian series. In the present chapter I propose to consider the problems associated with the correlation of the Waverly, the Marshall, the "Black shale" and the Goniatite limestone formations, and secondarily the Kinderhook and Chouteau. In the first chapter is discussed the development of opinions and nomenclature concerning these formations up to 1843, and in the chapter on the general correlations of the formations westward from New York to the Mississippi Valley, this development is traced onward to about the year 1851.

The succession of strata in Michigan as published in 1838–'41, arranged in descending order, as compiled from Dr. Houghton's Annual Reports, is as follows:[1]

XXXI. Recent Alluvium.
XXX. Ancient Alluvium.
XXIX. Erratic Block and Diluvium.
XXVIII. Tertiary Clays.
XXVII. Brown or gray sandstone.
XXVI. Argillaceous iron ore.
XXV. Coal strata.
XXIV. Red or variegated sandstone.
XXIII. Gray or yellow sandstone.
XXII. Shales and coal, Lower Coal Measures.
XXI. Blue compact slaty sandstone.
XX. Gray limestone or upper lime rock.
XIX. Fossiliferous ferruginous sandstone.
XVIII. Kidney iron formation.[2]
XVII. Sandstone of Point aux Barques.
XVI. Clay slates and flags of Lake Huron.
XV. Point au Grès and Manistee limestone.
XIV. Soft, coarse-grained sandstone.
XIII. Black bituminous, aluminous slate.
XII. Limestone of Lake Erie.
D. Corniferous limestone; C. Thunder Bay and Little Traverse Bay limestone (*f*–*a*); B. Black bituminous limestone; A. Blue limestone.
XI. Mackinac limestone.
X. Polypiferous portion of Upper Limerock.
IX. Pentamerus portion of Upper Limerock.
VIII. Lower limerock and shale.
VII. Sandy limerock.
VI. Upper gray sandstone.
V. Lower or red sandstone and shale.
IV. Mixed conglomerate and sandstone.
III. Conglomerate.
II. Metamorphic rock.
I. Primary rocks.

[1] First Biennial Report of Progress of the Geological Survey of Michigan, etc., Lansing, 1861, pp. 12, 13, 14, 15.

[2] In this classification No. XVIII is made the lowest bed of the Carboniferous.

In 1851 Charles Whittlesey[1] gave an exhibit of the strata in New York, Ohio, and Kentucky, reckoning from the Conglomerate downward to the "Cliff limestone:"

NEW YORK (after Hall). Chautauqua County.

Classified by fossils.

1. Old Red sandstone, very thin.
2. Chemung group, 1,200 to 1,500 feet.
3. Portage group, 1,000 feet.
4. Genesee slate, 23 to 150 feet.[2]
5. Tully limestone.
6. Hamilton group.
7. Marcellus shale.
8. Corniferous limestone.
9. Onondaga limestone.

OHIO. Chagrin Falls, 18 miles east of Cleveland.

Classified by external characters.

Conglomerate.

1. Ash-colored shale, 110 feet.
2. Thick bedded argillaceous sandstone, 13 feet.
3. Black shale, 13 feet.
4. Grindstone grit, 38 feet.[2]
5. Fine-grained sandstone, thin and thick bedded ("Waverly"), with red, blue, and green shales interstratified—flags and ripple marks—strips of ironstone and iron rust with fossils. Lower part—"black slate" of Ohio Reports: thickness to Cliff limestone probably 400 feet. (This embraces 3, 4, 5, 6, and 7 of the New York column.)
6. Cliff limestone.

KENTUCKY. Falls of Ohio, by Dr. Yandell and Shumard.

Arranged by fossils.

1. Carboniferous limestone (Mammoth Cave).
2. Button Mould Knobs.
3. Bituminous black slate, 104 feet; in Tennessee (Owen and Shumard), 8 to 51 feet.
4. Encrinital beds, 8 feet.
5. Water-lime beds, 12 feet.
6. Shell beds, 16 feet.
7. Coralline beds[3] (upper and lower), 40 feet.
8. Catenipora beds, = "Niagara."
9. Pentamerus beds, "Blue limestone," "Clinton," "Carodoc."

According to Hall in the New York Reports, No. 5 of the Ohio section is the equivalent of the Chemung, Portage, Hamilton, and Marcellus. The author suggested the name "*Protean group*"[4] for rocks in

[1] Whittlesey, Charles. On the equivalency of the rocks of northeastern Ohio, and the Portage, Chemung, and Hamilton rocks of New York. Am. Assoc., Proc., vol. 5, 1851, pp. 207-221.

[2] No. 4 is seen at Euclid, Newburg, Independence, etc.

[3] 7. M. Verneuil placed the division point separating the Silurian and Devonian between the upper and lower Coralline beds. (See Ibid., p. 215.)

[4] The name "Protean group" had been already used by L. Vanuxem for a series of rocks at the base of the Upper Silurian in New York in 1838. (See New York Geological Survey, second Ann. Rept., p. 285.) This was afterward restricted to the Saliferous group and the name abandoned. Fourth Ann. Rept., pp. 53 and 374, and Final Report on Geology, Third district, pp. 79 and 90. The name "Protean member" was afterward proposed by J. M. Safford for the lower part of the Siliceous group of Tennessee. (See ante, p. 165.)

Ohio occupying the interval between the "Grit" No. 4 and the "Cliff limestone" No. 6.

In the same year J. W. Foster reported the absence in Ohio of the representative of the conglomerates of New York State. The "Cliff limestone" he thought should be divided on biologic grounds. The sandstone formerly known as the "Waverly" should for like reasons be divided into three parts. The fossils have more Carboniferous than Devonian affinities.

The rocks of the Ohio coal field consist of sandstones, shales, limestones, seams of coal, and buhrstone. The limestones and sometimes the shales contain exclusively marine faunas, while the sandstones contain a Carboniferous flora. The alternations of marine and terrestrial remains were noticed in a vertical distance of 700 feet. The faunas and floras contained in each formation were described in detail.[1]

In 1862 James Hall[2] began to see the incorrectness of his correlation of the Waverly group and wrote:

> The Waverly sandstone group of the Ohio Reports, at one time regarded as entirely equivalent to the Portage and Chemung groups, may in its upper members constitute a distinct group, though we do not yet know any line of demarkation between them.

From 1862 to 1870 Alexander Winchell wrote several papers bearing upon the correlation of the Marshall group of Michigan. The fossils in this group proved to be closely related to those of the Waverly fauna, and thus the problems of the Marshall group of Michigan became intimately associated with those of the Waverly group of Ohio. In 1862 he briefly described the rocks of this group in lower Michigan, and their fauna.[3]

The following is a synoptical view of the strata described:

	Feet.
Carboniferous limestone	66
Michigan Salt group	184
Napoleon group	123
Marshall group	173
Huron group	210
Hamilton group	55

The rocks chiefly interesting him in this paper were a series of fine, friable, ferruginous sandstones not over 300 feet in thickness, whose upper portion, more grayish, firmly cemented, and homogeneous than the lower, is remarkably destitute of organic remains and is separated from the lower by 15 feet or more of shale containing a large amount of ferruginous matter. The lower portion of the sandstone is rich in fossil remains belonging to the genera *Goniatites*, *Nautilus*, *Orthoceras*, *Bellerophon*, *Nucula*, *Solen*, *Myalina*, *Chonetes*, etc. The upper

[1] On the alternations of marine and terrestrial organic remains in the Carboniferous series of Ohio. By J. W. Foster. Am. Assoc., Proc., vol. 6, pp. 301-304.

[2] "On the Catskill group of New York." By James Hall. Canadian Naturalist and Jour. of Science, new series, vol. 7, 1862, p. 381.

[3] Notice of the rocks lying between the Carboniferous limestone of the lower peninsula of Michigan and the limestones of the Hamilton group, with descriptions of some cephalopods supposed to be new to science. By Alexander Winchell. Am. Jour. Sci., vol. 33, 1862, pp. 352-366.

sandstones were called the "*Napoleon group*" and the lower the "*Marshall group.*" Mr. Winchell traced the course of the outcrops of these groups to the northeast and west and spoke of their being overlaid by the *Michigan Salt group* at Grand Rapids and vicinity and underlaid in the southwestern counties by a considerable thickness of argillaceous strata. In Huron County the "*Huron group*" of gritstone, green shales, and bituminous shales is found beneath the *Marshall sandstone*, and farther north the Hamilton limestones precede this group.

The descriptions of supposed new Cephalopods comprise ten species of Orthoceras, seven of Nautilus, one of Cyrtoceras, and eight of Goniatites.

In a paper[1] published in 1863 Mr. Winchell stated his conviction that a comparison establishes "fully the equivalency of the Chemung, Marshall, Ohio [i. e., Waverly], Rockford [i. e., Goniatite limestone], Burlington [i. e., Kinderhook], and Chouteau strata."[2]

Further investigation modified this conviction, as we shall see beyond.

In 1864 appeared another paper.[3] This was devoted to a description of certain western rocks near the line between the Devonian and Carboniferous systems and their contained faunas. "The paper shows an extended net-work of identification among the fossils from States west of Pennsylvania." The author identifies also "four western species with those in the supposed Carboniferous conglomerate of western New York," two of which species are regarded as being at the top of Chemung rocks of western New York. He inclined to the view that since there appears no close resemblance between the Chemung of New York and western rocks, the "Carboniferous conglomerate" of western New York may be the eastern prolongation of the western sandstones and shales, at least of the fossiliferous portions of them, and that the Chemung of New York must be classed with the Devonian rocks. "Ninety-four species are described in this paper, of which thirty-six are described as new species, and two are made the types of new genera." This brief outline is followed by descriptions of the species.

The view that the so-called "Chemung" of the States west of New York should be correlated with the "Carboniferous conglomerate" system was expressed by Meek and Worthen in 1861.[4]

In 1870 Winchell completed his studies of the correlation of the Marshall group,[5] and published an elaborate memoir upon the subject. In the appendix are cited ninety papers on the geology of the rocks under consideration. He opened the paper by a reference to the "controversy which has long existed in reference to the age and equivalents of the strata lying between the Corniferous limestone and the limestone of the

[1] Winchell, Alexander, on the identification of the Catskill Red Sandstone group with the Chemung. Am. Jour. Sci., 2d ser., vol. 35, 1863, pp. 61–62.

[2] Ibid., p. 62.

[3] Descriptions of new species of fossils from the Marshall group of Michigan and its supposed equivalent in other States, etc., by Alexander Winchell, Phil. Acad. Sci. Proc., vol. 17, 1865, pp. 109–133.

[4] Am. Jour. Sci., vol. 32, 1861, pp. 167–177, 288.

[5] The Marshall group: A Memoir on its geological position, characters, and equivalencies in the United States. Proc. Am. Phil. Soc., vol. 11, 1869, pp. 57–83, and vol. 12, 1870, pp. 385–418.

Lower Carboniferous system."[1] He next gave a brief synopsis of opinions under the heading of "History of discovery and opinions," beginning with Hildreth's paper, 1836,[2] and citing the views of the chief contributors to the discussion up to 1869. Then follows a tabulation of the rock sections, as then interpreted, in the several States, including the corresponding sections of the States of New York, Michigan, Ohio, Indiana, Illinois, Iowa, Missouri, Kentucky, and Tennessee. He then proceeded to discuss "the parallelism of the formations on purely structural and lithological grounds," and remarked that "the identity of the black shale can not now be mistaken." He referred to its demonstrated position above the Hamilton group in Michigan, Kentucky, and Ohio, and below the Rockford Goniatite beds in Indiana. He thought it was unrepresented in Missouri. In Michigan it may be the lower part of his Huron group, and in New York he confined the typical equivalent of the black shale to the Genesee shale on paleontologic grounds.

The Carboniferous conglomerate was next taken as marking "a superior horizon which can not ordinarily be mistaken." The Parma conglomerate of Michigan the author considered as "stratigraphically equivalent to the carboniferous conglomerate." Lithologically he found no means of distinguishing the coal conglomerate of Ohio from the Chemung and Catskill conglomerates of New York. On paleontologic grounds, however, he separated the "Chemung" and Catskill conglomerates, which he made equivalent to the "Marshall group" of Michigan, from the "Parma conglomerate," which he placed higher in the scale above the carboniferous limestones of the interior; and after discussing the fossils underlying or associated with the conglomerates, he said:

"For these reasons I shall, for the present, regard the three conglomerates[3] in western New York, with the associated strata, as belonging together in the horizon of the Catskill group."

Later investigations, particularly those of the Second Pennsylvania Survey, have thrown clearer light on the relations of these several conglomerates.[4]

The third conspicuous formation which Winchell sought to correlate was the "Carboniferous limestone series" of the Mississippi Valley. In a foot-note[5] the author proposed the name "Mississippi limestone series or Mississippi group" for the "Carboniferous limestones of the United States, which are so largely developed in the valley of the Mississippi." My adaptation of this name and proposal of the name

[1] The Marshall group: A Memoir on its geological position, characters, and equivalencies in the United States. Proc. Am. Phil. Soc., vol. 11, 1869, p. 57.

[2] Am. Jour. Sci., vol. 29, 1836, pp. 133–136.

[3] Viz, the "Chemung conglomerate," the "Catskill conglomerate," and the so-called "Carboniferous conglomerate," near Panama.

[4] See Second Pennsylvania Survey Reports III, by J. F. Carll, 1880, and Report R, by C. A. Ashburner, 1880.

[5] Proc. Am. Phil. Soc., vol. 11, p. 79.

"Mississippian series" for the formations grouped under the names Subcarboniferous or Lower Carboniferous are given in a previous chapter.

This "Mississippi limestone series" of Winchell includes the rocks in the Mississippi Valley from the "Burlington" up to the "Kaskaskia" of Iowa, and in his usage it does not include the "Kinderhook" or "Waverly." But to be of practical use the series should extend from the base of the Carboniferous, i. e., including the "Goniatite beds," the "Chouteau series," the "Kinderhook," the "Marshall," the "Waverly," upward to where the marine fauna ceases at the approach of the conglomerates or similar deposits heralding the appearance of coal.

In discussing this group, Winchell only identified, with little argument, the "Carboniferous limestone" of Michigan, the "Knobstones" of Indiana and Kentucky, and the "Siliceous group" of Tennessee, with the "Carboniferous limestone" of the Mississippi Valley, not including here, however, the formation next to be considered.

The rocks between the "black shale" and the "Mississippi limestone" above presented greater difficulties, because of the radical lithologic differences of the various outcrops representing them. The several formations are the "Waverly" and "Gritstone" series of Ohio, the Chemung and Portage groups of New York, the "Marshall sandstones" of Michigan, the "Yellow sandstones," called in the earlier report "Chemung group," of Iowa, the "Rockford limestones" of Illinois, and the "Chouteau limestones, Vermicular sandstone and shale, the Lithographic limestone" of Missouri.

The general equivalency between the Waverly and Gritstone series of Ohio and the Portage and Chemung of New York had been asserted by James Hall, and, following his authority, had been the usage of geologists for years. From this position Winchell both departed and advanced. In Michigan he recognized below the Marshall sandstones, and above what he regarded the equivalent of the Genesee shale of New York, some 500 or 600 feet of argillaceous rocks, more arenaceous and flaggy to the north. These, which he called the "Huron group," he considered as the equivalent of the Portage and Chemung of western New York.

In Ohio, below the Waverly series, he found the extension of his Huron group [what is now called the "Erie shales"], equivalent to the Portage and Chemung of New York. On similar grounds, which are lithologic and stratigraphic, he identified the argillaceous beds above the black shale in Kentucky with his Huron group. He also referred to a similar horizon the "bluish, slightly micaceous sandstones of the yellow sandstone series of Iowa, the blue shales below the lithographic limestones of Missouri, and possibly the Illinois shales doubtfully referred to the Genesee by Prof. Worthen;" and having thus, on physical grounds, found what he thought to be equivalent formations to represent the Chemung and Portage of New York, he presented a lengthy argument for regarding the Waverly series of Ohio and the

Marshall group of Michigan on paleontologic grounds, the equivalents of the Catskill rocks of New York.

In the paleontological part of the paper is given a catalogue of the known fossils of the Marshall group and its supposed equivalents in the United States, with references to the place of publication of the descriptions of the species. Four hundred and sixteen species are enumerated. No attempt is made to determine or eliminate synonyms. The distribution of the species by States is indicated. As the author takes up his argument he first speaks of the fauna of the Huron group, and concludes from a comparison of the species that it is equivalent to "the Portage and Chemung groups, or to some portion of them," and then proceeds to determine whether the overlying Marshall group should be included with the Huron shales as equivalent to the upper part of the Portage-Chemung of New York. His first argument for equivalency was that furnished by the lists of species identified in two or more States. By this means he correlated—

(1) The Marshall group of Michigan with (2) the Gritstone and Waverly down to the Chocolate shales of Ohio; (3) the Goniatite limestone of southern Indiana and its equivalent sandstone in northern Indiana; (4) the Kinderhook group of Illinois; (5) the yellow sandstone series of Iowa, at least down to the bluish shales; (6) the series known in Missouri as the Chouteau limestones, the Vermicular sandstone and shales, and the lithographic limestones, and (7) the Silico-bituminous shales at the base of the Siliceous group of Tennessee.

These correlations had been practically demonstrated for all except the Marshall group by previous writers.

A long discussion of species then follows, to show that the species contained in these formations have "a Carboniferous aspect," a fact which M. de Verneuil had long before pointed out upon his first glance at the species then known of the Ohio, Indiana, Illinois, Iowa, and Missouri localities.

The next section announces that "the fauna of the Chemung group presents a Devonian aspect." This fact had been recognized for thirty years, and the Chemung of New York had been the recognized typical upper Devonian for all correlations in North America.

Section VI proposes the question "Can the Marshall and Chemung be synchronized?" Elaborate citations of principles of paleontologic science are made and prolonged argument to prove that this is not reasonable, and to reach the conclusion that the Chemung must remain "within the limits of the Devonian system, where it has been placed by the nearly unanimous judgment of paleontologists," and that "the Marshall group must be admitted within the boundaries of the Carboniferous system according to the present nearly unanimous judgment of western geologists."

The one point which is the gist of the whole argument is made in the last section, headed "Parallelism of the Catskill and Marshall." The author's theory is that the Catskill group of eastern New York instead of thinning out or disappearing by lack of sediments in western New

York is absent in consequence of subsequent denudation; that the "Old Red" is not necessarily all Devonian in age; that in the Marshall are some species which are considered as "having near analogues in the Old Red of Scotland;" that the Catskill, although identified as the equivalent of the Old Red sandstone of Scotland and Wales, is younger than that part of the Devonian represented in New York by the Chemung and its equivalents in Europe, and as the Marshall has been shown to be not the equivalent of the Chemung in New York, it must be, the author argued, the representative of the Catskill.

At the close a table of geological equivalents is given. The part of it of chief value here is that expressing the author's interpretation of the equivalents of the Marshall group of Michigan, which consists of the following, immediately overlying the Huron group, in ascending order:

(1) Huron gritstones, bluish or greenish gray, fine grained, regularly bedded, 15 feet.
(2) Marshall sandstone, reddish, yellowish, olive, obliquely laminated, highly ferruginous; the iron often a rudely concentric, concretionary arrangement; in places calcareous, highly fossiliferous, 160 feet.
(3) Napoleon sandstone, pale buff, often conglomeratic, obliquely laminated, thick bedded, 123 feet.

Followed above by the Michigan salt group.

According to the table the equivalents to these are, in New York, upper part of Catskill group, including "Carboniferous conglomerate" and "Chemung conglomerate;" in Ohio, "Waverly series, in part" (the "Chocolate shale series" and the "base of the Waverly series" are correlated with the Chemung and Portage of New York); in Indiana, the "Rockford limestone" and "Williamsport gritstone;" in Illinois, the "Kinderhook group;" in Iowa, the "Yellow sandstone series;" in Missouri, the "Chouteau limestone," "Vermicular sandstone," and shales, and "Lithographic limestone;" in Tennessee, part of the "Siliceous group" and the "Siliceous shales," and in Europe the "Old Red sandstone" of Scotland, "Yellow sandstone" of Ireland, and the "Westphalian schists."

In 1871 appeared the Report of Progress of the Geological Survey of Ohio.[1]

Two of the chapters have matter of interest in the present discussion: One by Mr. E. B. Andrews,[2]; a second by Mr. M. C. Read.[3]

The formations discussed in Mr. Andrews's article are the "Ohio black shale" or "Huron shale," the "Waverly sandstone," the "Maxville limestone," the "Conglomerate" of the Coal Measures, and the Coal Measures.

The Waverly sandstone is divided into three parts. The middle is coarse and often a conglomerate; the division above, a fine-grained sandstone, and that below sandstones and shales, with interstratified

[1] Geol. Survey Ohio, Rep. Progress in 1870; Columbus, 1871.
[2] Report of Labors in the Second Geological District during the year 1870 in Coal Measure district, pp. 55–251.
[3] Sketches of the Geology of Geauga and Holmes Counties, pp. 463–484.

sandy shales. The fine-grained sandstone lying above the Waverly conglomerate was first investigated in the vicinity of Logan, Hocking County, and thence received the name of "Logan sandstone." The whole thickness of the Waverly formation is about 640 feet. Fucoid stems are abundant and in the Logan sandstone in addition to these are found three varieties of an unnamed vegetation.

The Maxville limestone, lying directly above the Logan sandstone, is overlaid by a few feet of soft, coarse sandy shale and 40 to 50 feet of a soft laminated sandrock. Above this is a coarse sandrock rich in impressions of Lepidodendra. A considerable collection of fossils was obtained from the Maxville limestone at Newtonville, Muskingum County. A list of species and genera is given, of which eight species are Chester types and two are identical with species from the St. Louis limestone, leading the author to conclude that this Maxville limestone represents the Chester group of the Lower Carboniferous limestone series, while there may be some representation of the St. Louis limestone at some of the outcrops. These local patches of Maxville limestone never exceed 15 to 20 feet in thickness, and are generally no more than 8 to 10 feet thick, while in Kentucky the limestone is found nearly 100 feet thick.

The true Coal Measures Conglomerate is seen resting upon the Logan or Upper Waverly over limited areas. In general where there is Maxville limestone there is no Conglomerate.

In Vinton County a section is given showing the Waverly Conglomerate and the Logan sandstone extending up to the coal.

No true Coal Measures Conglomerate is found, but the coal, with its superincumbent shales, rests directly upon the Logan sandstone. This valuable section tends to verify deductions made elsewhere in regard to the Waverly conglomerate, and also in regard to the entire absence over certain large areas of the true Coal Measure Conglomerate. At this place no Maxville limestone was found resting upon the top of the Logan group.

Mr. Read reported that in Holmes County the lowest rocks observed belong to the Waverly sandstone, the ravines sometimes cutting down fully 200 feet into it. The Conglomerate appears above the Waverly in Prairie Township, and has a maximum thickness of 18 feet, with fossils which Mr. Meek determined to belong to the Carboniferous formation, pointing to the deposition of a Subcarboniferous limestone which has been cut out or removed by the agencies which brought in a deposit of the Conglomerate. Generally in the county the Conglomerate is wanting, and is represented in places by a thin layer of coarse sandstone without pebbles, sometimes by hard, compact, white siliceous rock a few inches in thickness and filled with *Stigmaria*, and sometimes the Coal Measures rest directly on the Waverly.

In the second volume of the Ohio Reports[1] the Carboniferous system of Ohio is classified.

[1] Report of the Geological Survey of Ohio, vol. 2, pt. 1, Chapter XXXI, by J. S. Newberry, chief geologist, 1874.

The following is a tabular expression of the classification:

	Feet.
Upper Barren Measures (?)	300
Upper Coal Measures	350
Lower Barren Measures	400
Lower Coal Measures	400
Conglomerate	

Maxville limestone (near Newtonville, Muskingum County, 15 to 20 feet thick, and 8 to 10 feet thick in the counties south).

Cuyahoga shale	150–250	Waverly group.
Berea grit	60	
Bedford shale	75	
Cleveland shale	21–60	
Erie shale (Chemung)		

The "Chemung" of New York is considered to have thinned westward and to be represented in the Erie shale. The Catskill, according to the author's view, thins out and does not appear in Ohio. The Vespertine of Pennsylvania changes its character on passing westward, and is the Waverly group in Ohio. The Umbral of Pennsylvania thins, disappears, or is blended with the Vespertine. The Carboniferous Conglomerate is traced as far as central Ohio. The "Maxville limestone" of Andrews furnished fossils which were submitted to Mr. Meek, who identified them as Chester and St. Louis species.

In the year 1878 Mr. L. E. Hicks published two papers concerning the Waverly group. In the first he stated that considerable discussion had arisen in attempting to synchronize sections in southern and central Ohio with a section at Cleveland, upon which Newberry has based his subdivisions.

The Cleveland section, in descending order, is as follows:

	Feet.
Cuyahoga shale	150 to 250
Berea grit	60
Bedford shale	75
Cleveland shale	21 to 60

The Cleveland shale is the only formation which retains its typical characters in central and southern Ohio. It holds a distinct fauna and, in some places, bears a close resemblance to the Huron shale. "*But the two never exist together in immediate contact.*" The persistency of the Cleveland shale has been demonstrated by its discovery in Delaware County, southern Ohio.[1]

In the second paper Mr. Hicks reported that in central Ohio five distinct members of the Waverly group are found, in descending order, as follows:

	Feet.
5. Licking shales	100–150
4. Black Hand conglomorate, or Granville beds	35–90
3. Raccoon shales	300
2. Sunbury black slate	10–15
1. Sunbury Calciferous sandrock	90–100

[1] Discovery of the Cleveland shale in Delaware County, Ohio. Am. Jour. Sci., 3d ser., vol. 16, pp. 70, 71. The Waverly group in Central Ohio. Am. Jour. Sci., 3d ser., vol. 16, pp. 216–224.

The upper limit of this series is determined to be the Conglomerate of the Coal Measures by the presence of Subcarboniferous fossiis below. The lower limit is very sharply defined by stratigraphical relations.

No. 5 consists mainly of soft, fine-grained shales, well exposed on Licking River. No. 4, best seen at Hanover and Black Hand, consists of coarse sandstones and conglomerates containing fucoids, with compact drab sandstones and shales at the base. No. 3 occurs along Raccoon Creek in Franklin and Delaware Counties, and is composed of blue and gray shales filled with nodular masses of iron ore. No organic remains except fossil sea-weed have been found in this deposit. No. 2 contains fossil remains of fish and corresponds very closely with beds in northern and southern Ohio. No. 1 is made up of compact and shaly sandstones, with alternating shales and limestones, and is well exposed on Rattlesnake and Walnut Creeks.

In regard to the determination of this series of rocks as Devonian or Carboniferous, the author concludes that there is "good reason for retaining the Cuyahoga sub-group in the Carboniferous, whatever may be done with the rest of the Waverly."

Mr. Edward Orton,[1] in 1882, in a paper on the bituminous matter of the black shales, further discussed the classification of the Waverly.

From the author's examination of the various black shales outcropping in Ohio and neighboring States, he concludes that the Huron and the Cleveland shales of Newberry, separated in the eastern part of Ohio by the greenish Erie shales, form a continuous series farther west and constitute a mass from 250 to 350 feet in thickness, which must be regarded as all of Devonian age. For this shale he proposes to retain the name "Ohio, Black shale," applied to it by N. S. Shaler in the Geology of Kentucky. The author recognized a second shale of similar nature in Ohio, situated about a hundred feet above the top of the former, called by Andrews the "Waverly Black shale." It was further defined by Meek, who separated it from the Cuyahoga shale by its fossil contents and called it the "Berea shale." It immediately overlies the Berea sandstone and forms the roof of most of the quarries of this famous sandstone. These three black shales, the Huron and Cleveland of Newberry and the Berea of Meek, are alike in being of marine origin and in being strongly bituminous. Analysis shows them to contain 8 to 20 per cent of organic matter, and frequently they have taken fire from burning brush heaps, and cases are recorded of their continuing to burn for weeks when once thus kindled. The bituminous matter in them was supposed by Newberry[2] to have originated from the decomposition of the "vegetation which lined the shores and covered the surface of a quiet and almost land-surrounded sea," like a Sargasso sea.

[1] Orton, Edward: A source of the bituminous matter in the Devonian and Subcarboniferous black shales of Ohio. Am. Jour. Sci., 3d ser., vol. 24, pp. 171–174.

[2] Geol. of Ohio, vol. 1, p. 156.

Since the writing of that report, the author had discovered several microscopic forms of vegetation occurring in these bituminous shales in great abundance. Dr. Dawson had previously observed these bodies, and recognized them as the spore cases of some lycopodiaceous plant, and named them *Sporangites Huronensis*.[1]

The author supposes that the great accumulations of gas and oil that have been found in the Devonian and Subcarboniferous formations of Pennsylvania, West Virginia, and Ohio are to be traced to the further distillation or decomposition of the bituminous matter, particularly the spore cases originally deposited with these black shales, a theory which was first outlined by Newberry,[2] although the presence of the spore cases was then unknown. To the spore cases the author would attribute the chief supply of bituminous matter.

In 1883 H. S. Williams[3] reported the discovery of a fauna in the midst of the upper Devonian rocks of New York, having a decided carboniferous aspect, but closely related to a fauna heretofore known in America only at the base of the Mississippian series in Iowa.

At the base of the Chemung group at Ithaca and High Point, Naples, New York, the author found a fauna which is strikingly similar to a fauna found at Lime Creek, near Rockford, Iowa. Although the general aspect of the fauna is Carboniferous, yet the occurrence of several of the species in the Chemung rocks requires consideration. The Lime Creek fauna was ascribed to the Hamilton group in 1858 by James Hall, but it was afterwards, in 1873, by him and by R. P. Whitfield referred to the "Chemung group."

By a close comparison of the faunas and minute and accurate examination of the specific relations of these faunas to each other, the author is convinced that the deposits of Lime Creek, Iowa, and all deposits carrying a like fauna, are not Lower Carboniferous, but are "geological equivalents of the Chemung of the East."

Mr. S. Calvin[4] took exception to the conclusions of Williams concerning the "strikingly Carboniferous aspect of the Lime Creek fauna," claiming, after an examination of the fossils, that they exhibit rather a Devonian and Silurian aspect, and Williams[5] replied.

The importance of the discovery consisted in the recognition of traces of the fauna, which is Carboniferous in its aspect, in America before the close of the Devonian in New York. The recognition of the same in Iowa proved the appearance there of a fauna of true upper Devonian age; that is, more recent than the Hamilton and older than the typical Kinderhook faunas of the Mississippian area.

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[1] On spore cases in coals; by J. W. Dawson, LL. D., F. R. S. Am. Jour. Sci., 3d ser., vol. 1, pp. 256–263

[2] Agricultural Report of Ohio in 1869.

[3] Williams, Henry S.: On a remarkable fauna at the base of the Chemung group in New York. Am. Jour. Sci., 3d ser., vol. 25, pp. 97–104.

[4] Calvin, S.: On the fauna found at Lime Creek, Iowa, and its relation to other geological faunas. Am. Jour. Sci., 3d ser., vol. 25, 1883, pp. 432–436.

[5] Williams, Henry S.: Equivalency of the Lime Creek beds of Iowa. Am. Jour. Sci., 3d ser., vol. 25, 1883, p. 311.

James Hall,[1] in a paper before the American Association, discussed the limitations between the Chemung and Waverly groups, according to paleontological evidence. *Spirifera disjuncta* is considered as characteristic of the upper part of the Chemung. Concerning the sandstones and conglomerates which had been considered as of Carboniferous age, it has been found by a study of the fossils that they represent the upper member of the Chemung group. Above them occurs a series of non-fossiliferous shales of unknown thickness. The correlation of this series of rocks was studied by Mr. C. E. Beecher, who prepared a section exhibiting about 1,500 feet and a list of fossils characteristic respectively of the Chemung group and of the Waverly group following it.

From the record of a well in Cleveland, Ohio, Edward Orton[2] determined the thickness of the shales below the Berea grit.

This well was commenced about 760 feet above tide-water and about 75 feet below the Berea grit. The first rock met was Bedford shale, followed by the Devonian shales, classified by Dr. Newberry as the Cleveland, Erie, and Huron divisions, and having a thickness of 1,300 feet.

In the years 1885 to 1888 C. L. Herrick[3] applied to the solution of the Waverly problem the new methods of correlation previously elaborated by Williams in the interpretation of the upper Devonian formations. (See chapter on the Chemung-Catskill problem.)

This paper is a fine illustration of what can be done in the way of dissecting out the individual faunas, showing their composition, and determining their affinities with faunas of other regions by a minute study of local geology.

Although the study was primarily of a local series of faunas, the author has made abundant use of material from other regions for comparison. The result is that we have a valuable series of the successive faunas of the Lower Carboniferous formations of central Ohio, which will serve as standards in all future work in correlation.

The great mass of the paper is devoted to specific descriptions; the final results of the study are given in volume IV.[4]

The section is divided into three parts or divisions by two conglomerates; these are subdivided into ten zones, and at the close a list of 321 species is given with the particular position or range in this scale of each species.

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[1] Hall, James: Note on the intimate relations of the Chemung group and Waverly sandstone in northwestern Pennsylvania and southwestern New York. Am. Assoc., Proc., vol. 33, 1884, pp. 416–419.

[2] Orton, Edward: The record of the deep well of the Cleveland Rolling Mill Company, Cleveland, Ohio. Am. Assoc. Proc., vol. 34, 1885, pp. 220–222.

[3] Herrick, C. L.: A sketch of the geological history of Licking County, accompanying an illustrated catalogue of carboniferous fossils from Flint Ridge, Ohio. Denison Univ., Bull., vol. 2, pp. 5–68, 144–148; vol. 3, pp. 13–110; vol. 4, pp. 11–60, 97–123, 1885–1888, with numerous plates illustrating the fossils.

[4] Ibid., pp. 95–114.

The following classification[1] modified from that of Mr. Edward Orton, is given by the author:

			Feet.
Cuyahoga or Waverly series...	Logan	Keokuk	100–150
		Burlington	
	(Conglomerate II.)		
	Kinderhook		50–60
	(Conglomerate I.)		
Berea or Transition Series (Western equivalent of upper Chemung).	Waverly shale		40
	Berea shale		200–400
	Berea grit		50–60
	Bedford shale		50
	Cleveland shale (local)		50
Erie shale.—Eastern or typical Chemung, lower part			100

The classification adopted in his tables is as follows:

III. *Keokuk and Burlington groups*, Upper Waverly (Upper Logan), separated into three zones in the table, but into five on p. 100 of the text, and there amounting to 80 feet of thickness, or not over 125 feet.

II. *Kinderhook* (part or all), middle Waverly.

This is subdivided into two zones in table, but into four zones on p. 101; the uppermost of which is Conglomerate II; the thickness, 52 feet, without the Conglomerate, which is but a few inches or feet in the specific cases given.

I. *Transition zone.*—Devonian, in part equivalent to Chemung and Portage.

The upper zone of this division is the Conglomerate I, 18 inches thick in one of the sections. In the table five zones are mentioned, on pages 100 and 101; seven zones are given, about 350 feet in thickness and not over 500 feet.

Below this is the *Bedford shale*, 51 feet (Hamilton facies in Chemung association), with the *Black or Hamilton shale* next below.

He concluded that his middle Waverly "is representative of the Catskill," but is not strictly equivalent to it.

The "Berea shale" is more than Orton's black shales, so named, but "the greater part of the shales below the Kinderhook."

He did not consider it necessary "to conclude from the fact that the Erie shales are of Chemung, age that all which lies stratigraphically above the Erie is certainly later faunally than the top of the Chemung as seen in New York strata."[2]

Above the Waverly group traces of the higher faunas were seen in the "Maxville limestone," east of Rushville. This "Maxville limestone" fauna is correlated with the Chester limestone of the interior.[3]

The latest systematic classification of the rocks of Ohio is reported in the sixth volume of the Geological Survey of Ohio.[4] This will exhibit the present state of development of correlations for the State:

	Feet.	
18. Glacial drift	0–550	
17. Upper Barren Coal Measures	500	Carboniferous.
16. Upper Productive Coal Measures	250	
15. Lower Barren Coal Measures	500	
14. Lower Productive Coal Measures	250	
13. Conglomerate group	250	

[1] Herrick, C. L.: A sketch of the geological history of Licking County, accompanying an illustrated catalogue of carboniferous fossils from Flint Ridge, Ohio. Denison Univ., Bull., vol. 4, pp. 105–106

[2] Ibid., p. 111.

[3] Ibid., vol. 3, pp. 21–23.

[4] Vol. VI., Economic Geology, by Edward Orton. Columbus, 1888.

12. Subcarboniferous limestone, Maxville, Newtonville, etc.		25	
11. Waverly group..	11*e*. Logan group	0–350	Subcarboniferous.
	11*d*. Cuyahoga shale	150–450	
	11*c*. Berea shale	20–50	
	11*b*. Berea grit	3–160	
	11*a*. Bedford shale	50–150	
10. Ohio shale	10*c*. Cleveland shale. 10*b*. Erie shale. 10*a*. Huron shale.	250–3,000	Devonian.
9. Hamilton shale, Olentangy shale		25	
8. Devonian limestone, Upper Helderberg or Corniferous, including West Jefferson sandstone		75	
7. Lower Helderberg limestone, etc.			

In this classification the Logan group is the equivalent of the Olive shales of Read, the Logan sandstone and the Waverly Conglomerate of Andrews. The "Berea shale" is a name proposed by Mr. Meek for the "Waverly black shale" of the reports. The "Waverly group" is differently delimited from the original Waverly group of the first and second reports, by the addition of the Logan group at the top and the exclusion of the Cleveland shale at the bottom. The reason for including the Cleveland shale in the Devonian was explained by Dr. Orton in previous papers. It is because of structural consideration which led to associating the three shales of Newberry in one formation, though there were recognized fossils in some of them which have been regarded as strictly belonging to the higher fauna.[1]

The correlation of the Goniatite limestone of Rockford, Indiana, involved a number of disputed questions, in all of which the fossils pointed to the right interpretation, while the apparent stratigraphy was misleading.

The elements of the problem were these: At Rockford a limestone, rich in Goniatites, was found above the black shale, and stratigraphically below arenaceous deposits and shales, which in other places were followed by the Mississippian limestone. In 1860,[2] a number of Goniatites and other fossils were described, and the author, Mr. James Hall, reported the limestones as Marcellus black shale. He had previously interpreted the black shale of the Southwest as Marcellus, and as the Marcellus shale of New York in calcareous layers was rich in Goniatites, he inferred that the bed at Rockford was the equivalent.

In this paper he said:

> The parallelism of these localities is inferred from the fact that the stratum containing the Goniatites is clearly above the limestone of the age of the Upper Helderberg group, and below the sandstones which are recognized as of the age of the Chemung group of New York. The exposures at the immediate locality are obscure; but the black shale, which I regard as the continuation of the Marcellus shale, occurs in the immediate neighborhood.[3]

[1] Vol. VI., Economic Geology, by Edward Orton Columbus, 1888, p. 29.
[2] Thirteenth Report to the Regents on the State Cabinet of Natural History, Albany, N. Y.
[3] Ibid., p. 95. (See Cristy's paper on the Goniatite limestone 1851).

In 1861, Messrs. Meek and Worthen replied, and gave their interpretation of the correlation. This paper, like that of M. de Verneuil, was based upon the evidence of fossils, and it augmented the arguments of the learned French paleontologist. The following is an abstract of the paper.

Messrs. Meek and Worthen,[1] after carefully comparing fossils in the Illinois State geological collection with specimens from the Goniatite bed of Rockford, Indiana, came to the conclusion that this bed was also represented in Illinois, Missouri, and Iowa, and that its stratigraphic position is much higher than that given it by Hall. They found that the black slate always occurs beneath the limestone, and that the latter is of the same age with the Chouteau limestone of Swallow, which had been placed on a parallel with the Chemung group, because it contained many fossils found in other beds in the West referred by Hall to the Chemung group.

A section is given showing the position of the Chouteau limestone with regard to the other Western formations, beginning with the Burlington limestone, which is acknowledged to be Carboniferous, and extending down to the Hamilton group, thus:

	Feet.
1. Burlington limestone attaining a thickness of	200
2. Chouteau limestone	100
3. Vermicular sandstone and shale	65 to 100
4. Lithographic limestone (rather local)	60
5. Black slate	30 to 40
6. Hamilton group	120

Numbers 2, 3, 4, are included by Swallow in the "Chemung." The Black slate is shown to come in everywhere above all the well-defined Hamilton group beds, and the authors assert that as the Chouteau limestone comes directly beneath the Burlington limestone and considerably above the horizon of the Hamilton group beds of the West as well as above the Black slate, therefore its representative in Indiana, the Goniatite bed at Rockford, can not be referred to any part of the Marcellus shale at the base of the Hamilton group. Neither can the Black slate be said to represent the Marcellus shale, as that lies at the base of the Hamilton group, and the Black slate is always found above the Hamilton. The position of the Black slate, they maintain, is more nearly that of the Genesee slate as suggested by M. de Verneuil.

The fossils of the Rockford limestone, including the Goniatites, were considered by the authors as more nearly allied to the Carboniferous forms than to those of the New York rocks; examples are given to prove this statement, and a section to illustrate the close relations between the Chouteau limestone (equivalent to the Rockford limestone) and the Burlington beds in Illinois. Reference is made to a paper of

[1] Meek, F. B., and A. H. Worthen. Remarks on the age of the Goniatite limestone at Rockford, Indiana, and its relations to the "Black slate" of the Western States and to some of the succeeding rocks above the latter. Am. Jour. Sci., vol. 32, 1861, pp. 167-177, 288.

Mr. C. A. White, in which he "shows that, out of a list of 102 described species occurring in the Burlington limestone, 15 commenced their existence in the beds below, referred by Hall to the Chemung, which, as is well known, represents the Chouteau limestone of Swallow."

After noting the intimate connection between these beds and the Carboniferous rocks above and remembering that the Chemung group in New York and Pennsylvania is covered by another Devonian formation (the Old Red sandstone) between 2,000 and 3,000 feet thick, the questions arose, should these Chouteau beds be referred to the Chemung Horizon? Is it possible that a great formation like the Old Red sandstone, with its own fauna, is wanting here between the Chouteau and Burlington limestones? The authors say, if asked what is to be done with the fossils of these rocks apparently identical with the Chemung forms, that they do not consider this identity proved, and find, if some are undistinguishable from Chemung species, there are numerous other fossils totally distinct from them, closely allied with Carboniferous forms, and even identical with them. Mr. C. A. White had inferred from the presence of these "Chemung" species "that they originated at the east and were migrating westward during the time that the bottom of the Chemung seas was sinking and receiving upon it the deposit of the Old Red sandstone, thus making these Devonian rocks equivalent to the Chemung of New York, and contemporaneous, at least in part, with the Old Red of the Catskill Mountains." But the authors add that in that case they should not refer the rock in which the Chemung forms occur to the Chemung, but either to the Old Red or to the Carboniferous, as in using these names they refer to a period of time, as well as to a group of strata, and they consider that the entire group of fossils is far more nearly allied to the Carboniferous than to the Old Red.

In conclusion they affirm "that the relations between the Chouteau and Burlington limestones in Missouri, Iowa, and Illinois, where both occur together, as well as of the affinities of the fossils found in the former in the States mentioned, and at Rockford, Indiana, show that it should probably be referred to the Carboniferous system, or, at any rate that it is much more recent than the Chemung, and not equivalent to any New York rock."

In a note on p. 288 of vol. 32, the authors propose the name "Kinderhook Group" for "the beds lying between the Black slate and the Burlington limestone which have heretofore been considered the equivalents of the Chemung group of New York."

Messrs. C. A. White and R. P. Whitfield dissented from the views expressed in the above paper in an article published in the Proceedings of the Boston Society,[1] the same year. Their chief objection was to

[1] "Observations on the rocks of the Mississippi Valley which have been referred to the Chemung group of New York, together with descriptions of new species from the same horizon at Burlington, Iowa." by C. A. White and R. P. Whitfield. Boston, Soc. Nat. Hist., Proc., vol. 8, pp. 289-306. Reviewed by "Anon." Am. Jour. Sci., 2d ser., vol. 33, pp. 422-426.

the correlation of the beds lying between the horizon of the "Black shale" and the base of the Burlington limestone as carboniferous. Their argument was as follows: On passing westward from New York, the representative of the Chemung in Ohio offers considerable change in the paleontologic characters, and between the correlated faunas of Ohio and Michigan a still greater difference is seen. Yet we feel warranted in regarding them "as of the age of the Chemung group of New York, and, so far as we know, no one has questioned it.[1]" They were "confident that some of the species found at Burlington and other places in the west of the same geological horizon are identical with some of those found in the Chemung rocks of Ohio, which rocks can be traced continuously to New York," and, "notwithstanding their carboniferous character, we think their reference to the Chemung of New York legitimate and proper.[2]" They accounted for M. de Verneuil's correlation of the "Chemung" of Ohio as carboniferous by supposing that he was ignorant of the tendency to change on passing westward, which they believed belonged to the faunas. They further maintained that "a direct continuity of the strata of the Chemung Rocks of New York can be traced from that State to those of Ohio," and that Hall considered that but for the Cincinnati axis the continuity could be traced to the Mississippi Valley. They noticed the difference in faunas, but believed with Hall that a stratigraphic continuity had been established.

When we examine the argument critically, we find that the error was at the start, on passing from Chautauqua County, New York, to Ohio. It was supposed that continuity of strata had been traced, and, in spite of the difference observed between the species in the Ohio rocks and those of the New York Chemung, the belief in the identity of strata led to a theory to account for the difference of fossils.

This is one of the best illustrations we have seen of the principle that correlations by lithologic characters cannot be relied on, even when the continuity is affirmed by a careful geologist after a special survey. Whereas the testimony of fossils can always be relied on to the extent and with the precision which our ability to interpret them will permit, and the reason is not far to seek. Petrographic characters have no relation to age. The characters of fossils are intimately associated with the time and environment of the living organisms they represent.

[1] "Observations on the rocks of the Mississippi Valley which have been referred to the Chemung group of New York, together with descriptions of new species from the same horizon at Burlington, Iowa," by C. A. White and R. P. Whitfield. Boston. Soc. Nat. Hist., Proc., vol. 8, pp. 289–306. Reviewed by "Anon." Am. Jour. Sci., 2d ser., vol. 33, p. 200.

CHAPTER IX.

THE PERMIAN PROBLEM OF KANSAS AND NEBRASKA, 1858-1886.

The determination of the upper limit of the Paleozoic rocks of America was a problem which did not trouble the students of the geological formations east of the Mississippi River until it had been suggested by studies farther west. The Carboniferous period in the Appalachian province was terminated by an uplift, which may have taken place during the Permian epoch, as suggested by Messrs. Fontaine and White, but stratigraphically the system was terminated by cessation of deposition, the result of the permanent elevation of the great mass of the Paleozoic deposits above ocean level. West of the Mississippi, at the western boundary of the outcrop of the Carboniferous system, in Nebraska, Kansas, and Texas, and around elevated masses in Dakota and New Mexico, the Permian problem arose for solution.

The first announcement of the discovery of Permian fossils was made in 1857, in a letter to F. Hawn, dated September 3, 1857, written by F. B. Meek, regarding the identification of some fossils sent by the former to the latter for that purpose. Mr. Meek's identification of the forms was recorded in written memoranda in the Smithsonian Institution January 19, 1858. Mr. Hawn had sent similar fossils to Mr. Swallow, who reported their identification with Permian forms to the St. Louis Academy of Science in a letter dated February 18, 1858, which was read February 22. Mr. Meek communicated a paper announcing the discovery of fossils "indicating Permian rocks in Kansas" to the Albany Institute, March 2, 1858, and also in a letter to the Philadelphia Academy of Natural Science, of the same date.[1] Following these announcements came fuller descriptions and other discoveries in other parts of the outcrop of the same terrane, made by J. G. Norwood, B. F. Shumard, and others.

At the beginning of 1858, F. Hawn was United States geologist in Kansas; G. C. Swallow was State geologist of Missouri; F. B. Meek was assisting as paleontologist in the explorations of F. V. Hayden, United States geologist in the Territories; J. G. Norwood was State geologist of Illinois, and B. F. Shumard was assisting G. C. Swallow in Missouri.

The Coal Measures had been studied and pretty thoroughly classified for all the States east of the Mississippi. Their marine fossils had been gathered in most of the States, and partially identified.

[1] Am. Jour. sci., 2d ser., vol. 44, pp. 38, 39.

The Permian system had been named and defined by Murchison in the report on the geology of Russia.[1]

William King's monograph of the Permian fossils of England was published in 1850.

Murchison's idea of the "Permian" was, that it was a system equivalent in rank to the Silurian or Carboniferous, and that it was characterized "by one type of animal and vegetable life." The question as to whether this idea was a correct one did not come definitely before the American geologists till a later period. When they discovered above the Coal Measures fossils indicating a Permian fauna, the question was as to whether or not the Permian system was present in the American geological series.

Those who took the most active part in the discussion were Messrs. Meek, Hayden, Swallow, Shumard, Hawn, Marcou, Geinitz, Norwood, Newberry, and C. A. White.

The typical sections whence the fossils came were along the Kansas River in northeast Kansas, and in Nebraska and south and west of these (at that time) Territories. In Swallow and Hawn's paper on "The Rocks of Kansas"[2] is given the typical Kansas section made by F. Hawn, consisting of—[3]

	Feet.	Strata Nos.
System I. Quaternary	169	1–3
System II. Cretaceous	72	4–5
System III Triassic(?)	420½(?)	6–25
System III. Permian:		
Upper Permian	263	26–31
Lower Permian	557	32–70
System IV. Carboniferous:		
"Coal Measures, probably above the upper Coal Measures of Missouri"	1,073	

The section made independently by Messrs. Meek and Hayden, including about the same section of rocks, is published in their paper on "Geological Explorations in Kansas Territory."[4]

The section is entitled "General section of the rocks of Kansas Valley from the Cretaceous down, so as to include portions of the Upper Coal Measures." Forty strata are given, numbered from above downward, 1 to 40. The point where they draw the line between the Upper Coal Measures and what may be called the Permian is at the top of their stratum No. 11. No. 10 above contains well authenticated Permian fossils; the locality of both sections is on Cottonwood Creek, in the neighborhood of Fort Riley. Most of the fossils reported as Permian by Swallow and collected by Hawn were from the Valley of the Cottonwood and from Smoky Hill Fork.

[1] Murchison, Verneuil, and Keyserling in 1845. The first announcement of the system was made in a letter from Murchison dated Moscow, September, 1841, and published in the Philosophical Magazine, vol, 19, p. 419.

[2] Trans. St. Louis Acad. Sci., vol. 1, pp. 173-197.

[3] Ibid., pp. 174–175.

[4] Proc. Acad. Nat. Sci., Phil., vol. 2, pp. 8-30.

In the early discussions Meek and Hayden recognized only "the Upper Permian" of Swallow as equivalent to the Permian of Europe; the "Lower Permian" of Swallow they considered as intermediate, and called it "Permo-Carboniferous." After a thorough study of the fossils in 1865 and later, Mr. Meek dropped the term "Permo-Carboniferous," and included all the rocks, except the upper zone of Swallow and the barren rocks above and their equivalents, in the Upper Coal Measures.

The facts emphasized by Mr. Meek were the gradual coming in of the Permian faunas at the top of the Coal Measures, followed above by a series of barren ferruginous beds and magnesian limestones with gypsum, and these followed by the Cretaceous. But all along this southwestern border of the Carboniferous there was a gradual passage from the Coal Measures lithology to that of the Permian type above, with no stratigraphic break, and a gradual change in the faunas, the Permian types coming in during the prevalence of Upper Coal Measure types, and by degrees increasing in dominance till the latter had nearly ceased.

There was nothing to suggest a distinct system except the European classification, and in ignorance of European Geology no one would have thought to draw a line of higher value than separating two étages, between the two sets of rocks.

The correlation with the European Permian was made on purely paleontological grounds.

A letter from G. C. Swallow to B. F. Shumard was read before the St. Louis Academy of Science,[1] announcing the identification of fossils collected by Hawn from Kansas. The letter states:

> All of the described fossils, with perhaps two exceptions, are identical with Permian species of Russia and England, while all of the new species appear to be more nearly allied to Permian forms than to any other.

At the same meeting a paper was read by Messrs. Swallow and Hawn.[2] Mr. Swallow considered the evidence of identity of fossils as sufficient to justify the decision that "the rocks are Permian."[3]

Messrs. Meek and Hayden[4] announced to the Philadelphia Academy of Science, March 2, 1858, by letter, the identification of fossils sent Mr. Meek by Mr. F. Hawn from near the junction of Solomon's and Smoky Hill Forks of Kansas River, "indicating the probable existence of Permian rocks in Kansas Territory."

The fossils were in the form of casts in a yellowish magnesian limestone, were "unlike any forms known to them from the Carboniferous

[1] Swallow, G. C.: Discovery of Permian Rocks in Kansas. Read February 22, 1858. St. Louis Acad. Sci., Trans., vol. 1, 1860, p. 111.

Shumard, B. F.: Discovery of the Permian formations in Mexico. Read March 8, 1858. St. Louis Acad. Sci., Trans., vol. 1, 1860, p. 113.

Swallow, G. C., and F. Hawn: The Rocks of Kansas. St. Louis Acad. Sci., Trans., vol. 1, 1860, pp. 173–175. This paper was communicated to the Society February 22, 1858.

[2] "The Rocks of Kansas, with descriptions of New Fossils from the Permian formation in Kansas Territory." This was published in full later, in the same vol. 1, pp. 173–197.

[3] The same announcement appeared in the American Journal of Science, March, 1858. (Vol. 25, p. 305.)

[4] Proc. Phila. Acad. Sci., vol. 10, pp. 9, 10.

system," and were "very nearly allied to types considered characteristic of the Permian of the Old World." The letter states that when Major Hawn was informed of the identification, several months previous, he reported that the bed from which the fossils were obtained was above the well marked Coal Measures, "and seems to have been deposited upon an uneven surface."

On the same day that this announcement was made to the Philadelphia Academy, a paper entitled "Description of new organic remains from northeastern Kansas, indicating the existence of Permian rocks in that Territory," by Messrs. Meek and Hayden, was read before the Albany Institute.[1]

In this paper, which was read before the Albany Institute March 2, 1858, the authors announce that fossils had been examined by them, received from Maj. F. Hawn "from near the mouth of the Smoky Hill Fork of the Kansas River, in a hard, rather compact, yellowish, brittle magnesian limestone." They differed "from forms known to us in any part of the Carboniferous system, yet were more nearly like Upper Carboniferous than Triassic or Jurassic types. * * * Suspecting this rock might represent the Permian system of the Old World, a hasty comparison was made * * * which almost established the conviction (six or eight months ago) that they belonged to that epoch."

"From the unquestionable relations of some [of the species] and the apparent affinities of others, taken in connection with the lithological characters and the stratigraphical position of the rock in which they occur, we think there is scarcely room to doubt that it is of Permian age."[2]

These announcements of the Permian character of the fossils discovered by F. Hawn in Kansas were followed later by the recognition of Permian fossils by B. F. Shumard from the white limestones of the Guadalupe Mountains, New Mexico, March 8, 1858, collected by G. G. Shumard.[3]

J. G. Norwood, April 5, 1858, announced to the St. Louis Academy that comparison of fossils found in the upper part of the sections in Bureau, La Salle, and Henry Counties, Illinois, with those identified by Messrs. Swallow and Meek, had convinced him that the upper beds of his sections were of the same age as those belonging to the Permian rocks of Kansas.[4]

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[1] Trans. Alb. Inst., vol. 4, pp. 73–88. Also, Am. Jour. Sci., vol. 25, pp. 440, 441.

[2] The following species are described: *Monotis Hawni* (p. 76); *Myalina* (*Mytilus*) *perattenuata* (p. 77), *Bakevellia parva* (p. 78), *Leda* (*Nucula*) *subscitula* (p. 79), *Edmondia*? *Calhouni* (p. 80), *Pleurophorus*? *occidentalis* (p. 80), *P.* (*Cardinia*) *subcuneata* (p. 81), *Lyonsia* (*Penopœa*) *concava* (p. 82), *Penpœa Cooperi* (p. 83), *Nautilus eccentricus* (p. 83).

[3] See Trans. St. Louis Acad. Sci., vol. 1, p. 113; also March 23, 1858, Proc. Acad. Nat. Sci., vol. 10, p. 14. The description of these fossils is published in the transactions of the St. Louis Academy of Sciences, vol. 1, pp. 387–403.

[4] Trans. St. Louis Acad. Sci., vol. 1, p. 115. See also Norwood, J. G.: The Permian in Illinois, Am. Jour. Sci., vol. 26, 1858, pp. 129, 130.

Hayden, F. V., and F. B. Meek. [On the probable existence of Permian rocks in Kansas.] (Read March 2, 1858.) Philadelphia Acad. Sci., Proc., vol. 10, 1859, pp. 9, 10.

Messrs. Swallow and Hawn,[1] in "The Rocks of Kansas," 1858, gave a section with 820 feet of "Permian rocks" above the Coal Measures, and still higher, 420½ feet of Triassic(?). They enumerate 72 species as Permian; 30 of these are identified with species before described; others are doubtfully referred to described species or are given new names.

In the article in the American Journal of Science, Swallow[2] acknowledged that Mr. Meek first discovered the Permian character of the Kansas fossils, and communicated it to Hawn September 3, 1857, and verbally to a friend at the Smithsonian January 17, 1858, and to Leidy the 16th of March, 1858, and he stated that Hawn first received the idea from Meek.[3]

Messrs. Hayden and Meek[4] found upon more thorough study of section and fossils, and comparison with the Nebraska section, that only Swallow's Upper Permian of Kansas is equivalent to the European Permian, and Swallow's Lower Permian, with several hundred feet of what he regarded as the top of the Coal Measures, in which *Monotis* was discovered by Meek, they call transitional and name "Permo-Carboniferous," or, if it must be placed one side or the other of the line, suggest that it be put in the Carboniferous.[5]

In a paper[6] read in May, 1857, Meek and Hayden presented a section of the rocks of Nebraska in which the base, of unknown thickness, is called "Carboniferous." It is seen along the Missouri River at De Soto; and at Council Bluffs, at low stages of the river, fifteen or twenty feet of it are exposed. This part is a yellow limestone, with *Fusulina cylindrica* and other Coal Measure fossils.

Above this the section for five members is called "Cretaceous."

No. 1 is described as yellowish and friable sandstones with alternation of dark and whitish clays, seams and beds of impure lignite, fossil wood, impressions of dicotyledonous leaves, *Solen*, *Pectunculus*, *Cyprina*, etc. This bed is "not positively known to belong to the Cretaceous system." The authors correlate this No. 1 with *f* of the New Jersey sections furnished by G. H. Cook, "mainly resting the opinion upon stratigraphic and lithologic evidence." Its correlation in the Alabama section is with E of Alexander Winchell's section. (See Table, beyond.)

In the same paper is given a section of the rocks of Kansas furnished by Hawn. It is a compiled section, based upon his observations made

[1] Reviewed Am. Jour. Sci., vol. 26, p. 115, and substantially the same paper read before the Am. Assoc. Adv. Sci., at Baltimore, lacking the descriptions, and printed in the Am. Jour. Sci., vol. 26, p. 182.

[2] Vol. 25, p. 188.

[3] See also Hayden's paper, Am. Jour. Sci., 2d ser., vol. 44, 1867, pp. 32-40.

[4] Am. Jour. Sci., vol. 27, 1859, pp. 31-35.

[5] See also notes explanatory of a map and section illustrating the geological structure of the country bordering on the Missouri River, from the mouth of the Platte River to Fort Benton, in latitude 47° 30′ N., longitude 110° 30′ W., by F. V. Hayden, M. D., Proc. Acad. Nat. Sci., Phila., vol. 9, 1857, 109-116.

[6] Descriptions of new species and genera of fossils collected by Dr. F. V. Hayden in Nebraska Territory, under the direction of Lieut. G. K. Warren, U. S. Topographical Engineer; with some remarks on the Tertiary and Cretaceous formations of the Northwest, and the parallelism of the latter with those of other portions of the United States and Territories, by F. B. Meek and F. V. Hayden, M. D., Proc. Acad. Nat. Sci., Phila., vol. 9, 1857, pp. 117-148.

in the country east of the sixth principal meridian and between the northern boundary of Kansas and the Republican Fork of the Kansas River. In this section the lowest bed, *m*, a siliceous limestone, is regarded as Carboniferous. The strata *c* to *l*, next above, are considered as equivalent to No. 1 of the Nebraska section. The lower part of these beds, *f* to *l*, is correlated with the Triassic of Marcou; the higher part *a* to *e*, with Marcou's Jurassic. The Pyramid section of New Mexico, according to Mr. Marcou, is given, p. 132. The lower members of this section, *c*, *d*, and *e*, called Jurassic by Marcou, and *f*, called Triassic by him, are correlated with No. 1 of the Nebraska section.[1]

In a second paper by F. V. Hayden,[2] a strip of Permian is colored in Kansas between the Carboniferous and the Cretaceous, a little west of Nebraska City and west of Fort Riley, in what in the first map was colored Cretaceous. This change is based upon facts reported by Hawn.[3]

It appears from this paper that the insertion of No. 1 of the Nebraska section of the Cretaceous was made upon the report of Hawn as to the species contained in it or below it, which belonged to genera characteristic of the Cretaceous.[4] Upon examination of fossils derived from No. 1 they were found by Meek to be of Permian or Carboniferous types. The presence of the leaves of dicotyledonous trees was the evidence upon which the authors (Meek and Hayden) relied as positive indication of the Cretaceous system. These occurred above No. 1. The evidence for this correction apparently did not reach the authors in time to adjust the body of the paper.

Meek and Hayden. Nebraska section.	Hawn. N. E. Kansas.	Marcou. Pyramid Mountain, New Mexico.	Winchell. Alabama.	Cook. New Jersey.
Tertiary Miocene.				
Cretaceous No. 5..	.....	.....	A	*g*
No. 4..	.....	.....	B. C. D.	*c. d. e.*
No. 3..	*a*	*a*		
No. 2..	? *b*	*b*		
Permian or Carboniferous No. 1.	*c–l*	*c* *d* *e* Jur.		
		f Trias.	E	*f*
Carboniferous	*m*			

In the Judith River section a bed called "No. 1 (?) is defined, and its true position was uncertain to F. V. Hayden in May, 1857.[5]

B. F. Shumard, in a paper[6] read before the Academy of Science, in

[1] Description of new species and genera of fossils collected by Dr. F. V. Hayden in Nebraska Territory, under the direction of Lieut. G. K. Warren, U. S. Topographical Engineer; with some remarks on the Tertiary and Cretaceous formations of the Northwest, and the parallelism of the latter with those of other portions of the United States and Territories, by F. B. Meek and F. V. Hayden, M. D., Proc. Acad. Nat. Sci., Phila., vol. 9, p. 129.

[2] Proc. Acad. Nat. Sci. Phil., vol. 10, pp. 139-158.

[3] See note, Ibid., p. 144.

[4] See note, Ibid., p. 145, 146, foot-note.

[5] Ibid., vol, 9. p. 116.

[6] "Observations upon the Cretaceous strata of Texas," by B. F. Shumard, State Geologist, Trans., vol. 1, No. 4, p. 582.

St. Louis, in 1860, correlates the lower Cretaceous beds ("Arenaceous and Red River groups") with No. 1, of the Nebraska section; in it are recorded characteristic Cretaceous fossils.

Messrs. Meek and Hayden[1] having examined the fossils and other geological specimens collected by Lieut. G. K. Warren, topographical engineer in and near the Black Hills, Nebraska, gave the succession of geological formations indicated by them.

The main body of the Hills is granite, and superimposed upon it is—

(1) A group of highly metamorphosed sedimentary formations.

(2) A sandstone equivalent to the Potsdam sandstone of the New York series.

(3) Limestones containing fossils which are a mingling of Coal Measure and Lower Carboniferous types.

(4) Two red beds containing specimens of fossils closely allied to Coal Measure forms. These red beds may be of Permian age, though the fossils point rather to the Upper Carboniferous series. It is not improbable that the upper bed may be Triassic or even Jurassic.

(5) Strata containing fossils of Jurassic type. The strata are argillaceous shales and various colored sandstones.

(6) Beds regarded as belonging to the older Cretaceous, though a large portion of them may be Jurassic.

Above all these formations are in regular succession, No. 2, No. 3, No. 4, No. 5, of the Cretaceous series of Nebraska.[2]

Mr. Swallow examined a collection of fossils from the Upper Coal Measures of Kansas Territory, made by Mr. Hawn, compared them with Permian fossils from Russia of Verneuil, and decided that the Kansas fossils are also Permian.

On his journey to New Mexico, J. S. Newberry[3] found Permian fossils in Kansas, and the beds described by Meek and Hayden as between the Lower Cretaceous and the Permian, which they state may be either Jurassic or Triassic. He also saw the same red or brown sandstone from which these gentlemen collected the fossil leaves which Heer and Marcou pronounced to be Miocene, but which Newberry says are the same which mark the base of the Cretaceous in New Jersey, Nebraska, and Kansas. And farther southwest he found this same sandstone overlaid by the same Cretaceous seen by Meek and Hayden surmounting it in Nebraska, these Cretaceous beds containing well known and admitted Cretaceous fossils, and also the very *Gryphæa* relied upon by Marcou to prove the existence of the Jurassic, proving, if Marcou and Heer are right, that the Miocene is older than the Cretaceous and Jurassic.

In New Mexico Mr. Newberry discovered facts sustaining the presence of the Trias there, as in the red gypsum-bearing marls containing cycadaceous plants, similar to those of the Keuper (Upper Trias) of Europe.

In the letter[4] from B. F. Shumard, read by Joseph Leidy, to the

[1] Meek, F. B., and F. V. Hayden: Fossils of Nebraska. Am. Jour. Sci., vol. 25, 1858, pp. 439-441.

[2] Swallow, G. C.: On Permian strata in Kansas. Am. Jour. Sci., 2d series, vol. 25, 1858, p. 305.

[3] Newberry, J. S.: Explorations in New Mexico. Am. Jour. Sci., vol. 28, 1859, pp. 298-299.

[4] On Permian rocks of New Mexico. By B. F. Shumard, Phil. Acad. Sci., Proc., vol. 10, 1859, p. 14.

Academy of Science, Philadelphia, the undoubted occurrence of Permian fossils in the white limestone of the Guadalupe Mountains, New Mexico, was announced. The collection consists of forty species, part of which are identical with the Permian forms of England and Russia. Below this limestone is a sandstone containing the same fossils found in the same formation in Missouri, Iowa, and Illinois, "but in New Mexico scarcely a single species ranges from the Coal Measures into the Permian."

Sir Roderick Murchison,[1] in a letter to the editors of the American Journal, expresses his surprise at the statement made by Mr. Marcou with regard to the term Permian, as given by Murchison, for the strata of the government of Perm, which term he considered a very improper one, and also that Murchison has included in his Permian a part, if not the whole, of the Trias.

Considering this a serious charge, Murchison asked an explanation of Marcou of the grounds upon which it was made, and this was finally given in the memoir noticed in this letter. Murchison objected strongly to criticisms upon his work by one who had never been in Russia, spoke of the absolute distinction between the fossils of the Permian group and those of the Trias, whether we refer to the reptiles, fishes, and shells, or to the plants, but Mr. Marcou unites these two deposits in one natural group under the name of New Red sandstone.

The author concludes by requesting the editors to translate into English the last page of Mr. Marcou's memoir, considering it the best argument against the adoption of that gentleman's views that could be produced.

The editors gave the summary referred to, in which Mr. Marcou regards the New Red sandstone, comprising the Dyas and Trias, as a great geologic period equivalent to the Paleozoic epoch, the Carboniferous, Mesozoic, etc., and says that he restricts the limits ordinarily given to the Paleozoic and Mesozoic, and gives them proportions more in harmony with those of the Tertiary and recent epoch, in order to have a well balanced and natural classification. He considers the Carboniferous forms of life found in the lower beds of the "New Red" as a kind of rear guard to the preceding organisms, and the forms found in the upper beds as precursors or advance guard of the Mesozoic populations.

In 1859, Messrs. Meek and Hayden acknowledge their mistake[2] in having placed certain rocks of Kansas on a parallel with No. 1 of Nebraska section, having ascertained by their fossils, which are similar to the Permian of the Old World, that these rocks should be placed lower, and the same was done with the lower 200 feet of Mr. Marcou's

[1] Murchison, Sir Roderick J.: Notice of a memoir by M. Jules Marcou, entitled "Dyas and Trias, or the New Red Sandstone in Europe, North America and India." Am. Jour. Sci., vol. 28, 1859, pp. 256–259.

[2] Meek, F. B., and F. V. Hayden: On the so-called Triassic rocks of Kansas and Nebraska. Am. Jour. Sci., vol. 27, 1859, pp. 31–35.

Pyramid Mountain section (New Mexico), referred by him to the Trias. These 200 feet the authors consider equivalent to the Kansas deposits between the base of No. 1 and the beds containing Permian fossils, and the rest of the Pyramid section, which he referred to the Jurassic, as equivalent to the Cretaceous formations, Nos. 1, 2, 3, of Nebraska.

The authors refer to their having considered No. 1 as a Cretaceous formation from the presence in it of dicotyledonous leaves (*Ettingshausiana*, etc.), while Major Hawn pronounces this formation in Nebraska, Kansas, and New Mexico, to be Trias, and they give Newberry's opinion after having seen the whole collection, affirming the correlation with the Cretaceous formations. They also speak of the beds between the base of No. 1 and those from which Permian fossils are obtained in Kansas, as possibly Jurassic or Triassic, or both, but do not attempt to define their age with certainty. With regard to the Permian rocks of Kansas, as classified by Swallow and Hawn, they are inclined to the opinion that the lower Permian of these gentlemen should be considered as intermediate in age between the Permian and Upper Coal Measures of the Old World, while the Upper Permian only, of their section, really represents the Permian rocks of Europe, and they propose the name of "Permo-Carboniferous" for this intermediate series, but if this be not adopted, think it should be placed with the Carboniferous rather than with the Permian.

In conclusion, they state that there is no unconformability among all the rocks of Nebraska and northeastern Kansas, from the Coal Measures to the top of the most recent Cretaceous.

Mr. J. C. Norwood,[1] writing to B. F. Shumard, President of the St. Louis Academy of Science, March 31, 1858, spoke of having found in 1855–'56 organisms new to him in the upper beds of the La Salle coal field, which he supposed to belong to the true Carboniferous era. But after the announcement of the existence of Permian rocks in Kansas by Professor Swallow and Messrs. Meek and Hayden, he reviewed some of these fossils found in Bureau, La Salle, and Henry Counties, and became satisfied that the upper beds, at least, of the La Salle rocks are of the same age as those considered Permian in Kansas. The beds are composed of sandstones, conglomerates, magnesian limestones, slates, and red and blue gypseous marls, all of them resting *unconformably* on the underlying beds. Thin seams of coal also occur, showing that if this formation belongs to the Permian period, the great probability is that the upper beds of coal in several sections of the State are of the same age. A section of the rocks at La Salle accompanies the letter.

In 1864 M. Jules Marcou[2] wrote upon the section at Nebraska City and

[1] Norwood, J. C.: Discovery of Permian rocks at La Salle, Illinois. St. Louis Acad. Sci., Trans., vol. 1, 1860, p. 115.

[2] Marcou, Jules: Une reconnaissance géologique au Nebraska. Soc. géol. France, Bull., 2e sér., vol. 21, 1864, pp. 132–146.

vicinity. He regarded the section $\frac{D}{C}$ $\frac{B}{A}$ as representing in America "la partie supérieure du Dyas d'Europe."[1] Of the section of the bluff at Plattesmouth he said: "elles appartiennent à la partie inférieure du Dyas."[2]

In Missouri he reported islands of Carboniferous in the midst of the Dyas. Two members of the Dyas were recognized, viz, the Rothliegende and the Zechstein.

In regard to Brachiopods as a means of correlation, he remarked:

> Les plus mauvais fossiles dont on puisse se servir comme fossiles caractéristiques des formations, et qu'en réalité ils ne sont même pas du tout des Leitmuschel * * * plus bas même dans la série que les coraux.[3]

Had he appreciated better the value of Brachiopods in making correlations his conclusions might have been more accordant with those of other geologists.

This paper of Mr. Marcou was criticised in 1865 by Mr. Meek,[4] who took issue with him upon almost every point made. Although the discussion was of interest at the time, its rehearsal here may be omitted without loss.

In 1866 Mr. H. B. Geinitz published his description of the fossils collected by Mr. Marcou from the localities in Kansas and Nebraska named in the paper above referred to.[5]

There are mentioned in the work 99 species, 2 of them plants. Of these, 67 were found at the typical Nebraska City section, the zones of which were called, from below upward, A, B, C, D, by Marcou. Sixty-three of the 67 species were from the zone C. Twenty-three species of invertebrates and one plant from the Nebraska City section were identified with already described "Dyas" species of Europe. The author says: "Die bei Nebraska-City vorkommenden Versteinerungen gehören einer Zone an, welche den untersten bis mittleren Schichten den deutschen Zechsteinformation (Oberen Dyas) entspricht."[6]

The Plattesmouth and Rock Bluff sections were thought to represent a lower horizon, the "Fusulinenkalk" or "oberen Kohlenkalk."

The bulk of the work, pages 1 to 72, is devoted to the description of the fossils and their comparison with typical species of the Carboniferous and Permian formations. Although the correlations of the author were based upon this paleontological study, it is impracticable here to discuss the merits of the identifications of species.

In the following year (1867) Mr. Meek made an extended review of

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[1] Marcou, Jules: Une reconnaissance geologique au Nebraska. Soc. géol. France, Bull., 2e sér., vol. 21, 1884, p. 137.

[2] Ibid., p. 138. [3] Ibid., p. 146.

[4] Meek, F. B.: Remarks on the Carboniferous and Cretaceous rocks of eastern Kansas and Nebraska, and their relations to those of the adjacent States and other localities further eastward; in connection with a review of a paper recently published on this subject by M. Jules Marcou, in the Bulletin of the Geological Society of France. Am. Jour. Sci., vol. 39, 1865, pp. 157-174.

[5] Carbonformation und Dyas in Nebraska, von Dr. H. B. Geinitz, 1866, pp. i-xii and 1-91, Plates I-V.

[6] Op. Cit., p. 89.

Mr. Geinitz's paper.[1] As a preparation for his criticisms Mr. Meek had thoroughly studied the species obtained from the same localities, and before completing the article had gone over the sections from which they were obtained and examined the stratigraphy of the whole region where the rocks in question were exposed, from Iowa across Nebraska, Missouri, and Kansas, collecting fresh materials. He also had access to the numerous collections of the Smithsonian, among which were a considerable number of European Permian fossils. He had the advantage of Mr. Geinitz in his thorough knowledge of the Carboniferous marine fossils of the Mississippi Valley, comprising the fauna with which the fauna above had to be immediately compared. With such preparation he made a careful and critical review of the identification of species and genera made in Geinitz's work. The author differs respecting the identification both of genera and species from Geinitz, and suggests as explanatory of the unsatisfactory identifications made by Mr. Geinitz that the latter was ignorant of the Coal Measure fossils of America, and was therefore not in a position to see the close relationship between the faunas below and those which follow. Mr. Meek had previously noticed in the rocks called Permian by Swallow a mingling of Coal Measure and Permian types, and calls attention to the frequent alternation of beds containing these two types of fossils through considerable thickness of strata which must be regarded as typical Upper Coal Measures. He also remarks that Mr. Geinitz had only descriptions of species already described in America, and had not access to the originals. In his remarks regarding two schools of observers among paleontologists and zoologists he defines the two classes as, "first, those who give wide latitude to genera and species, and second, those who restrict both genera and species within more precise limits." In commenting on *Astarte Nebrascensis* (p. 179) he remarks: "At any rate, specific identification and even generic references of such shells can be admitted only provisionally until the hinge and interior is known." On page 183, commenting on *Rhynchonella angulata* Linnæus of Geinitz, he writes:

> I hope I shall be excused for adding here that the practice of positively identifying species from widely distant parts of the earth upon such merely superficial points of general resemblance, and thus complicating and vitiating all conclusions respecting the geographical and geological range of species, can not be too carefully avoided.

The conclusion reached in this paper regarding the Permian problem is to the effect that the rocks in Nebraska from which the so-called Permian fossils have been obtained contain also a much larger number of characteristic Coal Measure fossils, and therefore that the rocks above the mouth of the Platte River called by Marcou "Mountain limestone," those of Plattsmouth and Rock Bluff called "Lower Dyas"

[1] Remarks on Professor Geinitz's views respecting the Upper Paleozoic rocks and fossils of southeastern Nebraska. By F. B. Meek, Am. Jour. Sci., 2d ser., vol. 44, 1867, pp. 170–187, 282–283, 327–339.

by Marcou, and by Geinitz placed in part in the upper "Mountain limestone," and in part in the Upper Coal Measures and the "Upper Dyas" rocks of Marcou and Geinitz at Wyoming, Bennett's Mill, and Nebraska City, with possibly the exception of C and D of the latter place, belong to the horizon of the Upper Coal Measures. C and D he thinks may be equivalent to the "Permo-Carboniferous" of the Kansas section.

All through this region the fossils of the Upper Coal Measures are found either associated in the same stratum with those of Permian type, or in strata intercalated between beds holding the other fauna; and the Coal Measure fauna becomes by degrees less conspicuous and the Permian types more dominant on passing upward. Mr. Meek maintains that the critical study of the fossils confirms the view published by Hayden and himself in 1858 regarding the rocks of Nebraska and Kansas, that—

> there is in this region a gradual shading off from an Upper Coal Measure to a Permian fauna through a considerable thickness of strata forming a somewhat intermediate group, which is called the "Permo-Carboniferous series;" also there is no defined break between the intermediate series and the Permian above, or the Coal Measures below.[1]

He further adds:

> Under such circumstances it must be evident that all attempts to correlate particular unimportant beds here with minor subdivisions adopted in Europe, where a different state of things obtained, must necessarily fail.

Mr. Meek recognized in his early studies in the section along the Kansas River certain beds containing a fauna which he identified then, in 1858, with the Permian, i. e.: Stratum 10 of the Cottonwood section. Above this were some more or less Barren Measures of 100 to 200 feet thickness, containing gypsum, followed by rocks of unmistakable Cretaceous age. In his early studies the rocks immediately below this unmistakable Cretaceous bed he had, in conjunction with Mr. Hayden, called "Permo-Carboniferous." This paper of 1867 which refers beds in Nebraska to the Upper Coal Measures evidently considered only these "Permo-Carboniferous" rocks of his early classification. The question in dispute was as to whether the rock should be divided, making a Permian system distinctly separate from the Carboniferous below. This Meek positively objected to, his argument being that there was a gradual mingling of the higher faunas with the Upper Coal Measure faunas, and a gradual transition of the deposits from the lower horizon to the upper without break, and without any marked change in paleontology or lithology.

Mr. Marcou,[2] in 1868, wrote that in Nebraska the "Dyas rocks" form the bluffs on the Missouri River in the counties of Nemaha, Otoe, and Cass. The rocks differ from those of the Carboniferous upon which they rest. They consist of clays of red, green, and blue colors; of

[1] Remarks on Professor Geintz's views respecting the Upper Paleozoic rocks and fossils of southeastern Nebraska. By F. B. Meek, Am. Jour. Sci., 2d ser., vol. 44, 1867, pp. 338-339.

[2] On the Dyas in Nebraska, by Jules Marcou. St. Louis Acad. Sci., Trans., vol. 2, 1868, pp. 562-564.

whitish, gray, and yellowish limestones; of dolomites, and yellow and gray sandstones.

A section of the Dyas taken at Nebraska City is given.

The fossils collected were determined by Mr. Geinitz, of Dresden, Saxony. Many of them are said to be identical with species found in Europe in the Zechstein or Magnesian limestone, as *Serpula planorbites*, *Schizodus Rossicus*, *Allorisma elegans*, etc., and the new species are very nearly allied to Dyassic species of Saxony, Russia, and England. The author speaks also of Carboniferous species, the Brachiopods espe cially, which pass into the Dyas.

F. V. Hayden, in a paper on the Geology of Kansas, reviewing Swallow's Preliminary Report of the Geological Survey of Kansas,[1] objects to Swallow's statement that "the lower Permian strata rests unconformably upon the upper Coal Measures." He questions the accuracy of Swallow's determination of species, in the paper of 1858, and he states that Mr. Swallow has identified fossils coming from a single stratum as equivalent to species of the Carboniferous, Permian, Trias, and Lias, and holds that the community of genuine Carboniferous fossils with those of Permian type indicates that no break, such as unconformity would presume, occurs.

Hayden remarks further that in the few cases of Permian types occurring down in the genuine Coal Measures in Kansas "they appear in particular layers similar to the Permian rocks in composition, and alternating with the other beds containing only carboniferous fossils, much like Barrande's 'Colonies' in the Silurian rocks of Bohemia." He remarks upon the claims to discovery of the Permian in Kansas, and defends Meek, whose announcement of the fact was first mentioned in the records of the Smithsonian Institution, the date being January 19, 1858.

Again Mr. Swallow, remarking on Meek's notes on the Geology of Kansas,[2] goes at some length to show that he first discovered and published as a conclusion the fact that certain rocks were Permian, and makes much point of the fact that Meek claimed only that the fossils sent by Major Hawn "indicated the existence of Permian rocks," and it is stated that at the Baltimore meeting Meek "still doubted whether there really is any Permian system."

This caution on the part of Mr. Meek shows that he saw the true state of the discovery, and maintained that the presence of certain fossils of Permian type did not indicate certainly that there was a representative of the Permian system in Kansas and Nebraska, while Swallow had no doubt that the fossils must indicate the presence of the system. The fact is conspicuous that during this discussion Mr. Meek speaks almost every time of "rocks containing fossils of Permian type," or words to that effect, rather than "Permian rocks,"

[1] Am. Jour. Sci., 1867, 2d ser., vol. 44, pp. 32–40.

[2] Trans. Acad. Sci., St. Louis, vol. 2, pp. 507.

indicating his clear perception of the difference between identity or resemblance of fossils, and absolute correlation of horizon. It may be noted in passing that the solution of this problem, as in other different cases, was by United State geologists; the wide comparative methods of Hayden and Meek led to clearer views than those attained by the local State geologists, Swallow and Shumard, although the latter had closer familiarity with the country and opportunity to get a better view of the local facts.

Swallow reported his section along the south side of Kansas River as follows (according to Meek and Hayden):

Cretaceous	= Cretaceous.
? Triassic Gyps. Sh. Marls, 388 feet	= ? Triassic.
Upper Permian, 141 feet	= "So-called Permian."
Lower Permian, 563 feet	= Permo-Carboniferous.
Carboniferous	= Carboniferous.

Swallow stated that if his lower Permian is not Permian there is no Permian in Kansas, etc. (p. 521), and defended the "unconformability." He stated that Messrs. Marcou, Agassiz, Heer, Geinitz, Shumard, Swallow, Hawn, D'Archiac and others differ from Messrs. Hayden and Meek on the point in question (p. 522). The whole article is controversial and adds little to the settlement of the problem, but brings out clearly the attitudes of the disputants.

The appearance of Permian types in the midst of rocks in which the majority of the forms are typical Coal Measure forms, is taken by Meek and Hayden as evidence of the earlier appearance of Permian types in these regions of America than in those of Europe.

In the final report of the Hayden survey of Nebraska,[1] Mr. F. B. Meek gave a description of the fauna and fully described the correlations of the Permian in Nebraska.

He holds in this paper, in opposition to the view of Geinitz, that the rocks of eastern Nebraska do not belong either to the Lower Cretaceous or to the Permian. The terms Upper, Middle, and Lower Coal Measures are used to express parts of the Coal Measures not clearly divisible by fossils. He does not use the term "Lower Coal Measures" as meaning below the Mountain limestone.[2] He proposes the name "Platte Division" for the upper part of the Coal Measures as exhibited about the mouth of the Platte River, at Bellevue, Plattesmouth, Rock Bluff, and Nebraska City. This he estimates to be two or three hundred feet thick. His Division B outcrops at Nebraska City, Bennett's Mill, and Wyoming; Division C at Nebraska City, and he says that between C and B there is no paleontologic or constant lithologic break. The rocks of the Bellevue section were referred by Marcou to the mountain

[1] Meek, F. B. Report on the Paleontology of Eastern Nebraska with some remarks on the Carboniferous rocks of that district (pp. 81–261), constituting Pt. II. of "Final Report of the U. S. Geol. Survey of Nebraska and portions of the adjacent territories, made under the direction of the commission of the General Land Office" by F. V. Hayden, U. S. Geologist, Washington, 1872.

[2] Ibid., page 84.

limestone series. The Plattesmouth section Marcou called New Red. The section at Rock Bluff follows that of the Plattesmouth section from 1, 2, 3, upward: this latter section Marcou had referred to the Lower Dyas or New Red. The Cedar Bluff section the author correlated with the part of the Rock Bluff section lying above No. IX. This was called "Upper Permian" or "Dyas" by Marcou and Geinitz. Meek thinks that both Marcou and Geinitz determined the Dyas, in some cases at least, on lithologic instead of paleontologic grounds.

Meek uses the names "Lower Carboniferous," "Millstone grit," and "Coal Measures" to indicate the three grander divisions of the Carboniferous System, with "Permian" and "Dyas" for the still higher member. "Mountain limestone" is used also for Lower Carboniferous. The name "Permo-Carboniferous" is applied by Hayden and Meek to rocks in Kansas, equivalent to Division C at Nebraska City. All the other sections along the Missouri he regards as certainly belonging to the Coal Measures. In Kansas, the division between Permian and Carboniferous is arbitrary, not founded on physical or paleontologic break. Permian rocks in Kansas were first announced in the Transactions of the Albany Institute, vol. 4, 1858. Later investigations led the authors to consider the so-called Permian as merely transitional from the Upper Coal Measures.[1] Meek thinks that facts indicate that these fossils belong in the Carboniferous or Coal Measures, and that there is no abrupt break between the Carboniferous and Permian.

Mr. Meek's Review of Professor Geinitz's paper, 1867, and this Nebraska Report of 1872 practically closed the debate on the Permian problem of Kansas and Nebraska.

Mr. F. B. Meek had been for several years associated with Mr. Hayden in the collection, study, and description of the fossils of these and neighboring Territories. Messrs. Swallow, Shumard and others had examined and reported their identification of fossils from Kansas, which they defined as new species or referred to European species of the Permian age. A collection made by Mr. Marcou had been sent over to Mr. H. B. Geinitz, of Dresden, and there figured and described by him. But Mr. Meek had examined the sections thoroughly in connection with Hayden, and had made an exhaustive study of the fossils, comparing them with European specimens, and studying fully the literature of the whole subject. His paleontological work exhibits a degree of precision of observation, broadness of thought, and thoroughness of study surpassing any of his predecessors in America, and all combined with scrupulous honesty.

Leaving out of the question the dispute as to the real discoverer of the Permian, which provoked considerable discussion and, apparently, ill feeling, the Permian problem was more purely than any that had

[1] See Meek's paper, Am. Jour. Sci., vol. 44, p. 170 and p. 331, in regard to the misidentification of Geinitz.

previously arisen in America a paleontological one. The discovery of some fossils by F. Hawn in Kansas, some of which were sent to G. C. Swallow among Carboniferous species for identification, and others of the same species among Cretaceous forms to Mr. Meek, led to the discovery by both Swallow and Meek of their Permian character. Mr. Swallow appears to have made the first printed announcement of the "Permian rocks," although Mr. Meek had previously announced the identification in private letters, and a few days later Messrs. Meek and Hayden defined the same fossils as "indicating Permian rocks" in papers read at both Albany and Philadelphia.

The fossils in question were identified and described by Swallow, Geinitz, and Meek separately; and the argument for the presence of the Permian system of rocks in Kansas and Nebraska and New Mexico, made by Swallow and seconded by Geinitz, Marcou, and others, was, that in the rocks were found a number of species identical with species characteristic of the Permian rocks of Russia, Germany, and England.

Mr. Meek, supported by Mr. Hayden and others, maintained that the rocks lying above unmistakable upper Coal Measure rocks in this Territory, contained fossils of Permian type, in a few cases showing possible specific identity with European Permian species; but that there was a gradual passage, both lithological and paleontological, from the Coal Measures to the beds containing these Permian types. After obtaining abundant material and giving it exhaustive study, Mr. Meek found the identifications of Swallow, of Marcou, and of Geinitz unsatisfactory. He recognized many species of Permian types, but only a few that he was able to regard as identical with the Permian fossils of Europe. In his report of 1872 he identified from the so-called Permian of the southwest seven genera which had not hitherto been reported below the Permian of Europe, but in the same beds he identified sixteen genera not otherwise known above the Carboniferous. He called attention, however, to the fact, that of the seven genera several are closely related to forms occurring below; secondly, he found several of the species, which are confessedly of Permian type, still lower and in association with unmistakable upper Coal Measure faunas. In his list of the species in question in Nebraska, amounting to one hundred and twenty-two, only thirteen are named which have not been discovered in the Coal Measures of some of the other States. Besides this mingling of species and genera, and their passage upward in such large numbers, he found evidence neither of sudden change in the lithologic character of the strata, nor of stratigraphic break, and his conclusion is, that these rocks belong to the Coal Measures, "and that here we have no abrupt break between the Carboniferous and Permian" (p. 133); "that all these strata under consideration along the Missouri, that have been referred in part to the Mountain limestone, in part to the Permian or Dyas, and in part to the Coal Measures, really belong

to the true Coal Measures," with the exception that the Permo-Carboniferous may be recognized in Bed C of Nebraska City.

This practically closed the debate, although it did not solve the Permian problem. The debate was ended, because the evidence was perfectly clear that the rocks and fauna referred to the Permian, were separable from those below by no stratigraphic or paleontologic break, and petrographically only by differences such as are recognized in two formations almost anywhere in the geologic series. The question whether they be called "Permian" or "Coal Measures" would be settled one way by those who considered it of chief importance to establish uniformity in the geological nomenclature of America and Russia; and it would be settled the other way by those who sought to establish a natural classification of American rocks.

The application of the name "Permian" to these rocks was purely artificial, and as was stated several times during the debate, the classification thus implied would not have been thought of if the rocks of this region alone had been considered.

The general question as to whether the Permian shall be ranked as a system separate from the Carboniferous, is still an open one, and bids fair to continue so until a natural method of classification for the time-scale be devised, which shall be independent of the lithologic character of the rocks.

The correlation of the Permian in the Acadian and Appalachian provinces is a distinct problem from that in the Mississippian province. In the former plants enter into the question, and as I have previously stated the correlative value of plants is not attempted in the present essay.

In chapter IV the Appalachian representatives of the Permian are considered.

The correlations of the Upper Carboniferous and Permian of the Acadian province are discussed in Chapter XII, but a few words may here be said regarding Dr. J. W. Dawson's correlations in the "Acadian Geology," second edition, 1868.

Dr. Dawson considered the Permian as absent in the Acadian district. The Trias rests unconformably upon the Upper Carboniferous, and the author held that the time represented by the Permian in Europe was a period of disturbance in Acadia, with land extending over the greater part of the region.

The limestones of Colchester and Hants contain some fossils which were regarded by Davidson as allied, if not identical with Permian fossils[1] and Mr. Meek suggested that these may have constituted a colony, in the Barrandian sense, of Permian forms in the Carboniferous age. The author, however, thought the deposits undoubtedly Carboniferous, and Lower Carboniferous, but that they assume some of the

[1] Pp. 278-285.

modifications more characteristic of the true Permian faunas of Europe.[1] In regard to the conditions of deposition, he interpreted the series as follows:[2] Marine limestones indicate lowest depression; coal beds were formed during the greatest elevation, and the condition of Millstone grit and the newer coal formations was intermediate between these two. Tidal currents were recognized in the Carboniferous, cutting out channels called "tidal channels."[3] The author also recognized that Devonian and Silurian rocks were above the water during the deposition of the rocks of the Coal Measures of Nova Scotia, so that the coal deposits are more or less separated from each other.

The flora was regarded as identical throughout the whole Middle Coal Measures, and the Lower, Middle, and Upper may be distinguished by their plants. Dawson also held that the flora of the Lower Coal Measures of Nova Scotia is wholly Carboniferous, and that the flora of the Chemung, Vergent, and Ponent, IX and X, of Lesley, is decidedly Devonian.

The author recognized, not 25,000 feet for Nova Scotia Coal Measures, but Logan's measure of 15,570 feet for the Joggins, and for the Middle Coal Measures, 1,000. He mentioned the fact that in England it is the usage to apply the term Lower Coal Measures to the lower part of what he called the Middle Coal formation, that is, above the Millstone grit. He quoted Geinitz in identifying the divisions of the coal formations by plants. His Lower Coal formation is the Lycopodiaceous Zone or Culm of Europe; his Middle Coal formation is the Sigillaria and Stigmaria Zone; the Upper Coal formation is the Zone of Calamites of Geinitz.

Mr. C. A. White wrote in 1874 that Dr. L. G. De Koninck had identified many of the species from the Coal Measures of Springfield, Illinois, with Lower Carboniferous species of Europe, and Geinitz had identified species found in the Upper Carboniferous of Nebraska as Permian. The mingling of faunas thus indicated, the author held, is due to the fact that while the region in which true Coal Measures were being deposited were little invaded by the seas during the whole Carboniferous period, America was occupied in some places by the sea, which fact accounts for the wide distribution of marine faunas as compared with those of Europe. Chronological development is also proved by the similarity of the floras of the two countries, as has been pointed out by Dr. Newberry and Mr. Lesquereux.

The next four papers give additional information upon the Permian and Permo-Carboniferous formations of Kansas and Nebraska.[4]

Coal belonging to the Lower Coal Measures is found in marketable quantities in Osage County. It is well exposed on the southern side of Neosho Valley, running through Miami County. Upper Coal Meas-

[1] Pp. 283-285.
[2] P. 133.
[3] P. 125.
[4] Broadhead, G. C.: The Carboniferous rocks of southeastern Kansas. Am. Jour. Sci., 3d ser., 1881, vol. 22, pp. 55-57.

ures also occur west of the Verdigris River, and are soon covered by Permian rocks. The western limit of the coal is along the line between Greenwood and Woodson Counties.

The Permian rocks are found along a ridge running through Cowley and Chautauqua Counties and southern Kansas, which is known as the "Flint Hills," having an elevation of 1,600 feet above sea level. The Permian rocks rest conformably on the Carboniferous, rendering it difficult to draw any absolute line between them. It is estimated that the Permian has a total thickness of 1,500 feet in southern Kansas, while the Upper Coal Measures are about 500 feet in thickness, consisting mainly of sandstones and limestones.

In a second paper[1] the same author further reported: The valley traversed by the Neosho River is in the lower part of the Middle Coal Measures, which are only productive in the southern extension, but northwardly, in Osage County, coal is mined belonging to the Lower Measures, showing "an uplift of Lower [Middle?] Coal Measures, flanked to the east and west, as we proceed northwardly, by the Upper Coal Measures."

In Neosho, Wilson, Labette, and Montgomery Counties we find sandstones in even, flag-like layers, 50 feet thick at Thayer, Neosho County, where coal is extensively worked. Many fossil plants are found in the coal, including *Calamites*, *Lepidodendron*, etc.

In Johnson and Wyandotte Counties limestones and calcareous shale beds of the Upper Coal Measures with molluscan remains are recognized, corresponding with similar beds in Cass and Jackson Counties, Missouri; and at Eudora, Douglas County, is found the Plattsburg limestone of Missouri, containing many beautiful Bryozoans. Above this is a gray limestone abounding in *Syntrielasma hemiplicata*, its interior lined with clear crystallized calcite. A little higher is a limestone containing *Fusulina cylindrica*.

The Productive Coal Measures are found in the eastern tier of counties south of Miami County and include valuable coal beds.

In Miami and Anderson Counties the upper limestone is surmounted by an oolitic limestone. In Woodson and Greenwood and the northeast part of Elk Counties there are about 50 feet of coarse brown sandstone, almost without fossils, with only occasional fragments of fucoids and *Cordaites*.

In the southeast, near the line of Cowley and Chautauqua Counties, are the "Flint Hills," so called from the numerous fragments of flint strewn over the surface. These hills include the Permian rocks of Kansas, reaching a thickness of about 500 feet. A section of the rocks is given, showing 19 divisions of strata, the upper 12 of which are of Permian type, and the remaining 7 belong to the Upper Coal Measures. Several of the Permian layers abound in *Fusulina*. They are mostly

[1] The Carboniferous rocks of eastern Kansas, by G. C. Broadhead. St. Louis Acad. Sci., Trans., vol. 4, pp. 481–493, 1882.

limestone, shaly, magnesian, or cherty, while the lower layers are more arenaceous.

The highest coal series is seen in Greenwood County, its position being about the base of the Permian or top of the true Upper Coal Measures.

One thousand five hundred feet of Permian beds in southern Kansas are assumed. In this region it is the newest rock below the Quaternary. It rests conformably on the Coal Measures, and there is no decided line of separation between the two.

The Permo-Carboniferous was identified in southern Kansas by Mr. F. W. Cragin, in 1885.[1]

The most interesting feature of this region is the occurrence of a large stratum of gypsum. This is considered as a Permo-Carboniferous deposit. This horizon is entirely different from that of the gypsiferous deposits represented in Barber and eastern Comanche Counties, which is considered as Mesozoic.

In 1886, commenting upon the Carboniferous and Permian rocks of Nebraska, in the American Naturalist,[2] L. E. Hicks describes a series of limestones and marls in Nebraska evidently distinct from the Coal Measures. They are blue, yellow, and buff in color, and have a total thickness of about 200 feet The dip at Big Blue River from Beatrice to Homesville is southeast; at Indian Creek it is west. Of the 123 species described by Meek from the Coal Measures, not more than 10 or 14 entered into the Permian. The author uses the term "Permian" provisionally for these limestones and marls.

[1] Cragin, F. W.: Notes on the geology of southern Kansas. Washburn College Lab. Bull., vol. 1,1885, pp. 85–91 and 112.

[2] Hicks, L. E.: The Permian in Nebraska. Am. Nat., vol. 20, 1886, pp. 881–883; abstract in Am. Assoc. Proc., vol. 35, pp. 216, 217.

CHAPTER X.

DEVONIAN AND CARBONIFEROUS CORRELATIONS IN THE WESTERN AND NORTHERN PROVINCES.

In the Rocky Mountain region and the western part of the United States and in British North America are large tracts of territory which have been roughly surveyed, and in places with sufficient detail for the correlation of the grand geological divisions; but in little of this region have the details of either the stratigraphy or the paleontology been worked out with sufficient minuteness to permit of fuller correlations than with the systems of other parts of the world or their upper or lower parts without precise reference to limits. The literature concerning these correlations will be reviewed chronologically in the present chapter, beginning with the Hayden reports of 1868, prior to which date little of interest for this essay can be gleaned.

In 1868, Mr. F. V. Hayden, in the American Journal of Science,[1] gave a brief report of the results of his examinations of the geology of the Rocky Mountains, in which some generalizations are made based upon his wide knowledge of the region. The object of this paper was to show that quite marked lithological and paleontological changes occur in the rocks of the Rocky Mountains as we proceed from the north southward. The nucleus of the mountains at any one point along the eastern range is composed of massive granite rocks; then follows a series of metamorphic rocks. Upon these the Silurian period is represented by the Potsdam sandstone; the Devonian is wanting; then follow the Carboniferous, Red Beds, Jurassic, Cretaceous, Tertiary.

There is no marked change in the Tertiary from the North to the Arkansas River, but many changes were observed in the Cretaceous. The Jurassic thins out to the southward, as do the Red Beds or supposed Triassic. In the far north the Carboniferous rocks are often 500 to 1,500 feet in thickness, and from 500 to 1,000 feet thick as far south as the Red Buttes, and are quite distinct from the Red Beds, but the latter prevail farther south. The Carboniferous rocks become of a red arenaceous character, with a few layers, from two to ten feet in thickness, of a whitish or yellowish limestone. Dr. Hayden could find no break to separate the Red Beds from the Carboniferous, and concluded they might possibly all be of that formation. The Potsdam sandstone

[1] Hayden, F. V.: Remarks on the geological formations along the eastern margins of the Rocky Mountains. Am. Jour. Sci., vol. 45, 1868, pp. 322–326.

thins out entirely south of the Red Buttes on the North Platte. The Carboniferous seemed to rest directly, though not conformably, upon the metamorphic rocks.

The conclusions drawn from the observations made were that all the formations of the west undergo more or less change in both their mineral and fossil contents in their extension toward the west and south, and that the Potsdam sandstone and Jurassic beds present more remarkable changes than any of the others.

In 1868 Mr. F. B. Meek examined several lots of fossils collected in British America, some of which he found to be new; these he described and figured. Others he identified with already known fossils, and by these correlated the formations in which they occurred with formations in other parts of the country. The localities are on the Clearwater River, near its mouth into the Athabasca; on Laird's River, near Fort Resolution; on Slave Lake, and several localities along the Mackenzie River Valley to old Fort Good Hope, and one locality on Porcupine River.

From the study of the fossils the following conclusions were reached: That along the Mackenzie River and its tributaries, between the Clearwater and the Arctic Ocean, "no Carboniferous or characteristic Silurian formations are seen," and that there is "a continuous stretch of Devonian rocks, mainly of the age of the Hamilton group, extending from Rock Island, Ill., in a northwesterly direction to the Arctic Ocean, a distance in a right line of nearly 2,500 geographical miles."

The great general similarity with frequent specific identity in the faunas from the extreme ends of this line, the author considers, "strongly corroborates the generally accepted opinion that climatic conditions, if not uniform over the whole world, were at least little, if at all, influenced by differences of latitude during paleozoic epochs."[1]

F. H. Bradley reported in 1872[2] the discovery of a few small trilobites of Quebec group age, in the base of the mass of limestones overlying the central granites of the Teton Range in Idaho. These limestones continue up to the typical Carboniferous. The Quebec group is about 400 feet thick, partly argillaceous, blue, and mostly pebbly. Above this group are 600 feet of a magnesian limestone, drab to buff color, which Bradley correlated with the "cliff" limestone of the Mississippi Valley; and over this he found the true Carboniferous.

In August, 1872, Professor Tenney[3] found corals in the Wahsatch Mountains, southeast of Salt Lake City, in a dark bluish limestone, nine or ten thousand feet above the sea. His own opinion that the corals were Devonian was confirmed by R. P. Whitfield, who referred

[1] Meek, B. F.: Remarks on the geology of the valley of Mackenzie River, with figures and descriptions of fossils, etc. Chicago Acad. Sci., Trans., vol. 1, 1869, pp. 61–114, and plates.

[2] Bradley, F. H.: On Quebec and Carboniferous rocks in the Teton Range. Am. Jour. Sci., 3d series, vol. 4, 1872, pp. 230, 231.

[3] Tenney, Sanborne: On Devonian fossils in the Wahsatch Mountains. Am. Jour. Sci., 3d series, vol. 5, 1873, pp. 139, 140.

them to *Zaphrentis* and *Syringopora*, one species of the latter and two of the former. They were the first fossils of the Upper Helderberg period brought to light from the range of the Wahsatch.

Mr. James Richardson,[1] in 1874, reported a few fossils from, and gave a section, of Ballinac Island, consisting mainly of epidotic rocks, diorite, and reddish limestones, carrying well preserved fossils of encrinites, corals, and brachiopods. He considered that the "age of these rocks is either Carboniferous or Permian, most probably the former."

In the third volume of the report upon the geographical and geological explorations and survey west of the 100th meridian, Mr. G. K. Gilbert reported identifications of sections made in the cañons and other regions west of the Rocky Mountains.[2]

In southern Nevada, the rocks of the Spring Mountain Range consist of fossiliferous limestones, with bands of sandstone of Carboniferous age. The strata seem to be conformable throughout the whole vertical range. Again, in the Black Hills, Arizona, sedimentary rocks of Carboniferous aspect were seen overlying a crystalline series similar to those noted in Bowlder Cañon. In Arizona the plateaus consist of Carboniferous limestone (Aubrey limestone, Red Wall limestone). The adjacent ranges show the Tonto sandstones. The exploration of the Colorado plateau system showed that the rocks which compose it range from Eocene Tertiary to the Tonto group, which underlies the Carboniferous rock of the Grand Cañon of Colorado. The next bench below that, named by Powell the "Shinarump Mesa," is capped by a Carboniferous limestone extending from Paria Creek southwest to Aubrey Valley. Through this section the Grand and Marble Cañons have cut their way. After giving a general topographical description, and at the same time referring to the geologic age of the rocks in general, the author adds a series of twenty-one vertical sections, indicating physical characters and thickness, together with fossil remains. These sections are finally correlated in tabular forms, thus giving a view of the whole vertical range. Of the twenty-one sections given, Upper Carboniferous rocks occur in the following:

SECTION V. *Jacob's Pool.*—The rocks consisting of massive sandstones, alternating with gypsiferous cherty clay-shale and chocolate shale and cherty limestones, containing *Productus Meekella, Pseudomonotis, Hemipronitis, Aviculopecten*, etc. Total thickness, 3,750 feet.

SECTION VI. *Kanab Creek.*—Physical character of rocks similar to those of Section V; additional fossils in cherty limestone. *Fenestella* (?) *Spirifera lineatus, Orthis, Chonetes*, etc. Total thickness, 4,200 feet.

SECTION VII. *Grand Cañon.*—Rocks similar to those of Section VI. Total thickness, 4,825 feet.

SECTION VIII. *Aubrey Cliff*, 15 miles southeast of Bill Williams Mountain, Arizona.—Rocks, limestones and yellow-red friable sandstones. Total thickness, 2,100 feet.

[1] Richardson, James: Report on geological explorations in British Columbia. Geol. Survey Canada; Report of Progress for 1873-'74. 1874, pp. 94-102.

[2] Report on the geology of portions of Nevada, Utah, California, and Arizona, examined in the years 1871 and 1872, by G. K. Gilbert, A. M., pp. 17-187 of report upon the geographical and geological explorations and survey west of the one hundredth meridian. 1875.

SECTION IX. *Aubrey Cliff, at Cañon Creek, north Arizona.*—Rocks consist of alternating sandstones, limestones, and shales. Total thickness, 2,360 feet.

SECTION X. *Carrizo Creek, north Arizona.*—Rocks consist of yellow sandstone and dark gray fossiliferous limestones. Total thickness, 1,420 feet.

SECTION XI. *North from and near Camp Apache, Arizona.*—Physical characters similar. Total thickness, 2,260 feet.

SECTION XII. *Spring Mountain, Nevada.*—Total thickness, 2,395 feet.

SECTION XIII. *Ophir City.*—Fossils numerous. Thickness, 1,975 feet.

The occurrence of Lower Carboniferous and Devonian rocks is somewhat questionable, except at Ophir City. The author also reported the discovery at the top of the "Aubrey limestone" of a few fossils suggesting the Permo-Carboniferous of the Mississippi Valley.

The Carboniferous formations of northern Arizona and in the Grand Cañon were classified as follows:

	Feet.
Aubrey limestone—Aubrey Valley, north Arizona	820
Aubrey sandstone—(no fossils except in an intercalated limestone below the middle—a few Coal Measure fossils)	1,000
Red Wall limestone—named from the red appearance of escarpments in Grand Cañon	2,500

The above names were proposed by Mr. Gilbert and Mr. Marvine.

The middle of the Red Wall limestone furnished fossils which Mr. Meek doubtfully referred to Lower Carboniferous. The upper portion, by its fossils, was correlated with the Coal Measures.

It is stated that Mr. Marcou, in the Geology of North America, had called the Aubrey limestone "Permian," the sandstone "Coal Measures," and the Red Wall limestone "Carboniferous limestone or Mountain limestone." Mr. Gilbert referred to the local character of the sedimentation in the Grand Cañon; that 75 miles westward he was unable to correlate the series in detail. Mr. A. R. Marvine, in the same volume, reported the identification of beds between the Black Mesa and the Sunset tanks as "? Permo-Carboniferous."[1]

Mr. A. J. Brown reported in Pancake Mountain a vein of coal which was regarded by the author as probably the first carboniferous coal discovered west of the Rocky Mountains, unless some of the Utah coals belong to this age. This vein is worked at the north end of this range of hills, about 14 miles west of Hamilton. It has a thickness of from 5 to 6 feet, with a dip of 40° to the west.[2]

In 1876, Mr. J. W. Powell presented a classification of the sedimentary rocks of the Plateau Provinces.[3]

In this classification the Aubrey group of Mr. Gilbert is divided into the upper and the lower Aubrey groups. The upper Aubrey group consists of sandstone and cherty limestone of 1,000 feet thickness, seen

[1] Report on the geology of route from St. George, Utah, to Gila River, Arizona, examined in 1871, by A. R. Marvine, pp. 189-225.

[2] Carboniferous coal in Nevada, by A. J. Brown, Trans. Am. Inst. Mining Eng., vol. 3, 1875, pp. 31-33.

[3] Department of the Interior. U. S. Geol. and Geogr. survey of the Territories, 2d division. J. W. Powell, geologist in charge. Report on the geology of the eastern portion of the Uinta Mountains and a region of country adjacent thereto, by J. W. Powell. Washington. 1876.

along Marble, Cataract, Grand, Green, Horseshoe, and Split Mountain Cañons. In its upper part it is "Bellerophon limestone," and in its lower part the "Tampa sandstone."

The lower Aubrey group consists of massive and shaly limestones and sandstones 1,000 feet in thickness.

The "Red Wall group," which is most conspicuous in the Grand Cañon and those adjacent, has a thickness of 2,000 feet, and consists of two distinct members, the upper part of massive saccharoid limestones, the lower of indurated limestones, very irregularly stratified. This division was also recognized in the Uinta Mountains. Below this is a series of sandstones and shales, termed the "Lodore group," and supposed by the author to be the equivalent in the Uinta Mountains of the Tonto group in the Grand Cañon. It forms the base of the Carboniferous formation, but is considered by Mr. Gilbert as probably of Silurian age. The total thickness of the Carboniferous series amounts to 4,460 feet. It rests upon the "Uinta group," which is not seen at Cataract Cañon, but is well displayed in the Uinta Mountains. This formation in turn overlies uncomformably the "Red Creek quartzites," which are believed to be of Eozoic age.

In his geological report on the Santa Fé Expedition, J. S. Newberry reported Carboniferous, Permo-Carboniferous, and true Permian.[4]

The "upper and lower Magnesian limestone" of his report, seen near Cottonwood Creek, he correlated with C and B of the Nebraska City formations, as described by Marcou and Swallow. His correlation was substantially as follows:

Nebraska City.	Swallow.	Meek & Hayden.	Newberry.
C.	Upper Perm.	Permian.	Upper Magnesian limestone.
B.	Lower Perm.	Permo-Carb.	Lower Magnesian limestone.

Mr. Clarence King[1] gave a preliminary account of the results of the survey along the fortieth parallel in 1876.

The area described in this paper extends from the eastern base of the Rocky Mountains to the eastern boundary of California, along the fortieth and forty-first parallels, and is a little over 100 miles from north to south. The object of the paper is "to announce the stratigraphical divisions established in the field and their relation to the Paleozoic subdivisions as established in New York and in the Mississippi Basin."

In the region of the Rocky Mountains the entire Paleozoic series, including Coal Measure beds and strata bearing Potsdam fossils, is found within a section of from 900 to 1,200 feet thickness, the whole entirely conformable and resting discordantly upon the Archean rocks. Going westward the series expands from 1,000 to 32,000 feet. The Rocky Mountain region represented Archean islands and shallows, around and over which sediments were deposited, while to the west-

[4] Report of the Exploring Expedition from Santa Fé, New Mexico, to the junction of the Grand and Green Rivers of the great Colorado of the West in 1859, under command of Capt. J. N. Macomb, 4°, pp. 9–143. Map and plates. Washington. 1876.

[1] King, Clarence: Paleozoic subdivisions on the 40th parallel. Am. Jour. Sci., 3d ser., vol. 11, 1876, pp. 475–482.

ward the Paleozoic ocean deepened over a broad basin, which probably continued to a great depth until it reached the western shore, in longitude 117° 30′. It is a striking fact that no unconformity has been found in the exposures studied between the members of the series, from the Primordial to the summit of the Coal Measures.

The author remarks that the key to the subdivision of the whole Paleozoic is obtained in the Wasatch Range, where he observed a single section, of about 30,000 feet thickness, of conformable rocks, extending from the Permo-Carboniferous strata, conformably underlying the red sandstones of the Trias, down to low exposures of the Cambrian, and he notes in their order, from the base of the Cambrian upward, the important stratigraphic divisions, with their position in the New York scheme.

The lowest division of the series is composed of three prominent terranes, the lowest a series of siliceous schists and argillites, from 800 to 1,000 feet in thickness; next is a series of quartzite and quartzo-feldsitic strata, with limited beds of slate interspersed through it, and dark micaceous zones near the top, the whole in Cottonwood Cañon reaching a thickness of 12,000 feet; the third terrane is a narrow zone of variable argillites, calcareous shales, and thin, slightly siliceous limestones, whose extreme thickness is 75 feet. The only fossils found in this division occur in the shaly zone and are of Primordial type.

The author includes the uppermost beds in the Potsdam epoch of the Primordial period, and considers the whole underlying conformable series as Cambrian down to the Archean. This Cambrian formation varies in thickness, not reaching an exposure of over 100 feet at the extreme east of the field, while in middle Nevada the uppermost thin, shaly member of this terrane in the Wasatch Range is an immense body of dark limestone, 3,000 feet in thickness, carrying Primordial fossils throughout. A list of fossils obtained from the Cambrian series is given.

Above the shales of the Cambrian is a bed of limestone, having a maximum thickness of 2,000 feet in the Wasatch, which the author calls the "Ute limestone," and which has yielded only fossils of the Quebec group. In western Nevada the calcareous shales of the Potsdam and the Quebec limestone have greatly thickened, and represent from 4,000 to 5,000 feet of continuous limestone, yielding fossils of the Lower Helderberg, Niagara, Quebec, and Primordial.

Overlying the Ute limestone is a quartzite from 1,000 to 1,500 feet thick, called by the author the "Ogden quartzite," from its exposure in the Ogden Cañon; it is seen in western Nevada between the Upper and Lower Helderberg horizons, and is included provisionally within the Devonian system, being considered as the probable equivalent of the Schoharie and Cauda-galli grits.

Next above is the "Wasatch limestone," reaching 7,000 feet in thickness in the Wasatch and over 8,000 in middle Nevada. Its lower

1,200 or 1,400 feet belong to the Devonian, having fossils of the Upper Helderberg and Chemung groups. The fossils obtained from the Upper Helderberg horizon are mentioned, and those also from the upper members of the Devonian. The Genesee and Chemung faunas of the Wahsatch limestone are followed by beds whose forms closely resemble those of the Waverly group, but Messrs. Hall and Whitfield considered them Upper Devonian. A gap of barren limestones occurs between the Waverly and this fossiliferous zone, so that the thickness of the Waverly is not definitely known, but in the Oquirrh Range the combined thickness of the Waverly and Subcarboniferous can not be less than 1,000 feet. The remaining 4,000 feet of the Wahsatch limestone contain at intervals beds with distinct Coal Measure forms. The Wahsatch limestone, therefore, represents 4,000 to 4,500 feet of Coal Measures, 1,000 to 1,200 feet of Subcarboniferous and Waverly [Mississippian], and 1,000 to 1,400 feet of Devonian.

Above the Wasatch limestone is found a bed of siliceous material called the "Weber quartzite," from its typical exposure in the Weber Cañon. It is about 6,000 feet in thickness, with a few red sandstones at the base, occasional limited fine beds of shale interspersed at three or four different horizons, and varied by thin sheets of conglomerate and rounded quartz pebbles. It is referred to the middle Coal Measures, though no fossils are found in it in this locality. Six thousand feet is its minimum thickness; it reaches 9,000 to 10,000 feet in the Oquirrh. The great terrane of sandstones, with intercalated shales and conglomerates, forming the body of the Uinta Range, is referred to this member of the series.

Overlying it is a terrane of about 2,000 to 2,500 feet of limestones, chert beds, calcareous and argillaceous shales, and beds of calcareous sandstones and arenaceous limestones, a very variable series, and throughout carrying Coal Measure forms; and above this is another variable terrane of argillaceous and calcareous shales and mud rocks, with limited beds of limestone and sandstone, containing many ripple marks. It contains forms referred by Meek and Hall and Whitfield to the Permo-Carboniferous. Its maximum thickness is 500 feet.

"Aside from the intimation of a local shallowing at the close of the Wahsatch limestone in western Nevada, the evidences are all of deep-water deposits till near the close of the Upper Coal Measure series, when ripple-marked shales make their appearance, and the Permian depositions thereafter seem all to be of a shoal-water character."[1]

In the year 1878 Mr. Clarence King's[2] first volume of the U. S. Geological Exploration of the Fortieth Parallel was published.

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[1] The details of this series of correlations is given in Volumes I, II, and IV of the reports of the "United States Geological Exploration of the 40th parallel, Clarence King, Geologist in charge, Washington, 1877 and 1878."

Vol. I. Systematic Geology, by Clarence King.

Vol. II. Descriptive Geology, by Arnold Hague and S. F. Emmons.

Vol. IV. Part I, Paleontology, by F. B. Meek; Part II, Paleontology, by James Hall and R. P. Whitfield.

[2] "Systematic Geology," by Clarence King, U. S. Geologist, Washington, 1878.

A chart of "Paleozoic subdivisions, Wahsatch and Middle Nevada," is given on page 248, expressing the nomenclature used and the correlation.

Above the Silurian formations the sections were as follows:

Wahsatch section.	Middle Nevada section.
Carboniferous, 15,000 feet..	Permian, 650 feet, clays, marls, and limestones..(absent)
	Upper Coal Measures, limestone.....2,000 feet
	Weber quartzite.....6,000 feet
	Wahsatch limestone.....7000 feet
Devonian, 2,000 feet.....	Waverly. Ogden quartzite, 1,000 feet

Fossils were collected from which correlations were made of Devonian, including Upper Helderberg, Chemung, and Genesee horizons in the lower Wahsatch limestone, of Waverly faunas above, and then of Subcarboniferous forms in the lower 2,200 feet. The upper 4,500 feet were characterized by abundant Coal Measure forms. The Weber quartzite separates the lower from the upper Coal Measure limestone. The upper Coal Measure limestone contains some of the same species seen in the upper part of the Wahsatch limestone, but over 20 species were named that did not occur below the quartzite. "In the Wahsatch and Uinta exposures a series of argillaceous and calcareous shales, with muddy marls, overlying the upper Coal Measure limestones" reached the thickness of 650 feet and carried "from summit to base a characteristic Permo-Carboniferous fauna."[1] The species are Lamellibranchs, several of them identical with Meek's species described in the faunas of Nebraska and Kansas.

In 1879, at a meeting of the Philosophical Society of Washington, Capt. C. E. Dutton announced the discovery of the Permian system in southern Utah.[2]

The discovery was made by C. D. Walcott of well marked Permian fossils in the red sandstone beds at Kanab, southern Utah. The beds were known before, but had not yielded fossils. Heretofore they were regarded as Triassic. In the author's opinion this established the Permian age for the lower part of the red beds of Colorado, Wyoming, the Uinta Mountains, and New Mexico, the variegated marls of Newberry in Arizona and New Mexico, and the Shinarump of Powell (pp. 6, 7).

Mr. C. D. Walcott published an account of the facts in 1880.[3]

[1] Page 245.

[2] On the Permian formation of North America (abstract), Washington Phil. Soc. Bull., vol. 3, pp. 67, 68; Smithsonian Miscellaneous Collection, vol. 20.

[3] The Permian and other Paleozoic groups of the Kanab Valley, Arizona. Am. Jour. Sci., 3d ser., vol. 20, pp. 221-225.

The following table exhibits the essential facts of the paper:[1]

Shinarump conglomerate.		
Unconformity.		
Permian	Upper gypsiferous and arenaceous shales, marls, and limestones	710 feet
	Unconformity.	
	Lower, chiefly massive limestones="Permo-Carboniferous" of Gilbert	145 feet
Unconformity.		
Upper Aubrey limestone		835 feet
Lower Aubrey sandstone		1,455 feet
Red Wall limestone		970 feet
Unconformity.		
Devonian, sandstone and impure limestone		100 feet

Mr. G. M. Dawson[2] in 1879 reported: "Between Kamloops and Little Shuswap Lake, on both sides of the South Thompson, rocks belonging to the Nicola series, with older rocks referable to the Cache Creek group, occur." The occurrence of *Fusulina* in the Nicola limestone series proves it to be of Carboniferous age. This same fossil, along with Foraminifera, named by the author *Loftusia Columbia*, was found in the limestones of Marble Cañon, situated in the section between Lillovet and Bonaparte River.

Mr. Jacob Boll[3] in 1880 reported upon the geology of Texas, saying that the rocks examined appear to be of Permian age, judging by the fossil contents. After giving a description of their mineralogical characters he notes that no coal deposits have yet been found in the Permian. In the south of the Permian region genuine coal is found belonging to the Coal Measures.

Mr. C. D. Walcott[4] in 1880 gave account of his correlations in the Kanab Valley, Arizona, as follows:

The Permian rocks are unconformable with the Shinarump Conglomerate, which is considered as the base of the Mesozoic group. They consist mainly of gypsiferous and arenaceous shales, marls, and limestones, 710 feet in thickness, called Upper Permian, and 145 feet of Lower Permian, consisting chiefly of massive limestones. The Permo-Carboniferous of Mr. Gilbert is the equivalent of the author's (L. P.) "Lower Permian."

The Carboniferous rocks here have a total thickness of 3,260 feet, and are subdivided into three parts, the Upper Aubrey beds (835 feet), the Lower Aubrey (1,455 feet), and the Red Wall limestone (970 feet). The latter consists mainly of red sandstones, calciferous sandrock, and limestones interstratified with layers of chert.

The Devonian beds are made up of sandstones and impure limestones, having a thickness of 100 feet, and are slightly unconformable with the overlying rocks.

Mr. C. A. White,[5] during the year 1880, contributed two papers re-

[1] Am. Jour. Sci., 3d ser., vol. 20, page 223.

[2] Dawson, G. M.: Report on explorations in the southern portion of the interior of British Columbia. Geol. Survey Canada; Report of Progress, 1877-'78, 1879, pp. 1*b*-173*b*.

[3] Boll, Jacob: Geological examinations in Texas. Am. Nat., vol. 14, 1880, pp. 684-686.

[4] Walcott, C. D.: The Permian and other Paleozoic groups of the Kanab Valley, Arizona. Am. Jour. Sci., 3d ser., vol. 20, 1880, pp. 221-225.

[5] Remarks upon certain Carboniferous fossils from Colorado, Arizona, Idaho, Utah, and Wyoming, and certain Cretaceous corals from Colorado, together with descriptions of new forms, by C. A. White U. S. Geological and Geographical Survey of the Territories, F. V. Hayden, Bull. vol. 5, 1880, pp. 209, 221.

The subject of the Permian formation in North America. (Abstract.) Washington Phil. Soc. Bull., vol. 3, pp. 104-105. By C. A. White.

garding these correlations. In the first paper he reported the correlation of "Subcarboniferous, Carboniferous, and? Permian" by the fossils examined, but he thinks "there are no true Permian strata in Colorado, Utah, Wyoming, or Idaho, but may be farther west." In the second paper he accepted the evidence of the fossils ("*Bakewellia*," etc.) reported by Mr. Walcott from the red beds above the Aubrey limestone as proving them to be "correlatives of the Permian of Europe." "It does not follow that the periods were strictly coeval in the two continents."

Mr. Gilbert, in the Philosophical Society,[1] stated that "the contact of these beds is frequently, and perhaps generally, unconformable in the vicinity of the locality where the fossils are found, but there was no such break separating them from the Trias beds above." And Mr. J. W. Powell, discussing the same paper, remarked that "the stratigraphic evidence, as well as the fossils, confirmed the correlation of the beds as Permian from the Great Basin of Uinta and Arizona." The fossils found were substantially the same as those found by Mr. King.

In 1880 Mr. E. T. Cox[2] reported that the rocks about Tucson contain fossils of Devonian, Subcarboniferous, and Coal Measure species. The rocks are semicrystalline, coarse grained, and easily decomposed.

The most exhaustive study of the Paleozoic formations of the Great Basin province of the west was made by Mr. Arnold Hague in the Eureka district, an abstract of the report upon which was published in 1883.[3]

All the identification of fossils for this report were made by Mr. Charles D. Walcott, who prepared a report in 1882 to go with Mr. Hague's report, but subsequently enlarged it, adding results of his study of new collections and of the sections themselves, and published the final results as an exhaustive memoir in 1884.[4]

This Eureka section, Nevada, as reported by Mr. Hague, is 30,000 feet thick, made up of 7,700 feet Cambrian, 5,000 feet of Silurian, 8,000 feet of Devonian, and 9,300 feet of Carboniferous.

The nomenclature and classification adopted for the Upper Paleozoic is as follows:

		Feet.
Carboniferous	Upper Coal Measures (limestone)	500
	Weber Conglomerate	2,000
	Lower Coal Measures (limestone)	3,800
	Diamond Peak quartzite	3,000
Devonian	White Pine shale	2,000
	Nevada limestone	6,000
Silurian	Lone Mountain limestone, etc	1,800

[1] "Permian-Carboniferous overlap in the west," (abstract), by G. K. Gilbert. Washington Phil. Soc. Bull., vol. 3, pp. 105–106.

[2] Cox, E. T.: The Geology of Southern Arizona. Am. Nat., vol. 14, 1880, pp. 541, 542.

[3] Abstract of Report on the Geology of the Eureka District, by Arnold Hague. 3d Ann. Rept. of the U. S. Geol. Survey for 1881–'82, 1883, by J. W. Powell, Director, pp. 241–288.

[4] Monographs of the U. S. Geol. Survey, vol. 8, 1884. Paleontology of the Eureka District, by Charles Doolittle Walcott, pp. 1–298, Pls. I–XXIV.

The boundary line between the Silurian and Devonian is said to be arbitrarily drawn, as the passage from the lower to the upper limestone is gradual, "with poorly defined lithological distinctions, and without, as yet, any paleontological evidences" for making sharp distinctions.[1] But below the Lone Mountain limestone (Silurian) is a plane of unconformity.

The Nevada limestone, although so thick (6,000 feet), offers no lithologic or paleontologic evidence by which to divide it sharply into subdivisions. The fauna is rich and often well preserved, and contains species of the Upper Helderberg, Hamilton, and Chemung formations of New York. While there is recognized a lower and upper fauna, many of the species show a remarkable range, and some of them "have reversed their relative positions in the group as they have been known heretofore. Among the Brachiopods *Orthis tulliensis*, of the Tully limestone of New York State, is found at the summit of the Devonian limestone, and *Orthis impressa*, a Chemung species of New York, at the base, associated with eastern Upper Helderberg limestone species."[2]

The White Pine shale, in the White Pine district, carries a fauna which combines species ranging from Middle Devonian to Lower Carboniferous in the east. The Devonian fauna described contains 102 genera and 225 species, and 94 genera and 79 species of these are identified as common to Nevada and New York. Two species described from the Mackenzie River Basin were identified among the Eureka Devonian fossils. The Carboniferous age of the Diamond Peak Quartzite is determined by the occurrence of a Carboniferous *Productus* in an intercalated limestone stratum 500 feet from its base. The lower limestone contains evidence of proximity of land in the presence of fragments of plants and pulmoniferous mollusks, but the fossils throughout the carboniferous deposits of Nevada are of marine species, and no beds of coal occur in them. The whole series of formations of the upper Paleozoic presents strong contrast to anything seen in the eastern part of the continent, and the stratigraphy as well as the paleontology furnishes striking example of the unreasonableness of attempts to unify the geologic classifications of the world.

Mr. T. B. Comstock[3] in 1883 reported on the rocks of San Juan County, Colorado.

The Devonian rocks of this region are "exposed near the summit of the divide between Bear Creek and Cascade Creek and along a line running parallelwise with the Animas Cañon, forming the cliffs along the side of Lime Creek." The outcrop occurs again at Silverton and near the head of Cunningham Gulch. Although the Devonian is not sharply distinguished from the rocks below, the fossils in the upper part of the limestone point definitely to a Devonian horizon.

[1] Abstract of report, etc., p. 265.

[2] Walcott: Paleontology of the Eureka District, p. 4.

[3] Comstock, T. B.: Notes on the Geology and Mineralogy of San Juan County, Colorado. Trans. Amer. Inst. Min. Eng., vol. 17, 1883, pp. 165–191.

The Carboniferous rocks occur mainly in the southwestern part, along Lime and Cascade Creeks and branches of Mineral Creek. These belong to the Lower Carboniferous, and consist of argillaceous, arenaceous, and calcareous beds, having a thickness of some 1,200 feet, while those of the Upper Carboniferous are made up of red sandstones, 2,000 feet in thickness.

Mr. C. D. Walcott[1] reported identifications in the Grand Cañon as follows:

In the Grand Cañon of Colorado is found the Red Wall limestone of Gilbert forming the base of the Carboniferous series, and at the mouth of the Kanab Cañon about 1,000 feet of the Lower Aubrey sandstone are well exhibited. Evidences of Devonian rocks were noted resting upon the Tonto group (Cambrian), but in some places they were not recognized at all, and where they were seen they did not exceed 100 feet in thickness.

Mr. Frank Springer[2] reported that Burlington geologists, contrary to the ideas of others, have been inclined to divide the Burlington limestone into two parts upon paleontological evidence. This view is further demonstrated by finding a similar occurrence in Lake Valley mining district in New Mexico, thus showing its extended range.

Mr. A. C. Peale[3] in 1885 placed on record the first positive identification of Devonian strata in the Rocky Mountain region of Montana. Fossils were collected by the Hayden survey in 1872 from several localities in the Territory which Mr. Meek found to have a Devonian aspect, but he regarded them as belonging to the Lower Carboniferous, as they contained no strictly Devonian types of corals, crinoids, or lamellibranchs. The author visiting the region in 1884, in company with Dr. Hayden, obtained a collection of fossils which he submitted to Mr. Charles D. Walcott,[4] who identified them as undoubtedly Devonian.

Mr. Walcott says:

> Of the twenty-three species of fossils given in lists 1 and 2, twelve are identical with species occurring in the Upper Devonian of the Eureka district, Nevada. Of the others, two are Upper Devonian species in New York State, and *Athyris hirsuta* occurs at the base of the Carboniferous in the Eureka district.

The remaining forms resemble closely those of the Lower Carboniferous of the Eureka district.

Mr. A. McCharles[5] gave account in 1887, of the occurrence of Devo-

[1] Walcott, Charles D.: Pre-Carboniferous strata in the Grand Cañon of the Colorado, Arizona. Am Jour. Sci., 3d ser., vol. 26, 1883, pp. 437-442, 484.

[2] Springer, Frank: On the occurrence of the lower Burlington limestone in New Mexico. Am. Jour. Sci., 3d ser., vol. 27, 1884, pp. 97-103.

[3] Peale, A. C.: Devonian strata in Montana. Science, vol. 5, 1885, p. 249.

[4] Two lists of the fossils prepared by him are given, including in the first, *Discina lodensis* Hall (?), *Streptorhynchus chemungensis* Conrad, *Orthis Vanuxemi* (?) Hall (?), *Chonetes mucronata* Hall, *Productus speciosus*, *Spirifera disjuncta*, etc., and in the second are *Streptorhynchus chemungensis* Conrad, *Rhynchonella Horsfordii* Hall (?), etc.

[5] McCharles, A.: The footsteps of time in the Red River Valley, with special reference to the salt spring and flowing wells to be found in it. Manitoba Hist. and Sci. Soc., Trans., No. 27, 1887, p. 18. Description of occurrence of Archean, Ordovician, Silurian, Devonian, Cretaceous, and Quaternary.

nian and other Paleozoic formations in the valley of the Red River, British America. In the western part of the Red River Valley occurs a narrow belt of Devonian rocks, but their exact extent is not yet known. Devonian fossils belonging to the lower part of the system were found in river bowlders, probably transported from a distance by ice.

CHAPTER XI.

THE ACADIAN PROVINCE: THE CORRELATIONS AND CLASSIFICATIONS OF THE UPPER PALEOZOIC FORMATIONS IN THE ACADIAN PROVINCE.

The name "Acadian province" is applied geologically to the territory including the New England States, and the maritime provinces of Canada, i. e., Nova Scotia, New Brunswick, Cape Breton, and Prince Edward Island. Although at certain periods of geological time this region was little other than the northern extension of the great Appalachian province, it may be considered as distinct during the Devonian and Carboniferous ages. Its western limit may be arbitrarily fixed as the Green Mountains and the elevated hills just east of the Hudson River. The name is an adaptation of Sir William Dawson's term "Acadia."[1] The rocks under consideration find their typical representation in the region described in the "Acadian Geology."

The Carboniferous and Devonian systems are both represented in this region by extensive deposits. The author had devoted much time to a personal examination of the formations and had made a special study of the plant remains. The second edition presents some slight modification of the first in the classification. The classification is an expression of the general features of the Upper Paleozoic for this part of the continent at the time when it was written (1868). In chapter X and the following chapters, beginning at page 128, the classification and description of the Carboniferous system are given:

a. Upper coal formation, 3,000 + feet.
b. Middle coal formation, 4,000 feet.
c. Millstone grit series, 5,000 to 6,000 feet.
d. Lower Carboniferous marine formation or Carboniferous limestone, variable in thickness, characterized by marine invertebrates (*Productus cora, P. semireticulatus,* etc., with associated beds of gypsum and marls, and in some districts entirely represented by conglomerates.
e. Lower Coal Measures, holding some of the flora and fauna of the middle coal formation, but no productive coal beds; flora differing from that below in the Devonian, upon which it lies unconformably.

These last two divisions, "*e*" and "*d*," are considered as representing the Lower Carboniferous or "Subcarboniferous" of the western geologists.[2]

[1] Acadian geology: The geological structure, organic remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Island, by John William Dawson, etc. 1st edition 1856, 2d edition 1868.
[2] Page 131.

The top of this series is followed by the Triassic, resting uncomformably upon it.[1]

No Permian formations were known to the author, unless possibly the "upper coal formation may synchronize with the Permian of Europe" or "unless represented by the lower part of the sandstones of Prince Edward Island."[2]

Below the Carboniferous the following series of rocks of the Devonian system are reported from near St. John, New Brunswick:[3]

	Feet.
Mispeck group—Shales, sandstones, and conglomerates	1,850
Little River group—Upper part, conglomerates, sandstones, grits, and shales	2,350
Little River group—Middle and lower part, including the *Cordaite* shales in part and the *Dadaxylon* sandstone, shales, sandstones, and flags	2,800
Bloomsbury group—Conglomerates, tuffaceous rocks, and sandstones and shales	2,500

The upper part of the Devonian, correlated with the Chemung and Portage of New York, is reported in the "Gaspé sandstones" of eastern Canada. The typical section of the Carboniferous for this province is the famous South Joggins section along the coast of western Cumberland. It was measured and tabulated by Sir W. E. Logan in 1845; was examined and further reported by Lyell and Dawson in 1852 and 1853. Mr. Logan estimated the total thickness at 14,570 feet 11 inches. Mr. Dawson quotes it (pp. 156, et seq.) in detail. An abstract of the section is as follows:

		Feet.
Division 1.	Upper coal formation	1,617
2.	Upper coal, lower part	650
3.	Middle coal formation, upper part, including 23 coal groups	2,134
4.	Middle coal, lower part, with 49 coal groups	2,539
5.	Upper Millstone grit series	2,082
6.	Middle Millstone grit series	3,240
7.	Lower Millstone grit series	650
8.	Upper part, Lower Carboniferous formation	1,658

Immediately under these are beds of the marine limestone, containing *Productus cora*, etc. This correlation of the section is Mr. Dawson's. In an article read before the Philosophical Society in Philadelphia Mr. J. P. Lesley, having examined the coal field of Glace Bay, objected to the great thickness and to the correlation of the lower measures claimed by Mr. Dawson.[4] Mr. Lesley, chiefly upon lithologic grounds, urged that division 5 of the Joggins section is to be compared with the Lower Carboniferous on Vespertine No. XI of Pennsylvania, and that the deposits below (6, 7 and 8) would be Devonian. Mr. Dawson replied, and the substance of the debate is quoted in this volume,[5] claiming paleontologic evidence for his interpretation and, further, that the plants of the "Chemung of New York, of the Vergent and Ponent of Pennsylvania are decidedly Devonian."

[1] Acadian Geology, 2d ed., p. 128.
[2] Ibid., pp. 19, 126.
[3] Ibid., pp. 503, 504.
[4] Proc. Am. Phil. Soc., Phila., 1862.
[5] Acadian Geology, 2d edition, pp. 142–149.

The correlations of the Carboniferous and Devonian deposits of this Acadian province are based so greatly upon the evidence of plants that I will not here attempt to discuss the merits of the arguments, as the whole subject of the value of fossil plants as means of correlation is being considered by an expert paleobotanist. There are sufficient evidences of marine fossils to make clear that the base of the great series of arenaceous deposits overlying the Silurian in the Northeast is of Lower Devonian age and that the massive beds of limestone underlying the Coal Measures are Lower Carboniferous in age. The details are chiefly matters of classification within the Acadian province, and in any correlations that are made the fossil plant remains must be the chief witnesses.

As in the development of the geology of the Mississippian province, so in the development of that in the Acadian province, the coal beds were the guides to the general correlation, and the details were elaborated by degrees as the formations were studied.

In the following pages I have arranged in chronologic order brief abstracts of the results as they have been published, beginning with the year 1843, the few papers bearing upon this particular province prior to that date having been reviewed in the pages of the first chapter of this essay.[1]

In the year 1843 there appeared in the Quarterly Journal of the Geological Society, vol. 1, two articles on the geology of Nova Scotia and neighborhood, the first by Richard Brown.[2] In this paper the following formations were recognized: Coal Measures, Millstone grit, Mountain limestone, and the "Gypseous series." The latter were identified as occurring below the Carboniferous or Coal Measures. The second article is by J. W. Dawson,[3] and it has maps and sections and a description of the geological characters of the rocks. The Gypseous formation is referred to the Lower Carboniferous. Above them the author reported newer coal formations, and in the Red sandstone of Truro he reported another terrane, which was considered as "newer than any part of the coal formation."

In 1844 Lyell[4] in a short paper announced his opinion that these beds belong to the Carboniferous system.

In 1845 Dawson communicated a paper[5] to the Geological Society of London regarding the geology of Nova Scotia. In this paper the Carboniferous and Devonian formations are defined.

On East River, Pictou, occurs a series of Carboniferous rocks having

[1] In the preparation of these abstracts I have been assisted by Mr. V. F. Marsters, a graduate of Acadia College and now instructor in geology at Cornell University, whose assistance is hereby acknowledged.

[2] The Geology of Cape Breton, pp. 23–26 and 207–213, accompanied by a map.

[3] The Lower Carboniferous Rocks or Gypseous Formation of Nova Scotia, pp. 26–35.

[4] On the probable age and origin of a bed of plumbago and anthracite occurring in mica-schists near Worcester, Massachusetts. Am. Jour. Sci., vol. 47, pp. 214, 215.

[5] On the newer coal formations of the eastern part of Nova Scotia. By Dr. J. W. Dawson. Quar. Jour. Geol. Soc., vol. 1, pp. 322–330.

a thickness of some 5,000 feet and forming the "older coal formation." Above it is a coarse Conglomerate, which is in turn followed by the "newer coal formation." This Conglomerate occurs at New Glasgow, where it dips to the north on West River, and at Mengonish Harbor. Above the Conglomerate occurs a gray fossiliferous limestone, followed by a small bed of coal, whose outcrop can be traced parallel with that of the Conglomerate at Mengonish, having a dip of 25°. Red sandstones are prominent in the lower part and gray sandstones in the upper part of this series. Fossilized wood is abundant, consisting chiefly of *Calamites* and *Lepidodendra*. In Rogers's Hill occurs a Conglomerate apparently identical with the New Glasgow deposit. This is followed by reddish sandstones and shales.

The author gives a coast section of the newer coal formation from Cape John, consisting of reddish sandstones and shale with gray beds and limestones containing ferns, etc., and associated with conglomerates and gypsum. A section is given of French River at Tatmagouche (6½ miles), showing the relation of the newer coal formation to rocks bearing scales of *Holoptychius*, probably of Devonian age. This series is seamed by Trappean rocks.

The newer series of the coal formation was formerly considered as part of the "New Red sandstone," and as including also part of the gypsiferous deposits and the nonfossiliferous red sandstone on the shores of the Bay of Fundy.

The author also adds a section showing the contact of the Carboniferous rocks with the Silurian rocks at Maccara's Brook. Their separation is well shown by the unconformable superposition of the Carboniferous series. This section is also considerably disturbed by intrusive rocks.

In the American Journal of Science[1] Charles Lyell gave an account of "The Coal Formation of Nova Scotia, etc." In regard to its position, he considered it the equivalent of the Carboniferous, but as lying below the productive Coal Measures. The general rocks consist of red sandstone, red marl, with subordinate beds of gypsum and marine limestone, and occasionally coal grits and shales with thin seams of coal.

Mr. Lyell[2] in 1845 discussed the Devonian and Carboniferous systems.

The Hamilton group (7), which the author considered as concluding the Silurian series of North America, ranges chiefly along the eastern and southeastern flanks of the Alleghanies, while the Devonian and Carboniferous series appear farther west. The Devonian rocks of North America the author considered as the equivalent of the Old Red sandstone series of North Britain and Herefordshire.

The coal fields of the United States, consisting of the Appalachian,

[1] Vol. 45, pp. 356–359.

[2] See also Travels in North America in the Years 1841–'42; with Geological Observations on the United States, Canada, and Nova Scotia, in which he defends his determination of the age of the gypsiferous strata as the "Lower Carboniferous." By Charles Lyell. Vol. 2, chap. 25.

the Illinois, and the Michigan fields, the fields in Canada, in New Brunswick, Prince Edward Island, Nova Scotia, and Cape Breton, are of great importance.

The Carboniferous series of Nova Scotia are conveniently divided into three parts: "(1) An upper series, composed of shales and sandstones bearing fossil plants; (2) a middle series, containing the productive Coal Measures; (3) the lower series, consisting of red sandstones and marls, with gypsum and limestones."

The Albion mines, near Pictou, show the greatest thickness of coal (some thirteen yards or more). An admirable section of the whole series is also seen on the South Joggins River, containing numerous fossil plants.

Mr. Richard Brown[1] reported in 1846 the finding, in the Sydney coal field of Cape Breton, in a stratum of arenaceous shale, of erect fossil trees, showing attached rootlets. This stratum, which has a thickness of 5 feet, occurs *below* the main seam of coal. Vast quantities of *Sigillaria* stems, *Calamites*, and *Lepidodendra* were also recognized, as well as a great variety of ferns.

In 1847 the same author reported upon the gypsiferous strata of Cape Dauphin.

Mr. Lyell had shown that the gypsiferous deposits of Nova Scotia and Cape Breton are closely connected with the older Carboniferous series, and are representatives of the Carboniferous limestones of Europe. The author proves this statement by giving a section from Cape Dauphin,[2] in which the gypsiferous deposits are separated from the red granites only by a small deposit of conglomerate and limestones. In this series the Millstone grit is represented by 200 feet in the Sydney coal field, but in places it reaches 2,000 feet. The thickness of the gypsum beds can not be easily ascertained. Their minimum thickness seems to be about 8 feet. No organic remains were noticed in the gypsum.

In 1850 Richard Brown[3] described the section of the lower Coal Measures of the Sydney coal field.

The series is grouped under four divisions, viz:

4. The Productive Coal Measures.
3. A thick deposit of sandstone.
2. Limestone and shales, occasionally containing beds of gypsum.
1. A coarse conglomerate.

The first division, "probably representing the Old Red sandstone of Europe," outcrops "from beneath the Carboniferous limestone, west of Sydney Harbor." The second division, having a thickness of 820

[1] Brown, Richard: On a group of erect fossil trees in the Sydney coal field of Cape Breton. Quart. Jour. Geol. Soc., vol. 2, 1846, pp. 393–396.

[2] Brown, Richard: On the gypsiferous strata of Cape Dauphin, in the island of Cape Breton. Quart. Jour. Geol. Soc., vol. 3, 1847, pp. 257–260.

[3] Brown, Richard: Section of the lower Coal Measures of the Sydney coal field in the island of Cape Breton. Quart. Jour., Geol. Soc. vol. 6, 1850, pp. 115–133.

feet, consists chiefly of shales, sandstones, and limestones, and contains a few brachiopods, fish scales, and plant remains. The third division consists of sandstones, probably equivalent to the Millstone grit of England, and has a thickness of 1,800 feet. The fourth division, containing the Productive Coal Measures, shows on Boulardrie Island a thickness of 5,400 feet, but at other exposures only 1,000 or 2,000 feet. The coal measures begin at Stubbord's Point and end at Cranberry Head. The dip is 60° east, at an angle of 7°. The author adds a tabulated section of each stratum, giving thickness and physical character, after which several sections are appended, showing erect fossil trees from various parts of the section.

In 1852 J. W. Dawson[1] gave an account of his studies of the red sandstones of Nova Scotia.

The author, by further examination, has been enabled to trace the "New Red sandstone" from the mouth of the Shubenacadie River by broken patches nearly to the mouth of the Avon, and at some points it was found in very close contact with Lower Carboniferous rocks. A continuation of the sandstone is seen in the Cornwallis Valley, as at Petite River, of which he gives a cut, showing the black slate, shales, and limestones lying immediately below the red sandstone, and dipping at a high angle. A similar exposure of red sandstone is also seen at Salter's Head, near the mouth of the Shubenacadie River. The shales referred to above are identical with those of Horton Bluff and Noel, both exposures containing *Lepidodendra.*

The New Red sandstones of Shubenacadie River rest unconformably upon shales of Carboniferous age.

In 1853 J. W. Dawson[2] gave an account of the Albert mine, Hillsborough. The author regards these deposits as belonging to "the lower part of the Lower Carboniferous series," and nearly equivalent to "a band of pseudo-Coal Measures occurring in the Carboniferous limestones of Nova Scotia."

A section from the Joggins Coal Measures to the Albert mine is given, in which the rocks consist of gray sandstones, reddish sandstones, limestones, and gypsums, conglomerates, and the calcareo-bituminous shales of the Albert mine. No shales resembling those of the Albert series have yet been recognized in the higher members of the Carboniferous system. Fish remains are abundant in the Albert shales. The plant remains, though rare, bear very close resemblance to those of Horton's Bluff.

The shales in contact with the coal are much contorted and folded. No *Stigmaria* were seen. Underclays were noticed as associated with the coal. The coal bed has a general dip of N. 15° E. The peculiar position of this deposit is explained by faulting. Concerning its origin,

[1] Dawson, J. W.: Additional notes on the red sandstones of Nova Scotia. Quart. Jour. Geol. Soc., vol. 8, 1852, pp. 398-400.

[2] Dawson, J. W.: On the Albert mine, Hillsborough, New Brunswick. Quart. Jour. Geol. Soc., vol. 9, 1853, pp. 107-114.

it may have originated, first, "from a hardening of bitumen," or, second, by the "bituminization of woody matter under continued pressure."

In 1853 Dr. Dawson[1] reported upon the South Joggins as follows:

In this region is represented a series of rocks, 14,000 feet in thickness, extending from the "massive limestone of the Lower Carboniferous series to the top of the Carboniferous formation."

The author gave a detailed account under twenty-nine divisions of a section in the middle of the formations, some 2,800 feet in thickness. The rocks consist of shales and clays containing plant remains, black carbonaceous shales intercalated by thin beds of coals, and sandstones showing ripple-marks and erosive effects previous to the deposition of the superimposed strata. Trunks of trees in situ, covered with *Spirorbis*, were found embedded in these sandstone strata, which contained *Calamites* and *Sigillaria*. *Stigmaria*, *Cypris*, and *Modiola* were quite numerous in the underclays. Some new facts are noticed showing the relation of *Stigmaria* and *Sigillaria*, and attention is called to the occurrence of *Coniferous* trees, *Calamites*, and *Poacites*, together with animal remains, consisting of scales, teeth, jaws, spines, and coprolites. An abstract is added of Mr. Logan's section of South Joggins Coal Measures. (See p. 239–241.)

Messrs. Poole[2] (Henry) and Dawson (J. W.) in 1854 compared the Albion Coal Measures with the section at the Joggins.

The thickness of the Albion Measures varies. While, according to Mr. Logan, the Joggins section showed seventy-six coal seams aggregating 44 feet, and Mr. Brown's section at Sydney, thirty-one seams showing 37 feet, at Pictou there are only two seams 60 feet in thickness. At the Albion mines the argillaceous beds are very thick, while the sandstones and shales seen at the Joggins and Sydney are absent. The coal beds with their associated rocks seem to be unconformable with the coal formation immediately below. This is explained by unequal deposition.

In the Albion mines occurs a thick, reddish conglomerate above the Coal Measures, which has no equivalent in the other mines of Nova Scotia. Its outcrop extends across the valleys of East, Middle, and West Rivers, Pictou, and dips toward the north. This is considered as the base of the "Newer Coal Formation."

A detailed account of the great bed is added.

In 1856 Mr. Dawson[3] gave his views regarding the classification of the rocks of Nova Scotia in a paper before the American Association.

Nova Scotia is occupied by rocks of the Silurian, Devonian, and Carboniferous series, and sandstones superseded by traps. The Carbon-

[1] Dawson, J. W.: On the Coal Measures of the South Joggins, Nova Scotia. Quart. Jour. Geol. Soc., vol. 10, 1854, pp. 1–42.

[2] Poole, Henry, and Dawson, J. W.: On the structure of the Albion Coal Measures. Quart. Jour. Geol. Soc., vol. 10, 1854, pp. 42–51.

[3] Dawson, J. W.: On the parallelism of the rock formations of Nova Scotia with those of other parts of America. Am. Assoc. Proc., vol. 10, Pt. 2, 1856, pp. 18–25.

iferous rocks are especially well developed and lie unconformably upon the Devonian rocks. The author proposes to outline the equivalency of these Canadian geological changes and formations with those of the American Paleozoic and Mesozoic in the United States.

After enumerating instances of *modern changes of level* evidenced by submerged trees and stumps in situ, found along the Bay of Fundy and near Fort Lawrence, and probably connected with those in progress in Newfoundland, Prince Edward Island, and the coast of New England, together with an outline of the distribution of bowlders and direction of transportation, he described the New Red sandstone immediately underlying the above series, which are well developed in Nova Scotia and Prince Edward Island, the latter not associated with traps.

The Carboniferous series was described in descending order under five stratigraphic divisions.

(1) "Upper or New Coal Formations," consisting of several thousand feet of sandstones, shales, gray beds with fossil plants, but without workable coal or massive limestones.

(2) The "Productive Coal Measures," presenting three different types of structure; (*a*) a large number of alternating beds of coal and stigmaria under clays; (*b*) the coal accumulated in a few large seams, but destitute of marine limestone and with erect trees; (*c*) presenting the aspect of the first series, but without coal and its accompaniments.

(3) A very thick series of "gray and red sandstones," barren of coal plants, corresponding in part to the "Millstone grits" of England and the "Conglomerates" of the Appalachian and Western coal fields.

(4) The "gypsiferous series," consisting of red sandstones, red and green marls, limestones with fossils, and beds of gypsum; this series is wanting in the Appalachian, but is well developed in the West and South. It was noted that when the Carboniferous beds of limestone approached the older ridges of rocks the limestones diminished and were replaced by conglomerates marking ancient sea beaches, while the deposition of limestone took place in deeper waters, thus presenting an analogy to similar facts observed in the United States.

(5) At the base of the system occur "estuary deposits" of dark calcareous shales and sandstones, with coal plants and fish scales, to which series the author refers the fish-bearing shales of the Albert mine in New Brunswick.

He noted the great similarity of the coal flora of Nova Scotia to that of the Southern and Western States and of England, while the marine fauna seemed to be more closly allied to that of western Europe.

The features of the Devonian and Silurian rocks were outlined. Before the dawn of the Lower Carboniferous period violent disturbances had occurred, elevating and fracturing the rocks. The first fossiliferous beds of great thickness were supposed by Prof. Hall to belong to the Clinton and Oriskany sandstone of New York. In some parts the organic life is remarkably like that of the English Upper Ludlow. These

beds, occurring about the horizon of the Niagara group, are interstratified with beds of greenstones, the whole series being cut by dikes, similar to regions of the same age in New England. The older Silurian rocks consist of nonfossiliferous rocks made up of quartzites and clay slates of great thickness, passing in places into mica, chert, and gneiss, destitute of calcareous, magnesian, and metallic minerals, with the exception of iron pyrites, but including no representative of the Silurian limestones of the United States and Canada, though occurring but a short distance from the Province of New Brunswick.

Isaac Lea,[1] in 1859, compared the "Trias" formations of the eastern border of the United States with the older rocks of Prince Edward Island.

Mr. Dawson, in referring to the older rocks of Prince Edward Island, had said that they "either belong to the top of the Carboniferous system or to an overlying deposit of the Permian or Triassic age." Mr. Lea remarked that the rock in the bed of Deep River, North Carolina, formerly considered by Prof. Emmons as Trias, was in 1856 by him divided into two groups, Permian and Trias. He considered that the Chatham series of North Carolina, the Newark series of New Jersey, and the Greenfield series of the Connecticut Valley represent one epoch, the Permian. The Groynedd series and that of Phœnixville are evidently of the same horizon with the above mentioned. Prof. Emmons agrees with Mr. Lea in referring these rocks to the Permian epoch, identified as they are in North Carolina by the same Saurian forms, plants, fish scales, and the *Posidonia*.

Charles H. Hitchcock,[2] in 1860, made the following correlations of the coal beds of New England:

By means of the fossil plants Mr. Lesquereux had been able to systematize the Carboniferous coals. From comparison of his identifications Mr. Hitchcock concluded that the New England coal basins of Wrentham, Valley Falls, Portsmouth, and Newport, Rhode Island, belong to the lower series, probably below the Mahoning sandstone, and if the upper Coal Measures of other basins were ever deposited there they have been obliterated by denudation.

In a letter to Mr. B. Silliman, jr., Mr. O. C. Marsh[3] corrected a mistaken report that the Saurian vertebræ from Nova Scotia (discovered by Marsh in 1855) had been recently found by Agassiz. Mr. Marsh had postponed announcing the discovery, hoping to obtain further remains, but failing to do so, makes it public in this letter, saying that he found the bones beneath 5,000 feet of coal strata; that they resemble the vertebræ of an Ichthyosaurus; and he proposes for the species the name *Eosaurus Acadianus*.

In 1863, in the "Geology of Canada," the Devonian system was recog-

[1] Lea, Isaac: On Age of Trias of Eastern United States. Phila. Acad. Sci., Proc., vol. 10, 1859, pp. 90-92.

[2] Hitchcock, C. H.: Synchronism of Coal Beds in the New England and Western United States Coal Basins. Am. Assoc., Proc., vol. 14, 1860, pp. 138-143.

[3] Marsh, O. C.: On the Saurian Vertebræ from Nova Scotia. Am. Jour. Sci., vol. 33, 1862, p. 278.

nized by Logan in Canada West. Acknowledgments were made of the services of James Hall in tracing out in 1856 with Mr. Murray the boundary of the Upper Devonian rocks in a part of the western peninsula.

In the report[1] Logan recognized the Oriskany, Corniferous, Hamilton, Portage, and Chemung formations of the New York system. Reference is also made to the correlation of the higher Carboniferous rocks in Michigan and their relation to these Devonian rocks.

The Oriskany sandstone is reported from Waterloo, on the Niagara River, and extending westward at Oneida and North Cayuga, but is not recognized beyond the township of Windham. It is from 6 inches to 25 feet thick, but is frequently missing between the Waterlime and Corniferous formations.

The Corniferous formation is estimated at 160 feet. It presents various characters, cherty limestone, calcareous shales, light or dark, bituminous and hydraulic beds being reported at different localities.

A series of shales and shaly limestones is reported as "Hamilton formation." At Bosanquet the following section is seen:

	Feet.
Gray Encrinal limestone	2
Soft shales	80
Solid Encrinal limestone	2
Gray calcareous shales (*Spirifer mucronatus*)	4
Gray calcareous beds	25

At Austin Mill, 50 or 60 feet below the Encrinal limestone, occurs a solid arenaceous limestone, 7 inches thick, under which are black shales doubtfully referred to the Marcellus shales. The soft marly beds, with thin beds of limestone intercalated, containing *Spirifer mucronatus*, are also referred to the Hamilton formation. The thickness of the formation is estimated at 300 feet. In several localities (Cape Ipperwash, Kettlepoint, Bosanquet) a black, fissile, bituminous shale, 12 to 14 feet thick, weathering gray and holding spheroidal concretions, is correlated with the Genesee shale. The author expresses the opinion that the 363 feet of rocks in Michigan called "Chemung" and "Portage" by Winchell lie above the "Black shale."

In a paper[2] describing his studies of the Coal Measures on the coast of Cape Breton, J. P. Lesley[3] called in question the reported thickness of the Coal Measures. He said: "The geologists, Sir William Logan, Sir Charles Lyell, Professor Dawson[4] and other geologists who have described the Coal Measures of Nova Scotia and New Brunswick agree in assigning to them an almost incredible thickness."

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[1] Geological Survey of Canada: Report of progress from its commencement to 1863; illustrated by 498 wood cuts in the text. Montreal, 1863, 8vo., xxvii and 983 pp., by W. E. Logan.

[2] This discussion is referred to at the opening of the present chapter. The original papers were published in the American Philosophical Society Proceedings.

[3] Lesley, J. P.: Section of Coal Measures on the Cape Breton coast. Am. Phil. Soc. Proc., vol. 9, 1863, pp. 93–109, 167–170; Am. Jour. Sci., 2d ser., vol. 36, pp. 179–196 (Revised).

[4] Dawson, J. W.: Note on Lesley's paper on the Coal Measures of Cape Breton. Am. Phil. Soc. Proc., vol. 9, 1863, pp. 163–167, 208, 209.

The section of which Mr. Lesley gave a full account is situated between Luigan and Great Glace Bays on the east coast of Cape Breton. It includes the "Productive Coal Measures" of Cape Breton with five workable beds. In the North Sydney measures Mr. Brown has recorded thirty-four seams, but only four of them are workable, varying from 3 to 7 feet in thickness.

The author concluded that Mr. Brown's estimate of 10,000 feet for the Productive Coal Measures is too great. He added an analysis of Logan's "Joggin's section" having "a vertical thickness of 14,570 feet," and containing "seventy-six beds of coal, and ninety distinct Stigmaria underclays," and "twenty-four bituminous limestones."

In Dr. Dawson's reply he took exception to Mr. Lesley's views under the following heads: (1) It is not safe to make comparisons between the greatly developed Coal Measures of Nova Scotia and the thinner beds of the west; (2) The Coal Measures were deposited on the sides of the Silurian and Devonian hills in separate areas and not over the hilltops; (3) It is useless to make comparison between even the Joggins section and those of Wallace and Pictou. "A fortiori, detailed comparison with Pennsylvania and more distant localities must fail;" (4) "The whole of the Coal Measures in the Joggins section belong to the Upper and Middle Coal Measures. It is quite incorrect to indentify No. 6 of Logan's section with the Lower Coal Measures;" (5) "The flora is identical throughout the whole thickness of the Middle Coal Measures;" (6) The flora of the gypsiferous deposits and marine deposits of Nova Scotia is certainly Carboniferous, while the flora of the so-called "Chemung" is as decidedly Devonian.

In a letter[1] to the editors of the American Journal of Science, Dawson combats the action of some geologists in referring certain rocks, hitherto regarded as Upper Devonian, to the Carboniferous period, and gives facts derived from his own study of fossil plants which, he thinks, bear strongly against this view. Of all the species of Devonian land plants that have come under his observation, both of America and Europe, only an exceedingly small number are Carboniferous. In the Carboniferous system, in spite of numerous differences between the plants of the lower, middle, and upper divisions, "there is a grand unity of the fossil flora throughout." But when the Devonian is reached, there are new genera and a distinct assemblage of species. The author speaks of but one exceptional case, which is that of beds at Akron and Richfield, Ohio, regarded as equivalent to the Upper Devonian of New York. In a small collection from these places he saw two species which were identical with Lower Carboniferous forms, while the others, though having a Devonian aspect, were not identical with any New York or Gaspé species.

While it may be, he says, that in the Paleozoic period the range in time of marine forms exceeded that of terrestrial life, it would be an

[1] Dawson, J. W.: On American Devonian. Am. Jour. Sci., vol. 35, 2d ser., 1863, pp. 309-311.

anomaly to have a stratum of rocks include one flora and a part of another almost entirely distinct and characteristic of another period. But he thinks the gap greater in Eastern America between the Devonian and Carboniferous periods than it is elsewhere. The Ohio plants mentioned indicate passage beds, but in that case the author would suppose them to be newer than the Chemung group, and wanting or represented by barren deposits in New York.

In another paper,[1] which is copied into the American Journal of Science, from the Quarterly Journal of the Geological Society (with the exception of Part II, containing descriptions of species, which is omitted), Dr. Dawson speaks of the large number of species of the Devonian flora, more than 60, which he has had the opportunity of examining, from the collections of Messrs. Matthew and Hartt, Professor Hall, and Professor Hitchcock, and notices the geological character of the localities in which they are found, with lists of the fossils found in each. The localities are in the States of New York and Maine, in Canada and New Brunswick. The rocks of St. John in New Brunswick, from which a copious flora has been obtained, are described in detail, and a summary given of the deposits.

At the close conclusions are drawn from the observations recorded in the preceding part of the article as follows: (1) That the Devonian flora resembles the Carboniferous in its general character in the prevalence of Gymnosperms and Cryptogams, and the generic types of the two periods are nearly the same. Of thirty-two genera described, only six are peculiar to the Devonian period, though some are much better represented in the Devonian than in the Carboniferous, and several Carboniferous genera are wanting in the Devonian. (2) A majority of the species of the Devonian do not reappear in the Carboniferous, but a few species extend from the Upper Devonian into the Carboniferous, establishing a passage from the earlier to the later flora. But this connection is less close than that between the Lower Carboniferous and the true Coal Measures. (3) A large part of the difference between the two floras is owing to the different geographical conditions. (4) The conditions were less favorable to the preservation of plants in the Devonian than in the Carboniferous period. (5) The Devonian flora was not of lower grade than that of the coal period, but we find in it more points of resemblance to the floras of the Mesozoic period and of modern tropical and austral islands than in that of the true coal formation. (6) The *facies* of the Devonian flora in America is very similar to that of the same period in Europe, but the number of identical species in the coal fields of the two continents is greater. These conclusions do not differ materially from those of Goeppert, Unger, and Bronn, after consideration of the Devonian flora of Europe.

In a letter from Leo Lesquereux[2] the following points regarding cor-

[1] Dawson, J. W.: On the Flora of the Devonian period in Northeastern America. Am. Jour. Sci., vols. 35, 36, 1863, pp. 311–319, 41, 42.

[2] Lesquereux, Leo: On the character of the Millstone grit or Subcarboniferous conglomerate in the far West. Am. Phil. Soc., Proc., vol. 9, 1863, pp. 198–204.

relations of Nova Scotia formations are recorded, reviewing the paper above mentioned:

The first section described is situated 14 miles southwest of Fayetteville, in Washington County, Arkansas, and the second was made from the base to the top of the Boston Mountain, in Johnson County. The Millstone Grit Measures seem more persistent and greater in thickness in Arkansas than in the East, and may be greater than has been made out at Horsehead Mountain. From an examination of these sections, the author thinks that the "Nova Scotia basin is a separate member of our great American coal field," and agrees with Dawson that the flora of both countries is apparently the same. But while Dawson finds abundance of coniferous trees, and English geologists find them abundant in the Coal Measures of England, the author claims, in comparing sections of the East and West, that he finds none in his western section. The increased thickness of the sandstones and shales of the eastern deposits, in comparison with those of the West, and the local variations, the author accounts for by the fact that they are *shore* formations, and hence Dawson's sixth objection is not applicable to western deposits. The author in conclusion shows from Dawson's own statements that there is a gradual change throughout the flora of the Coal Measures, and even from Devonian to typical Carboniferous plants, while Dawson would claim there was a much less intimate connection between Upper Devonian and Lower Carboniferous than is apparent throughout the whole Carboniferous system.

G. F. Matthew[1] in 1865 commented on the "Fern ledges" of Lancaster, New Brunswick, in the following way:

The Middle and Upper Devonian rocks are known under three groups: The "Bloomsbury group," No. 4 of Dawson's list; "Little River group," Nos. 2 and 3, Dawson's list; "Mispeck group," No. 1, Dawson's list. These groups, lying unconformably on the Silurian, and in some places upon the Laurentian rocks, occupy a great part of the district towards the head of the Bay of Fundy. They contain numerous plant beds, and seem to be connected with those of Perry, Me. St. John County is largely covered by Devonian rocks, and detached pieces occur throughout Charlotte County. Dawson says that "the plant remains combine the features of the Hamilton and Portage groups." Professor Hitchcock also reports Devonian areas in northern Maine. The thickness of the Devonian sediments below the plant beds is about 5,000 feet.

The Lower Carboniferous rocks extend over Kings, Albert, and Westmoreland Counties, being about 100 miles in length, with varying width. They also occur along the Kennebeccasis Bay and in detached areas along the Bay of Fundy. They consist mainly of limestones, shales, and sandstones, associated with pyroschists resembling those

[1] Matthew, George F.: On the Devonian plant locality of the "Fern ledges," Lancaster, New Brunswick, with a detailed section and notes on the fossils.

Observations on the Geology of southern New Brunswick, by L. W. Bailey [et al.], pp. 131–140. Fredericton, 1865.

of the Albert mine, and yielding *Lepidodendrons*, *Cyclopteris*, and other Carboniferous forms. The Carboniferous rocks, consisting of gray sandstones and shales, cover the central and eastern part of New Brunswick. There is a slight nonconformity between the Lower Carboniferous and the Coal Measures of about 15°. They also appear in Westmoreland County, and extend along the north shore of the Bay of Fundy.

Dawson[1] in 1866 gave an interesting discussion of the conditions of deposition of coal, in which the classification and thickness of the Acadian formations are stated.

According to the estimates of Logan the Coal Measures at the Joggins are 14,570 feet in thickness, the deposits of Pictou 16,000 feet, and those of Cape Breton, according to Mr. Brown, 11,000 feet, excluding the Lower Carboniferous deposits.

The author arranged the Carboniferous series in the following groups:

(*a*) Upper coal formation, consisting of sandstones, shales, conglomerates, and thin limestones, bearing numerous plant remains.

(*b*) The middle coal formation, or Coal Measures proper, containing all the coal beds, but no limestones. Plant remains are quite abundant.

(*c*) The "Millstone grit," including the sandstones and shales, lying just below the Coal Measures. It contains the trunks of coniferous trees.

(*d*) The Lower Carboniferous marine formation.

(*e*) The Lower Carboniferous Coal Measures, or Lower Coal Measures. "The last two groups are equivalent to the 'Subcarboniferous' of American geologists." But the author did not find in Nova Scotia any reason for applying any more explicit term than "Lower Carboniferous."

There seem to have been three distinct conditions of deposition during the middle coal formation: (1) Deposition of coarse sediments, alternating with clays, sands, and gravels; (2) precipitation of limestone and growth of corals and shellfish; (3) deposition of fine sediments and accumulation of vegetable matter between bituminous limestones and shales.

The condition of the Devonian rocks shows that there was considerable igneous action at the close of the Devonian period, and before the deposition of Carboniferous rocks, from the fact that they are partially metamorphosed by the effects of injection of igneous matter.

The author thinks that the time of greatest depression was during the deposition of limestones; the time of greatest elevation took place during the formation of the coal beds, and the condition for the formation of the "Millstone grit" was intermediate. These remarks apply to New Brunswick as well as to Nova Scotia. The local differences are of the same character as those of the Appalachian and western fields and those of Great Britain.

There is marked evidence of a disturbance during the Carboniferous period, producing synclinal and anticlinal folds, similar to those of the

[1] Dawson, J. W.: On the conditions of the deposition of coal, more especially as illustrated by the coal formation of Nova Scotia and New Brunswick. Quart. Jour. Geol. Soc., vol. 22, 1866, pp. 95–166, plate.

Devonian period, and hence causing irregular deposition and local denudation, a condition very common in Nova Scotia.

The author has been unable to account for the separation between the lower and middle coal formations, but thinks "it may include much of the 'Lower Coal Measures' of Rogers in the Pennsylvania coal field." He maintains that the order of sequence noted in the Carboniferous period has its parallel in each of the other periods of the Paleozoic age, "each of which was characterized by a great subsidence and partial reelevation, succeeded by a second very gradual subsidence."

A detail account was given of the stratification of the South Joggins section and discussed under three divisions:

(1) Logan's section, 1,617 feet in vertical thickness on the shore of Shoulie River.

(2) Ragged Reef and vicinity, 650 feet in thickness, forming the lower part of the upper coal formation.

(3) From Ragged Reef to McCavins Brook, 2,134 feet in thickness, including 1,009 feet of sandstone, 912 feet of shales and clays, and 22 coal beds. This is probably equivalent to the "Upper Coal Measures" of American geologists and includes also the "Middle Coal formation."

In 1867[1] the same author announced some recent discoveries in the Acadian provinces of British America. He said the discovery of a land flora in a series of rocks near St. John, New Brunswick, underlying unconformably the Lower Carboniferous, has proved the presence of rocks of the Devonian age. For this discovery we are indebted to Messrs. Matthew, Hartt, and Bailey. With the flora were found six species of insects which have been described by Mr. Scudder. They are the first insects found below the Carboniferous. Below the Devonian shales and sandstones occurs a thick series of rocks embracing a fauna of Silurian aspect. This division is termed the "Acadian series." The labors of Mr. Davidson, Mr. Hartt, and the author have brought to light fossils closely allied to Permian species.

The announcement of the correlation of Devonian rocks in Maine was made by C. H. Hitchcock[2] in 1867.

A series of slaty deposits in Washington County, Maine, was referred to the "Lower Helderberg" and "Upper Devonian." In the northern part of the State occur the representatives of "(*Oriskany*) Cauda-galli grit" and other fossiliferous zones of Devonian strata.

A reconnaissance made for the government of New Brunswick[3] by Messrs. Matthew and Bailey, in connection with C. F. Hartt, brought to light a wide distribution of Devonian rocks along the shore of St. John River. After describing the occurrence of the lower metamorphic

[1] Dawson, J. W.: On recent geological discoveries in the Acadian provinces of British America. Am. Assoc. Proc., vol. 16, 1867, pp. 117–119.

[2] Hitchcock, Charles H.: Explanation of a geological map of Maine. In Am. Ass. Proc., vol. 16, 1867, pp. 123.

[3] Matthew, George F., and Bailey, L. W.: Remarks on the age and relations of the metamorphic rocks of New Brunswick and Maine. Am. Ass., Proc., vol. 18, 1869, pp. 179–195.

rocks, the authors gave a detailed account of the Siluro-Devonian formation occurring on each side of the granite ridges to the south of the Carboniferous. These sediments they divide into a lower and upper division, each of which is subdivided into two series. These occur chiefly in St. John, Charlotte, and Queen Counties. A gradual passage from the granites to undoubted Siluro-Devonian rocks is well exhibited in the Nerepis Valley and on the eastern shore of the St. Avise River, Charlotte County. A similar series occurs in Perry, Maine. The granitic rocks at the base are not considered as Siluro-Devonian.

The lower division consists of two series: First, limestones, felsites, etc.; second, gray sandstones, black slates, and *Dadoxylon* sandstones. These are followed by a series known as the "Mispec rock," consisting of diorites, conglomerates, and slates, which are followed by the green "Cordaite" slates.

The authors state that further investigations indicate that the Nerepis granites, formerly considered as Devonian, must be regarded as of Upper Silurian age, if not older.

Mr. Edward Hartley made a report[1] of a part of the Pictou coal field in the year 1870. The region reported upon lies "between the East and West Rivers of Pictou, and extends laterally from Conglomerate ridge, a prolongation of Fraser's Mountain, on the north of New Glasgow, to the Fox-brook Road, between the coal mines and Hopewell Village." The rocks are described under the following divisions:

1. Pre-Carboniferous.
2. Millstone grit.
3. New Glasgow Conglomerate.
4. Productive Coal Measures.

The rocks here called "pre-Carboniferous" were observed by Mr. Dawson, and in his "Acadian Geology" are said to be "probably of Devonian age." They consist of metamorphic rocks, mainly siliceous slates and conglomerates, and in one locality, Waters' Quarry, a limestone of 20 feet thickness. Comparing his section with the classification of the Carboniferous published in Dawson's Acadian Geology, viz, "(5) Lower Coal Measures, (4) Carboniferous limestone, (3) Millstone grit series, (2) Middle Coal formation, (1) Upper Coal formation," the author considered all but the (3) "Millstone grit series" and the (2) "Middle Coal formation" to be wanting; and in some places he found the Devonian rocks followed by the Middle Coal formation without even the Millsone grit.

The section at McLeod's Brook[2] represents 3,773 feet of sandstones and conglomerates; on East River, above Albion mine, 1,402 feet of sandstones; both of these are referred to the Millstone grit. Impure limestone beds are seen in the lower part of the formation in the East

[1] Hartley, Edward: Report on a part of the Pictou coal field. Geol. Survey Canada; Report of Progress for 1866-1869, 1870, pp. 55-107.

[2] Ibid., p. 60.

River section. On the west bank of East River, at New Glasgow bridge, occurs the New Glasgow conglomerate, 450 feet thick. The pebbles are of Millstone grit and Devonian, and in some cases the cementing matter is calcareous. A section of these conglomerates, at Alma Mills bridge, of 1,372 feet, is reported. This conglomerate, intermediate between the Millstone grit and the Productive Coal Measures, is the base of Dawson's Middle Coal formation. Tracing it westwardly it was found in places to lie directly upon altered Devonian rocks.

In describing the Productive Coal Measures the author gives a detailed account of the Measures at the Albion and Acadia mines, in which fourteen coal seams are mentioned, the total thickness of the Albion being 2,452 feet 11 inches. To show the variation in the character of the rocks in this section an account is given of the Forster Pit section. The Productive Measures are situated between three faults: one on the north passing through New Glasgow, one in the west bringing the Devonian series and Millstone grit in contact with the Coal Measures, and the third on the south side of the area. In this area are two synclinal folds running in an east and west direction, and designated as the Albion and Bear Creek synclinals; both are limited by the west fault.

Charles Robb, in 1870,[1] made a report on part of New Brunswick.

The Lower Carboniferous rocks of New Brunswick "lie between the southern boundary of the county of York and the unconformable altered slates to the northwest." They consist mainly of sedimentary deposits derived from the neighboring metamorphic hills. These deposits are occasionally invaded by igneous intrusions. The sandstones are of a reddish color, and at places contain considerable micaceous and calcareous matter. The author considers them to be about 1,000 feet in thickness. No fossils were observed.

The Upper Conglomerate consists of siliceous material, not calcareous, followed by gray sandstones containing *Calamites*, *Cordaites*, and other vegetable remains, with an occasional seam of coal.

The following classification of the Pictou coal field was made by Sir William E. Logan in 1870:[2]

Pre-carboniferous or Devonian....1. Conglomerates, quartzites, and compact slates.

Carboniferous
- 2. Greenish gray and red sandstones, with conglomerates and impure limestones.
- 3. Red coarse conglomerates.
- 4. Productive Coal Measures.

The rocks of the first series form parts of McGregor's and McLellan's Mountains. The author called them "pre-Carboniferous," and assigned them to the Devonian age on the authority of Mr. Dawson, who gave them that position in his "Acadian Geology." The author considered

[1] Robb., Charles: Report on the geology of a part of New Brunswick. Geol. Survey of Canada; Report of Progress for 1866–1869, pp. 173–209, map.

[2] Logan, W. E.: Report on a part of the Pictou coal field. Geol. Survey of Canada; Report of Progress for 1866–1869, 1870, pp. 3–17, map.

them as pre-Carboniferous, but found no direct evidence of their age. He identified them as occupying the same place in the series with similar rocks reported on the west side of East River by Mr. Hartley.

The second series, which he identified with the "Millstone grit" of Dawson's Acadian Geology, and with "Bonaventure formation" of Gaspé, and the "Millstone grit" of England, occurs on the east side of East River in a triangular area, and near the foot of Fraser's Mountain. Thin, impure limestones, carrying fossils, among them *Spirorbis carbonarius*, were noted at McLellan's Brook. For this formation he proposed the name "Grindstone grit."

The third series, named by Dawson the "New Glasgow Conglomerate," has a total thickness of 1,600 feet. It covers the south flank of Fraser's Mountain. In a white arenaceous limestone, 3 miles eastward of New Glasgow, occurring in the midst of a series of sandstones, shales, and other concretionary limestones, was discovered a number of minute coiled shells, referred to a new species of *Spirorbis*, and described by Dawson under the name of *Spirorbis arietina*.

The fourth series, the "Productive Coal Measures," is well represented by a section along McLellan's Brook, between McLellan's and McGregor's Mountains, but the upper part of the series is not shown in this section.

In 1871 Prof. Hitchcock[1] announced the discovery of Helderberg corals in Littleton, New Hampshire. The limestone containing the corals was traced for about 3 miles, and appeared to be duplicated by a synclinal fold. It overlies the metamorphic Quebec group on one side, and probably the Coös group on the other, and appears to be overlaid by a clay slate carrying a few worm trails. The corals were obscure, and were submitted to the examination of E. Billings, of Montreal. He recognized *Favosites basilica* and a *Zaphrentis*. The rock appeared to be identical with the Canadian limestone 55 miles to the northwest, supposed to range from the Lower to the Upper Helderberg.

Messrs. Bailey and Matthew, in 1872,[2] presented their preliminary report on the geology of southern New Brunswick. In this article the Devonian rocks of St. John County, New Brunswick, are described under the following classification:

Bloomsbury conglomerate.—Coarse reddish gray rock, red shales interstratified; thickness 500 feet.

Dadoxylon sandstone.—Sandstone and grits, with dark green shales; 2,800 feet; containing fossils, plants, crustacea, and wings of insects.

Cordaites shales and flags.—Two thousand four hundred feet, containing numerous plant remains.

Mispec conglomerate.—One thousand eight hundred feet.

The Devonian rocks of Lepreau Harbor are separated from those of

[1] Hitchcock, C. H.: Helderberg Corals in New Hampshire. Am. Jour. Sci., 3d series, vol. 2, 1871, pp. 148, 149.

[2] Bailey, L. W., and Matthew, G. F.: Preliminary report on the geology of southern New Brunswick. Geol. Survey Canada: Report of progress for 1870–'71, 1872, pp. 13–240.

St. John Harbor by a ridge of Laurentian gneiss. A similar division was also noted east of the same harbor. "The northern limit of Devonian rocks in the eastern part of St. John County may be traced from Carleton Heights across the harbor of St. John, through the southern part of the city of the same name." They occur again at Little River, and farther west at Black River, near Bloomsbury Mountain; thence south to Milligan's Lake, thence northeast toward Quaco Hills. In the western part of St. John County they overlie the Laurentian and Huronian series, but occupy only isolated patches, which, however, have been traced as far east as Charlotte County.

Reference was also made to the occurrence of sedimentary rocks "at Oak Bay and in the Nerepis Hills, which may correspond to the 'Dadoxylon sandstones' of St. John County." Also in northwest Charlotte occurs a series of argillites and sandstones resembling in appearance the "Cordaites group" of St. John County, but including a greater thickness of arenaceous beds.

The "Perry sandstone group," which is typically represented at Perry, Maine, is also seen at St. Andrews, New Brunswick. Although this sandstone contains plants of the Upper Devonian type, the author is inclined to consider it as lying at or near the base of the Lower Carboniferous, and characterized by an Upper Devonian flora. Similar conditions were also noted at Point Lepreau. The author gave a list of the fossil plants found in the Perry sandstone.

The "Lower Carboniferous rocks" of eastern and central New Brunswick occupy the Belleisle and Kennebeccasis Valleys, Kings County, extending along Petitcodiac River through Albert and Westmoreland Counties, around the margin of the central coal field, through Queen's, York, Northumberland, and Gloucester Counties to Bay Chaleur. Isolated areas also occur in Victoria and Carleton Counties. The "Carboniferous rocks" proper occupy by far the largest territory of any series in New Brunswick. They cover the counties York, Queen's, Sunbury, Kent, and Northumberland. Their most northerly limit is at Bathurst, Bay of Chaleur, the most southerly at Shediac, Westmoreland County. They consist mainly of sandstones, shales, and conglomerates of gray color and coarse texture. A list of the fossil plants of this series was also given.

Mr. L. W. Bailey,[1] in 1872, recorded the occurrence of undoubted Carboniferous rocks bearing plants in the eastern part of Kings County belonging to the Upper or Middle formation. There is also evidence of nonconformity between the Coal Measures and the Lower Carboniferous formation.

Mr. Charles Robb,[2] in 1872, reported that the Carboniferous rocks of northwestern New Brunswick consist mainly of arenaceous shales and

[1] Bailey, L. W.: Report on geological investigations in New Brunswick. Geol. Survey Canada: Report of progress for 1871–'72, 1872, pp. 142–144.

[2] Robb, Charles: Supplementary report on the geology of Northwestern New Brunswick. Geol. Survey Canada: Report of progress for 1870–'71, 1872, pp. 241–251.

gray, yellowish, and purple sandstone, 180 feet thick. They are locally calcareous and arenaceous. Southwest of Miramiche River the calcareous conglomerate is much disturbed by eruptive masses. Reference is also made to the Brighton outlier, which is situated between the north and south branches of Beccaguimac River, and contains Devonian plants. Although fossils of Devonian type have been found in this formation, in its physical characters it resembles the Lower Carboniferous rocks. Other small areas were noted to the northwest in Windsor Settlement.

Dr. Dawson reports the following correlation and classification for Canadian Carboniferous rocks in 1873:[1]

The Carboniferous rocks of Canada lie unconformably upon the Devonian and Upper Silurian formations. The author classifies them as follows:

(1) Horton Bluff series, or Lower Carboniferous Coal Measures, consisting of hard sandstones, calcareous shales, with conglomerate and grit, bituminous shales, and underclays, with plants and coal seams, with fishes and footprints of Batrachians.

(2) Windsor series, or Lower Carboniferous limestone and gypsiferous beds; marine and holding shells of the Lower Carboniferous period, containing limestones, marls, clays, and gypsum.

(3) Millstone grit series, consisting of conglomerate, shales, sandstone, and thin beds of coal, containing Naiadites. Thickness 5,000-6,000 feet.

(4) (*a*) Middle coal formation, and the (*b*) upper or newer coal formation.

The Lower Carboniferous deposits of Gaspé and Bay Chaleur, New Brunswick, consist mainly of sandstones and conglomerate, with few fossils, while in southern New Brunswick the bituminous shales attain a great thickness, as also does the Millstone grit. On Salmon River, West, East, and Middle Rivers of Pictou, the Millstone grit consists of chocolate sandstones and shales holding plants. Beneath the Millstone grit of Pictou, known as the "New Glasgow Conglomerate," occurs a hard sandstone holding fossils, which Mr. Dawson regarded as of Devonian age.

The author gave the following list of equivalents of the divisions proposed for the Canadian rocks, viz:

I.—*Equivalents of the Lower Carboniferous Coal Measures, or Horton series:*

(1) The "Vespertine group" of Rogers in Pennsylvania.
(2) The "Kinderhook group" of Worthen in Illinois.
(3) The "Marshall group" of Winchell in Michigan.
(4) The "Waverly sandstone" (in part) of Ohio.
(5) The "Lower or False Coal Measures" of Virginia.
(6) The "Calciferous sandstone" of McLaren, or "Tweedian group" of Tate in Scotland.
(7) The "Carboniferous slate" and "Coomhala grits" of Jukes in Ireland.
(8) The "Culm" and "Culm Grauwacke" of Germany.
(9) The "Grauwacke" or "Lower Coal Measures" of the Vosges, as described by Schimper.

[1] Dawson, J. W.: Introductory sketch of the geology of the Lower Carboniferous Coal Measures, and Millstone grit, with the equivalent formations abroad. Geol. Survey Canada: Report on Fossil Plants of the Lower Carboniferous and Millstone grit of Canada. Montreal, 1873. Pp. 5–14.

I.—*Equivalent of the Lower Carboniferous Coal Measures, or Horton series*—Continued.

(10) The "Older Coal formation" as described by Eichwald.

(11) The so-called "Ursa Stage" of Heer includes this, but he has united it with Devonian beds, so that the name can not be used except for the local development of these beds at Bear Island, Spitzbergen.

II.—*Equivalents of the Millstone grit are:*

(1) The "Seral Conglomerate" of Rogers in Pennsylvania, etc.

(2) The "Lower Coal formation," "Conglomerate," and "Chester" groups of Illinois (Worthen).

(3) The "Lower Carboniferous sandstone" of Kentucky, Alabama, and Virginia.

(4) The "Millstone grit and Yoredale rocks" of North England and the "Culmiferous rocks" of Devonshire.

(5) The "Moor Rock" and "Lower Coal Measures" of Scotland.

(6) "Flagstones and lower shales" of the south of Ireland and "Millstone grit" of the north of Ireland.

(7) The "Jungste Grauwacke" of the Hartz, Saxony, and Silesia.

The author also gave a short account of the distribution of the Carboniferous rocks in Nova Scotia and New Brunswick. The equivalent of the "Millstone grit" of Logan's section at "the Joggins" has a thickness of 5,972 feet. This series is also found on the flanks of the Cobequick Mountains, and running eastward connects with the Pictou coal fields. Another noted area lies south of Mira's Basin, which is called the "Horton Bluff series," and similar outcrops were noted at Walton, Noel, Windsor, and Shubenacadie.

The "Millstone grit series" is also well developed on Salmon River, West, East, and Middle Rivers, Pictou. Beneath it, in Pictou County, occur hard sandstones holding obscure plants which the author regards as of Devonian age. Carboniferous rocks similar to those of the "Horton Bluff group" were noted in Antigonish County, and also in Cape Breton.

Mr. Alexander Murray reported in 1873[1] that the boundary of the Carboniferous area of Newfoundland "may be traced from a little north of Cape Ray along the northwest flank of the Long Range of Laurentian Mountains up to the head of St. George's Bay, where it was supposed to cross over and, making a further stretch beneath the marshes to the north, finally sweeps around in a westerly direction and crosses Harry's Brook below Spruce Brook," where it rests on Lower Silurian rocks. It is there interrupted by the Indian Head range, but farther west it again comes to view on the coast of Port à Port Bay, Long Point, and in the valley of the Coal River. The total thickness is about 6,450 feet.

Messrs. Matthew, Bailey, and Ells reported[2] that the Carboniferous rocks of Queens, Sunbury, and part of York Counties are to be considered under three main divisions: "(1) Lower Carboniferous formation; (2) Middle Carboniferous formation; (3) Upper Carboniferous forma-

[1] Murray, Alexander: The Carboniferous series of Newfoundland. Geol. Survey Newfoundland: Report of progress for 1873. Montreal, 1873. Pp. 14–35, 42.

[2] Bailey, L. W., G. F. Matthew, and R. W. Ells: Report on the Carboniferous system of New Brunswick, in the counties of Queens, Sunbury, and a portion of York. Geol. Survey of Canada: Report of progress for 1872–'73, 1873, pp. 180–230.

tion." In addition to the general outline and distribution of this series of deposits previously described[1] the authors, as the result of more recent studies, remarked that the Lower Carboniferous rocks of the coast series show many important differences from the same deposits of the above-named counties. The gray Carboniferous rock of Dawson's "Lower Coal Measures," though seen in the Kennebeccasis Valley, is not known in the central Carboniferous area. The limestones so prominent in Nova Scotia are much limited to small areas in New Brunswick. But the "red sandstones and conglomerates" are numerically prominent in both provinces.

After giving a full account of the distribution and physical characters of the Lower Carboniferous, the authors treated of the Middle and Upper Carboniferous series of the same region in the same manner, describing numerous areas and giving sections of the same, together with notes on the fossil remains. The total thickness of the middle and upper formations is about 600 feet. The total area of the same is about 28,540 square miles. One-third of this area is covered with coarse gray beds forming a part of the "Middle Carboniferous formation." The total area of coal seams is about 112 square miles. This area is probably much larger than the above estimate.

Mr. Charles Robb,[2] in 1873, reported that the Sydney coal field covers about 200 square miles. It is bounded by the Atlantic coast on three sides, and on the fourth (southwest side) by Lower Carboniferous rocks.

Messrs. Huntington and Hitchcock,[3] in 1873, reported that the fossiliferous rocks of northwestern Maine were first noticed by Dr. Jackson, near Parlin Pond, and bowlders of this formation were found scattered to the south as far as the mouth of Kennebec River. Fossils were also noticed at Lake Brassua. The fossils obtained were recognized by Billings as characteristic of the Oriskany sandstone, and subsequently the Cauda-galli grit was recognized on the shores of Moosehead Lake.

In concluding the authors observed that: (1) The Oriskany sandstone, which can not be traced toward the White Mountains, was elevated before the deposition of the Devonian; (2) the thickness of the Oriskany is five times that represented in Pennsylvania, about 2,600 feet; (3) the discovery of Helderberg limestone in new localities indicates an extended submergence of eastern America in Upper Silurian and Middle Devonian times.

Mr. Charles Robb,[4] in 1874, attempted to clear up some of the diffi-

[1] Bailey, L. W., G. F. Matthew, and R. W. Ells: Report on the Carboniferous system of New Brunswick, in the counties of Queens, Sunbury, and a portion of York. Geol. Survey of Canada: Report of progress for 1872–'73, 1873, pp. 204–206.

[2] Robb, Charles: Report on the coal mines of the eastern or Sydney coal field of Cape Breton, Nova Scotia. Geol. Survey Canada: Report of progress for 1872–'73, 1873, pp. 238–290. Map.

[3] Hitchcock, C. H., and J. H. Huntington: Geology of the northwest part of Maine. Am. Assoc., Proc., vol. 22, 1873, part 2, pp. 205–214.

[4] Robb, Charles: Report on explorations and surveys in Cape Breton, Nova Scotia. Geol. Survey Canada: Report of progress for 1873–'74, 1874, pp. 171–178.

culties in regard to the relation of the members of the Productive Coal Measures in various parts of the Sydney field. Accordingly a section extending from the supposed limit of the Lower Carboniferous formation at Point Edward and Sydney to its base is indicated. The rocks consist of red and gray shales, with marls containing nodules of limestone and iron ore. The limestones often hold marine fossils of Lower Carboniferous types, also plant remains, fish scales, teeth, spines, and coprolites. The estimated thickness is about 4,637 feet. On the shore opposite Point Edward the rocks are of the Millstone grit formation. These rocks rest upon massive beds of conglomerate and sandstone, which are prominent in Cape Breton coal fields. In constructing sections of a minute character the author finds that the difficulties are caused by faulting. The rocks at Great Bras d'Or entrance appear to be analogous to the Millstone grit of the English coal fields, consisting of sandstones highly colored by oxide of iron, and occasionally a bluish gray, shaly, and bedded limestone.

In Mr. Brown's section, on the northwest of Sydney Harbor, the coal seams appear to run into the Millstone grit.

Mr. Scott Barlow,[1] in 1874, reported that the rocks of the Spring Hill coal field of Nova Scotia consist mainly of alternate beds of sandstones, blue argillaceous shales, fire clays, and coal seams. On the west slope of the Spring Hill Mining Company a section was run having a total thickness of 516 feet, about 12 feet of which are coal seams. A section is also given to the north of Spring Hill Mining Company's west slope, which has a total thickness of 918 feet 11 inches, of which 25 feet are coal deposits. The characters of the rocks are similar to those of the former section. In the Old Pit, belonging to the same association, the same physical characters already mentioned are maintained, the total thickness found at this point being 624 feet 6½ inches, 36 feet of which are coal seams.

Mr. Walter McOuat,[2] in 1874, reported on the coal fields of Cumberland County. The section specially examined by the author extends from the Chiegnecto and St. George Mines to the post-road from Amherst to Truro. As a result of his observations the following classification was arrived at, exclusive of the Lower Carboniferous rocks, as seen at Black River, given in descending order:

	Feet.
1. Millstone grit, red shale, flaggy sandstone (gray and greenish)	1,800
2. Conglomerate, coarse sandstone, reddish and brownish shales	1,500
3. Middle coal formation, gray sandstone and shale, probably the same as at the Joggins	4,500
4. Upper Coal Measures, gray sandstone with false bedding	1,000
5. Red shale, greenish sandstone, conglomerate, and arenaceous gray limestone	5,000
Total	13,000

[1] Barlow, Scott: Report on the exploration and survey of the Spring Hill coal field, Cumberland County, Nova Scotia. Geol. Survey Canada: Report of progress for 1873–'74, 1874, pp. 147–160. Map.

[2] McOuat, Walter: Report on a portion of the coal field of Cumberland County, Nova Scotia. Geol. Survey Canada: Report of progress for 1873–'74, 1874, pp. 161–170. Map.

Dr. Dawson,[1] after giving various views that have been held in regard to the rocks of Prince Edward Island, in 1874 declined to separate the "Red beds" of the lower series from the "newer coal formation." Prof. Geinitz, however, thinks that the fossils show "a decidedly Permian aspect." The author, after a more extended examination of the rocks of East River of Pictou, and in sections west of Caribou Harbor, concludes that "the beds which overlie the coal field of Pictou and extend into Prince Edward Island, and which constitute the upper part of the upper coal formation, have such strong points of resemblance to the lower part of the European Permian that they may be called "Permo-Carboniferous."

In 1876 Mr. Charles Robb reported upon the area recently explored by him, lying along the Atlantic coast and including Cow Bay, Glacé Bay, Sydney Harbor, and Bras d'Or basins. The rocks are referred to the following formations:

I. Carboniferous limestone.
II. Millstone grit.
III. Coal Measures.

The section of Sydney Harbor extending from South Bar to Sydney has a total thickness of 879 feet 7 inches, and is a continuation of the "Millstone grit series" from Victoria Mines to South Bar, Sydney Harbor, having a total thickness for the Millstone grit of 3,275 feet. The rocks consist mainly of fine and coarse sandstones, marls, and limestones, micaceous sandstones, and bituminous calcareous limestones, containing *Sigillaria*, *Lepidodendron*, fish scales, and *Naiadites*.

The "Lower Carboniferous rock" from Point Edward, Sydney Harbor, to Morrison Brook, consisting of yellow micaceous sandstones, red and green marls, calcareo-bituminous shales, and thin arenaceous limestones, has a total thickness of 4,591 feet 10 inches. *Sigillaria* and *Lepidodendron* were found in the shales, while *Brachiopods* and *Encrinites* appeared in the bluish gray limestones.

The section of "Millstone grit" from South Head to Mira Bay has a total thickness of 5,706 feet 8 inches. The rocks are of the same character as in the section given above. The Millstone grit of North Head, Cow Bay, is 537 feet 7 inches in thickness. Plant remains occur in the shales, mainly *Cordaites*, *Asterophyllites*, *Neuropteris*, *Stigmaria*.

The section of Millstone grit from Stubbart Point to Limestone Creek has a total thickness of 4,228 feet 5 inches. The rocks have the same physical characters, except that the coarse conglomerates are more ferruginous than in other sections. Coal seams were noted in the North Head section, varying from a few inches to 8 feet in thickness; the latter includes 18 inches of superior coal. The Millstone grit between Lorway and Sydney Harbor, consisting of argillaceous sandstones, shales, and thin coal seams, has a thickness of 2,619 feet 2 inches.

[1] Dawson, J. W.: On the Upper Coal Formation of Eastern Nova Scotia and Prince Edward Island in its relation to the Permian. Quart. Jour. Geol. Soc., vol. 30, pp. 209–219; Canadian Nat., vol. 7, 1874, new ser., pp. 303, 304.

No definite division line is drawn between the Coal Measures (III) and the Millstone grit. The limit of the Coal Measures in the south, however, "is indicated by the occurrence of angular blocks of coarse sandstone scattered over the surface. The rocks consist of argillaceous shales containing numerous fossil plants, and even large tree trunks; red and green marls containing a few plant impressions and *Naiadites;* sandstones, probably derived from the underlying Millstone grit, containing casts of *Calamites*, *Cordaites*, *Sigillaria*, etc., and forming the most persistent member of the series; and lastly, underclays charged with *Stigmaria ficoides*, and limestones full of organic remains, of which there are some sixteen layers, with thickness varying from one-half inch to 2 feet."

The fossils of the limestones are similar to those of the Joggins section,[1] and are of the genera *Naiadites*, *Cythere*, and *Spirorbis.*

The total thickness of the coal seams in the different subordinate coal basins is as follows:[2]

	Ft.	in.
Cow Bay coal basin	27	5
Glacé Bay basin	39	6
Luigan tract	47	
Sydney mines	30	5
Boulardrie	28	9
Cape Dauphin	15	5

In 1877, Mr. Hugh Fletcher[3] reported on explorations made by him in Cape Breton.

The Carboniferous rocks referred to in his report are divided as follows:

1. Carboniferous conglomerates.
2. Carboniferous limestone.
3. Millstone grit.

The "Carboniferous conglomerate," which the author considers as corresponding to the "Bonaventure formation" of Gaspé, is the "Basal conglomerate" of New Brunswick and Newfoundland, rests upon the Lower Silurian slates and sandstones, and has near the Coxheath Hills a vertical thickness of 1,890 feet 11 inches, while from Watson Creek to the above hills it attains a thickness of 2,525 feet, maintains its general character of brick-red color, and is somewhat friable. It consists of reddish, micaceous, friable, and argillaceous sandstone, with bands of marl intermixed, reddish friable conglomerate with interstratified fine-grained pebbly sandstone.

No distinct line can be drawn between the conglomerate and the lime stone. The latter occupies a narrow strip along Sydney River, widens toward Point Edward, extending into the valleys of Ball and Leitch Brooks. A section of this formation from the banks of the Sydney River is given. The maximum thickness is 1,041 feet, 6 inches.

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[1] See Acadian Geology, pp. 173-181.

[2] Robb, Charles: Report on explorations and surveys in Cape Breton, Nova Scotia. Geol. Survey of Canada: Report of progress for 1874-'75, 1876, pp. 166-266, map.

[3] Fletcher, Hugh: Report of explorations and surveys in Cape Breton. Geol. Survey Canada: Report of progress, 1875—'76, 1877, pp. 369-418, map.

In the Millstone grit, consisting of two synclines, and underlying the Coal Measures to the west of Sydney Harbor, no workable seams of coal have been discovered. The rocks consist mainly of greenish gray and white pebbly sandstone, sometimes falsely bedded with small areas of conglomerate containing *Calamites* and other plants.

Mr. L. W. Bailey and Mr. R. W. Ells,[1] in 1878, reported on the Carboniferous belt of Albert and Westmoreland Counties, New Brunswick.

The formations of this area are divided as follows:

1. Metamorphic rocks of pre-Carboniferous age with intrusive syenite.
2. Lower Carboniferous formation, including the "Albert shales."
3. Millstone grit, formation, or lower member of the Carboniferous system.

The "Lower Carboniferous rocks" of Albert County are but the extension of those in Kings County, where they are followed by patches of unconformable gray-rock of the Millstone grit series. The section in Albert County consists of: (1) The "Basal Conglomerate," which is sometimes wanting (thickness unknown); (2) calcareous, bituminous shales, including the "Albert shales;" (3) gray, bituminous, and micaceous oil-bearing sandstone; (4) red and gray argillaceous beds, alternating with conglomerates; (5) red and gray conglomerate, limestone, and gypsum; total thickness, 1,950 feet.

Sections are also given from Pollet River, Mapleton, Baltimore, Albert mines, Beliveau, and Taylorville, showing the relation of the different series and the system of faults. The series of Albert shales bears strong resemblance to the Horton Bluff series in its fossil contents, stratigraphical arrangement, and rock materials. The general structure of the Albert mine is outlined, with an account of the physical and chemical characters of albertite, and the proofs given of the vein structure of the Albert mine.

The "Millstone grit formation" is recognized by its gray, and rarely pale purple color, and slight dip. It occurs in the southern part of Albert County, running parallel to the metamorphic hills, and showing evidence of denudation, even before the deposition of the succeeding strata. The gypsum beds, which are quite extensive and pure, vary in thickness from 30 to 50 feet.

Mr. Hugh Fletcher,[2] in 1878, grouped the rocks of Victoria, Cape Breton, and Richmond Counties in the following manner:

Laurentian	1. Syenitic, gneissoid, and other feldspathic rocks. 2. George River limestones.
	3. Lower Silurian rocks.
Carboniferous	4. Carboniferous rocks. 5. Carboniferous limestone. 6. Millstone grit.

[1] Bailey, L. W. and Ells, R. W.: Report on the Lower Carboniferous belt of Albert and Westmoreland Counties, New Brunswick, including the "Albert shales." Geol. Survey Canada: Report of progress, 1876–'77, 1878, pp. 351–395, map.

[2] Fletcher, Hugh: Report on the geology of part of the counties of Victoria, Cape Breton, and Richmond, Nova Scotia. Geol. Survey Canada: Report of progress, 1876–'77, 1878, pp. 402–456, map.

Division 4 occurs most largely developed "in the southward extension of the Sydney Harbor basin, and on the Boisdale and Washabeck Hills." Division 5, which attains its greatest thickness on the Washabeck peninsula, is characterized by prominent beds of limestone and gypsum, accompanied by marls, sandstone, and conglomerate. Division 6 is "found on Sydney River and the eastern shore of Forks Lake, divided from similar deposits in the valleys of the Gaspereaux and Salmon Rivers by the East Bay anticline." Sandstones of this series are found on Boulardrie Island. Plant remains are reported from the sandstones.

Mr. Fletcher, in 1879,[1] reported a series of rocks, supposed to be of Devonian age, as "extending from Loch Lomond to St. Peter's, and reappearing on Isle Madame and in Guysborough and Antigonish Counties." They "bear a very close lithological resemblance to the Cordaite shales and Dadoxylon sandstones of New Brunswick." This series is also accompanied by intrusion of trap, such as Mount Granville and Campbell Hill.

The "Carboniferous conglomerate" was found at Mira Bay overlying the "pre-Silurian felsites." This is followed by limestones, and in turn is overlaid by the Millstone grit. The Carboniferous conglomerate and limestone were observed also at Belfrey Lake, Salmon River, and Grand River Falls, but only as small outliers.

The Millstone grit was recognized near Salmon River, having a dip S. 46° E. 80°. A coal seam was found in these rocks near Catalogue Gut.

According to Messrs. Bailey, Matthew, and Ells in 1880,[2] the Devonian rocks of southern New Brunswick occupy the following areas: (1) A basin east of St. John Harbor extending through the Mispec Valley and northeasterly across the Black River; (2) outcrops on Coal Creek, Canaan River, and North Fork; (3) small areas about St. John and Carleton, with possibly Partridge Island; (4) area east of Spruce Lake; (5) an area extending from Musquash Harbor to Lepreau Harbor, and including the Belas Basin, and a small area from Chance Harbor to Dipper Harbor; also an area in the north of Charlotte County and extending into Queen's County.

The estimated thickness of the Devonian rocks of the St. John Harbor series is 7,500 feet. Fossil remains of plants and insects occur in them. The Lower Carboniferous rocks occur around the head of Grand Lake and in the counties of Sunbury and Queens, on the south edge of the coal basin. They also form the greater part of the valley of the Kennebeccasis Bay and River. Although these beds contain fossils of Devonian types, they still lie unconformably upon the true Devonian

[1] Fletcher, Hugh: Report of explorations and surveys in Cape Breton, Nova Scotia. Geol. Survey Canada: Report of progress, 1877–'78. 1879, F, pp. 32. Map.

[2] Bailey, L. W., G. F. Matthew, and R. W. Ells: Report on the geology of southern New Brunswick embracing the counties of Charlotte, Sunbury, Queens, Kings, St. John, and Albert. Geol. Survey Canada: Report of progress, 1878–'79, 1880, pp. 1D–26D. Map.

formation, and their physical characters resemble the Lower Carboniferous rocks, consisting of red and gray conglomerates, brownish red shales, bituminous sandstones, and limestones.

Of the Middle Carboniferous there is considerable evidence that if it had ever attained any degree of development it has since been carried away by denudation, leaving only a shallow deposit in the great Carboniferous basin which underlies the Gulf of St. Lawrence, and which is bounded by the southern shore of the Gaspé peninsula on the north and by the Cobequick Hills and coast ranges of western Cape Breton on the south and east. Coal in thin seams has been discovered in this formation by borings, extending over quite an area. It was found in the Newcastle, Coal Creek, and Salmon River coal basins, having a usual thickness of from 18 to 20 inches. Other small areas were found in South Albert, as far west as Herring Cove; also about Quaco and Gardener's Creek rocks resembling Millstone grit were noticed overlying Lower Carboniferous rocks. A small area was also noted in the north part of Charlotte County.

Messrs. Barton and Crosby,[1] in 1880, reported that the Carboniferous rocks of Massachusetts are an extension of the Rhode Island series, and are mainly found in Narragansett Basin, which lies wholly within Norfolk County. This was determined by President Hitchcock.

These rocks are well developed on the island of Aquidneck, and also form a broad semicircular belt reaching from Warwick and Providence northerly by Valley Falls to Wrentham, in Massachusetts, and thence easterly through Attleborough and Mansfield into Bridgewater.

The rocks of this series consist of a very thick, coarse conglomerate, conglomerates passing into green sandstones about 600 feet in thickness, a series of carbonaceous slates including the true Coal Measures, with few sandstones and red rocks. Very close connection can be traced between the Norfolk belt and those at Wrentham. From a close examination of the Norfolk Basin the author is very doubtful whether coal will be found within its limits.

Dr. J. W. Dawson,[2] in 1882, classified the Paleozoic floras as follows:

I.—*Carboniferous flora:*

(1) That of the Permo-Carboniferous is best seen in eastern Nova Scotia, and is represented by *Dadoxylon, Pecopteris,* and *Calamites.*

(2) The coal formation contains the greatest number of species, and is especially rich in *Sigillaria* and ferns. One hundred and thirty-five species have been catalogued from this formation.

(3) Millstone grit: Here the species are limited. *Dadoxylon acadianum* is a characteristic conifer of this formation.

(4) Lower Carboniferous: The floras of this period consist mainly of *Dadoxylon, Lepidodendron,* and *Aneimites.*

[1] Crosby, W. O., and G. H. Barton: Extension of the Carboniferous formation in Massachusetts. Am. Jour. Sci., 3d ser., vol. 20, 1880, pp. 416–420.

[2] Dawson, J. W.: Comparative view of the successive Paleozoic floras of Canada. Am. Assoc., Proc., vol. 31, pp. 415–417; Canadian Nat., new ser., vol. 10, 1882, pp. 372–378.

II.—*Erian or Devonian flora:*

(1) Upper Erian (Catskill): The subflora is characterized by the genera *Archæopteris* and *Cyclopteris* (ferns).

(2) Middle Erian, corresponding to the Hamilton and Chemung of New York, contain mostly *Dadoxylon*, ferns, and *Lepidodendron*. *Sigillaria* is rare, but *Cordaites* is abundant.

(3) The Lower Erian is characterized by the genera *Prototaxites*, *Arthrostigma*, and *Psilophyton*.

The author also discusses Silurian floras.

Mr. J. F. Whiteaves,[1] in 1882, reported that fish remains had been discovered on the north shore of the Restigouche River, opposite Dalhousie, which prove to be Devonian species. Previously to 1879 these rocks had been considered as Lower Carboniferous.

Mr. R. W. Ells,[2] in 1883, speaking of the geology of Gaspé peninsula, reported that at Grand Pabos, Province of Quebec, Lower Carboniferous rocks are found lying upon Silurian rocks, and east of Little Pabos having a breadth of 2½ miles. Another small area occurs also between Grand River and Brech à Manon. At White Head Carboniferous rocks were noted lying upon Devonian rocks. Rocks of Devonian aspect were found in the vicinity of Black Cape, and also on Bonaventure River. Near Pércé Upper Devonian beds of some magnitude were recognized, lying nearly horizontal. Examination showed that there were three series of Devonian beds: (1) The upper deposit, made up of conglomerates and sandstones; (2) the middle deposit, made up of sandstones, shales, and some conglomerates; (3) the lower deposit, made up mainly of calcareous beds. The upper series has an estimated thickness of 3,000 feet. In a former report (1874) the thickness of the lower member of the Devonian is reported as about 7,036 feet. The series abounds in brachiopods, trilobites, etc., of which a long list is given.

Mr. Edwin Gilpin,[3] in 1884, comparing the Nova Scotian coal fields, says that in the three coal fields of Nova Scotia prominent east and west synclinal folds are noticeable. They are not complicated by faults, except when they come in contact with pre-Carboniferous rocks, as occurs on the south side of the Cumberland coal field. In the Sydney field it appears that the disturbing currents ran in a north and south direction, the materials being derived from the Lower Carboniferous rocks. In the Pictou field a distinctive feature was the formation of a barrier-reef of shingle formed from Millstone grit, back of which accumulated large amounts of argillaceous and carbonaceous sediments. The coal beds, fifteen in number, are situated in the lower part of the section, attaining a maximum thickness of 119 feet, while at Springhill, in

[1] Whiteaves, J. F.: Recent discoveries of fossil fishes in the Devonian rocks of Canada. Am. Assoc., Proc., vol. 31, 1882, pp. 353–356.

[2] Ells, R. W.: Report on the geology of the Gaspé peninsula. Geol. Survey Canada: Report of progress for 1880–'81–'82, 1883, pp. 1DD–32DD.

[3] Gilpin, Edwin: A comparison of the distinctive features of Nova Scotian coal fields. British Assoc., Report 54th Meeting, 1884, pp. 712, 713.

the lower 1,000 feet of the Coal Measures, with twelve beds of coal, they attain only a total thickness of 51 feet. The author naturally asks the question whether or not the Cape Breton coal fields may not have had a total thickness equal to the Cumberland and Pictou fields?

Sir W. Dawson,[1] in 1884, commented on ancient land floras, showing how the floras of the Devonian or Erian period and of the Carboniferous period present many points of likeness, and are very distinct from those of succeeding times. The conspicuous families are *Rhizocarpeæ*, *Equisetaceæ*, *Lycopodiaceæ*, *Filices*, and *Coniferæ*. The changes which have occurred since the Carboniferous consist mainly in the degradation of the three first families, and in the introduction of new Gymnosperms and Phænogams, the latter event marking the later Mesozoic age.

In 1885 Permo-Carboniferous rocks were reported by Mr. Ells[2] as occurring between Cape Bald and Bay Verte. Their similarity to rocks of Prince Edward Island was noted. Rocks of the same character, consisting mainly of soft red beds, sandstones, shales, and calcareous conglomerate, were recognized at Cape Brulé and between Shediac and Cocagne Head. The Carboniferous area of New Brunswick is made up of four anticlinals. One is situated between Bathurst and Miramichi; the second from Grand Lake to Richibucto Head and Miminegash; the third passes from Shediac and touches the island near Cape Egmont; the fourth from Cape Tourmantine to Cape Traverse, Prince Edward Island.

Specimens of *Lepidodendron* found by Mr. Joseph R. Perry[3] in a graphite deposit in the coal mine at Worcester, Massachusetts, were referred by Prof. Lesquereux to the very rare species *Lepidodendron acuminatum* of Goeppert, originally from the Carboniferous limestone of Silesia, corresponding to the American "Subcarboniferous." The great disturbance and working over of the rocks containing the Carboniferous deposit has transformed this deposit for the most part into graphite, and in the specimen found the carbon is in the form of graphite, though the scars of the plant are distinctly preserved.

The Sydney coal field, Cape Breton, is about 32 miles in length by 6 miles in width, extending from Big Bras d'Or on the northwest to Mira Bay on the southeast. The four basins of which this field is composed are as follows, according to Mr. W. Routledge[4] (1886):

1. Sydney Mine section, with 25 feet 8 inches workable coal.
2. The Lingan Tract, with 39 feet 5 inches workable coal.
3. Glacé Bay section, with 55 feet 9 inches workable coal.
4. Block House section, with 24 feet workable coal.

[1] Dawson, Sir W.: On the more ancient land floras of the Old and New Worlds. British Assoc., Report 54th Meeting, pp. 738, 739.

[2] Ells, R. W.: Report on explorations and surveys in the interior of Gaspé Peninsula and Prince Edward Island. Geol. Survey of Canada: Report of progress for 1882-83-84, 1885, 1°-34°, maps. (Separate in 1884.)

[3] Perry, Joseph H.: Note on a fossil coal plant at the graphite deposit in mica schist at Worcester, Massachusetts. Am. Jour. Sci., 3d ser., vol. 29, 1885, pp. 157, 158.

[4] Routledge, W.: The Sydney coal field, Cape Breton, Nova Scotia. Am. Inst. Mining, Trans., vol. 14, 1886, pp. 542-560.

In the region of Cobscook Bay Devonian rocks are reported by Prof. N. S. Shaler[1] as lying to east of Moose Island, with nearly uniform eastern dips. The section at Perry *may* contain Subcarboniferous as well as Upper Devonian rocks, but apparently the most important section is bearing the greatest likeness to Devonian rocks, is on Moose Island. Here the black shaly deposits have a thickness of from 1,000 to 1,500 feet.

Mr. Frank D. Adams,[2] in 1887, defining the coal-bearing rocks of Canada, says the coal fields of Canada are confined to Nova Scotia and Cape Breton, where there are three important basins, situated in Cumberland, Pictou, and Cape Breton Counties, respectively. The coal basin in the Cape Breton field extends under the Atlantic Ocean. On account of the imperviousness of the strata overlying the true Coal Measures they can be worked without any difficulty. The deepest seam of the Pictou coal field at the Dalhousie Pit is 36¾ feet in thickness. The coals of Nova Scotia are somewhat less bituminous than those of Cape Breton.

Sir William Dawson,[3] who has contributed so much to the elaboration of the Devonian and Carboniferous formations, in one of his later papers has given his matured conclusions regarding their classification and correlation. He retains the name "Erian" for the Devonian system, following his modified usage of "Erie Division" of the Geological Survey of New York. On the eastern coast this is represented by sandstones and shales, and is compared with the Old Red sandstone of Scotland and England.

The beds abound in fossil plants and locally in remains of fishes. Both plants and fishes are "generically similar to those of Britain;" they are of "estuarian and littoral" origin; and the author considers them divisible into two series, characterized by different genera of these organisms.

The only truly marine portion of the system in the Maritime Province is the lower part, corresponding to the Oriskany of the interior, and this may perhaps be regarded as an equivalent of the Downton sandstones of England.

The subdivisions of the Carboniferous system are described as follows:

1. A lower series corresponding to the Tuedian of the North of England and Calciferous of Scotland both in mineral character and fossils (the Horton series of my later papers).

2. A Carboniferous limestone, associated, however, with gypsum, and marly and red sandstones, but having fossil remains for the most part specifically identical with those of England (Windsor series of recent papers).

[1] Shaler, N. S.: Preliminary report on the geology of the Cobscook Bay district, Maine. Am. Jour. Sci., 3d ser., vol. 32, 1886, pp. 35–60.

[2] Adams, Frank D.: On the coal-bearing rocks of Canada. Brit. Assoc., Report 56th Meeting, 1886, 1887, pp. 639–641.

[3] On the Eozoic and Paleozoic Rocks of the Atlantic coast of Canada, in comparison with those of western Europe and of the interior of America, by Sir J. William Dawson, K. C. M. G., etc., 1888. Quar. Jour. Geol. Soc., pp. 797–817.

The Erian or Devonian system, p. 813. The Carboniferous system, etc., p. 814.

3. A Millstone grit series consisting of coarse sandstones and shales with conglomerate, mostly of red colors.

4. The Main or Productive Coal Measures, precisely similar in character to those of Britain.

5. A Permo-Carboniferous series, perhaps corresponding in age to the Lower Permian of England, and consisting largely of Red sandstones with species of plants characteristic in Europe of the Lower Permian, but including no limestones.

The conditions of the Carboniferous are on the whole similar throughout North America, except in the extreme West and locally in the Appalachian region; but in Nova Scotia, Newfoundland, and New Brunswick they are more nearly allied to the British type, except in the abundance of red marls and gypsum in the lower part.

CHAPTER XII.

CONCLUSIONS.

When this essay was begun it was thought possible to prepare a thorough paleontologic definition of the systems and series under consideration. The result has demonstrated that the facts are not yet accumulated to make this possible. In the first place, the formations themselves are not delimited on the same basis in different provinces, and, secondly, the fossils have been reported under so many different names that a thorough revision of the several biologic groups is necessary before the various lists prepared can be scientifically correlated. In the meantime such lists as Mr. Miller's "American Paleozoic Fossils" will suffice for all practical purposes. At the outset it was thought that an exhaustive review of all American literature on the Devonian and Carboniferous systems would be profitable. As the research has progressed it has become evident that this literature may be divided into three classes, viz: (1) Records of observations and facts; (2) discussions of the relations and classifications of the facts; (3) controversial literature. Although all the accessible literature has been consulted, I have concluded that the first class can not be abstracted to advantage; that the third class has generally been more concerned in the defense of personal opinions than in the elaboration of the truth, and in many cases the controversy has been occasioned by imperfect understanding of the views of others. For the present essay selection has been made chiefly from the second class of literature, written in most cases by those exhibiting some acquaintance with the immediate local problem under discussion, and also with the opinions of others, and with the corresponding formations in other regions. Another restriction was found necessary: To go into full details would have made a book so large that few would take the trouble to read it, hence whenever practicable formulations of results have been given, leaving the student to examine the original works for details. For these various reasons a large number of the authors consulted, probably a large majority, are not represented here by quotations or title.

The territory discussed may be classified for our purposes into the following geographic provinces: Acadian, Appalachian, Mississippian, Michigan, Western, and Northern provinces. The Acadian province is geologically isolated from the others, and has a history of its own. The facts accumulated for the Northern province, extending from Manitoba

along the Mackenzie River to the Arctic and about the shores of Hudson Bay, are too fragmentary to admit of generalization. The Western province has not been worked up with sufficient detail to admit of other than broad generalizations. The correlations in these three provinces were based upon purely paleontologic data. The other three provinces are partly connected at their boundaries and roughly defined are great basins, in which the more recent Carboniferous formations are partially, at least, surrounded by the older Devonian rocks.

The Appalachian province is separated from the Mississippian province by a geological anticline called the Cincinnati axis, extending from middle Tennessee in a northeasterly direction to near Sandusky, Ohio, and thence across Lake Erie into Ontario, Canada. The Michigan province is connected with both the Appalachian and the Mississippian provinces by a common band of Devonian rocks running from Toledo across to the southern end of Lake Michigan.

In the center of the Mississippian province the Ozark Uplift occupies, with Silurian and Archean rock, the southeastern third of Missouri and parts of adjacent Illinois and Arkansas. The western edge of this province is terminated by the overlying Cretaceous along an irregular westward curving line connecting Omaha and Austin, Tex. The northeastern or Acadian province is defined at the opening of the last chapter and exhibits an immense thickness of Devonian and Carboniferous shales, sandstone, and conglomerates, with little limestone, estimated at 9,500 feet of Devonian and 16,000 feet of Carboniferous. Along the eastern and northeastern borders of the Appalachian the thickness may be a third less, but the deposits are still arenaceous, with some argillaceous shales and with little limestone. The arenaceous deposits decrease on going westward for the whole Devonian until in Iowa the total Devonian is estimated at 200 feet of shales and Magnesian limestone. The Devonian is represented all around the Michigan province by considerable limestone in its early stage, running up into soft shales, then Lower Carboniferous sandstone and shales, and finally a few hundred feet only of Coal Measures. Passing southwestward along the Appalachian province, or from Iowa and Michigan southward in the Mississippian province, the Devonian loses the calcareous base and the arenaceous top and dwindles down to a black shale, varying from one hundred feet or so in Kentucky to nothing in Southern Tennessee and around the western and southwestern margins of the Ozark Uplift. With this change from the complex Devonian formation of New York to the simple black shale of Tennessee there is a corresponding change in the Lower Carboniferous from arenaceous and shaly deposits in Michigan, Ohio, and Indiana to limestones of over a thousand feet thickness in the Mississippian province, separating the black shale from the Coal Measures.

With all these differences in the stratigraphy there are corresponding differences in the faunas and floras, and as the geologists have surveyed

the rocks and brought the facts to light the difficulties of exact correlation have been as great as the complexity of the facts.

In the historical development of the geology the northern part or the Appalachian province was first developed; afterward, and by other men, the Mississippian province was surveyed and interpreted.

Among the numerous problems which American geologists have had to solve, I have selected a few to show the methods employed in correlations and the reasons why one method has led to erroneous and another to correct results. The object of correlation is and has been to bring newly discovered formations into their proper places in already established systematic classifications. Hence in studying the principles of correlation it has been necessary to deal mainly with the classifications. The original classifications may have been founded on wrong principles, and in such cases, however correct the methods of correlation may have been, the results were unsatisfactory. In the first stage of the history this was the case. The Wernerian classification was based on the supposition that the stratigraphic order of deposits and the lithologic composition of the separate members had some natural relation to each other. This is not the fact. It was on this account that all the work of Amos Eaton, in New York State, though based upon careful observation and accurate record of the facts, was a failure so far as the correlations were concerned. After he had perfected the Wernerian system, thoroughly adapted it to our facts, and provided an American translation, so to speak, of the German method, the fallacy of the method was exposed and the whole of his scheme was abandoned. The New York rocks were admirably adapted to the construction of a correct classification of the Paleozoic systems, except for the highest member. For that the adjoining State, Pennsylvania, furnished what New York lacked. For nearly half of the State the dip of the rocks is scarcely greater than 50 feet to the mile, and they are so regular that numerous sections could be easily examined running through the same series of deposits, the local variations noted, and, most important of all, great quantities of fossils were obtained. The result was that the New York rocks for the Silurian and Devonian systems furnished the standard classification for North America, and after 1843 (the date of the completion of the final reports of the geological survey of the State of New York) whatever imperfections might have been detected were easily corrected by reference to the strata themselves. All mistakes in correlations of these formations thereafter were the fault of the method of correlation, not of the classification used.

The Carboniferous rocks of Pennsylvania are mainly arenaceous and argillaceous, and marine fossils are rare in them. The classification that was developed was therefore one based chiefly upon stratigraphic and lithologic characters. Heroic attempts were made to trace the various lithologic units of the system beyond the State; but even from county to county in Pennsylvania the modifications were so constant

that correlation became a problem of dip and thinning of the rocks, or of number and thickness of coal-beds or of sandstone strata. The result was that almost every State having Coal Measures had its own classification of details, with the *apparent* symmetry of a lower, a middle, and an upper division. As far as a local coal bed could be traced so far there was correlation. This method of correlation led to the theory of "persistent parallelism of strata," which was applied very considerably in the second Pennsylvania survey, and to some extent in all the Coal-Measure areas. In Pennsylvania this theory was applied, and the resulting correlations were unsatisfactory in proportion to the distance the correlations were carried. It was not, strictly speaking, correlation. It was rather an actual tracing of the strata from outcrop to outcrop by geometrical processes. The correlations were unsatisfactory because in the clastic rocks which there prevail the details of lithologic characters, as composition, fineness, or coarseness of grain and thickness of strata, are not uniform, but vary considerably even in a short distance. Occasionally there were fossiliferous strata in the Coal Measures which gave a clew to the true position in the standard stratigraphic scale.

In the Mississippian province the first attempts at correlation were with European standards. In this case there were two fundamental data upon which the correlations were based. These were the "Coal Measures" and the "Mountain Limestone." The presence of coal beds in association with underclays and sands was taken as evidence of the Coal Measures of the English geologists, and the finding of limestones below these Coal Measures containing fossils determined to be identical with those described from the Mountain limestone of Derbyshire, in Martin's "Petrificata Derbiensia," was the reason for calling the limestone "Mountain limestone." As far as the general correlation was concerned the determination was correct, but when attempt was made to push the correlation to details it was found impracticable to fit either the standard English scale or that already developed in the Appalachian province to these rocks of the Mississippian province. The result was that as the details were accumulated by geological surveys the geologists developed a classification and nomenclature of their own, in the same way that the New York geologists had done for their State. The chief work accomplished in this province was the elaboration of the series between the Devonian and the base of the Coal Measures, called "Subcarboniferous" and "Lower Carboniferous," which is so characteristic of this region that I propose to give it the name "Mississippian series." The discussion of the facts determining the upper limit of the Coal Measures, as seen in the chapter on the Permian Problem of Kansas and Nebraska, may also be considered as one of the results of the study of this Mississippian province.

One of the most instructive illustrations of the principles of correlation is seen in the determination of the base of the Mississippian series.

In this determination two distinct methods of correlation were exhibited. The geologists familiar with the standard sections of the New York system, and of the Appalachian province in general, applied the principle of "persistent parallelism of strata," and, having gone carefully over the ground, believed they had established beyond dispute the correlation of rocks at the base of the Mississippian series with the upper member of the New York Devonian, i. e., the Chemung group.

The "Chemung group" of Iowa and Missouri was originally thus determined, and was defended on this basis for a number of years against the counter evidence of fossils. When the fossils were studied and compared with the fossils of the Chemung of New York they were found to closely agree generically, but specifically there were very few cases of identity. To correct this discrepancy a gradual modification of the species or combination of species constituting the local faunas was assumed to have taken place coordinate with difference in longitude on passing westward. The fallacy in this assumption deceived some of the ablest geologists of the country, and for nearly twenty years general reliance upon their authority stood in the way of the acceptance of the truth.

On the principle of establishing correlation of horizon by identity of the fossils all the evidence went to prove that the so-called "Chemung" rocks of the Mississippi Valley were of Carboniferous age. M. de Verneuil so identified the specimens he saw when on a visit to this country in 1847. D. D. Owen, one of the earliest geologists to study the rocks of this province, and others who followed him, recognized the "Carboniferous aspect" of the fossils. But these identifications of the fossils were not generally accepted as outweighing the other evidence of supposed correlation with Chemung rocks until the year 1861, when Messrs. Meek and Worthen established the Kinderhook group.

The Kinderhook group was the result of pure paleontologic correlation, in which the fauna at the base of the "Carboniferous limestones," often in sandy or shaly strata, was distinctly recognized, by comparison with authentic Carboniferous species of Europe, as of Carboniferous age. The identifications upon which the name was applied were of Illinois fossils; the correlation included led to the correct correlation of the "Goniatite beds" of Indiana, and later of the Waverly group of Ohio, and the recognition of the "Black shales" of the Mississippi province as the termination of the Devonian series. Although the correlation included the faunas of the Chemung of Iowa and Missouri, the application of the name "Chemung" there had become locally fixed to the particular rocks, irrespective of their supposed equivalency, and the name was not immediately dropped. The fundamental error in the Chemung correlation was made near the eastern end, on passing from Chautauqua County, New York, across to Cleveland, Ohio. Passing westward from Ohio the error was not noticeable, so that the identity of many Ohio Waverly species with those found in the Western Che-

mung helped to keep up the misinterpretations. Mr. Meek's success in correlations appears to have been due to his minute knowledge of the characters of fossils and their relations to each other, and perhaps still more to his firm faith in fossils as the one reliable guide to true correlation.

The principle of "persistent parallelism of strata" is defective in several ways: (1) Although it has been often observed that a stratum continues for a long distance with but slight variation in thickness and character of material, the constancy of lithologic and stratigraphic character can not be assumed to be the case, even for short distances, unless actually so observed. From this we deduce the law that "parallelism of strata" is not a safe means of correlation, although the correlation once being established, the parallelism of strata is a valuable aid in the recognition of the correlation for detached sections. (2) The errors made by this method of correlation occur at points where the evidence is lacking, therefore it is impossible by merely going over the field a second time to correct such errors. (3) Even when there is apparent continuity of a single stratum or of a series of similarly formed strata, for tens or hundreds of miles, this alone is not evidence that the deposits at the two extremes were formed synchronously. The correct interpretation of the continuity, in case the material is purely clastic, is more likely to be found in a gradual shifting of the shore line by rising or sinking of the land than in synchronism of deposition. On the other hand, the correlation of geologic formation by their fossil contents is (1) Always made upon actual evidence, any errors of interpretation of which can be corrected by critical review of the evidence; (2) the particular form assumed by any organic structure appears to be determined almost entirely by two factors, i. e., heredity and environment; hence we may deduce the law that, given the locality and the conditions of environment, the fossil has in itself the evidence of its geologic age.

The precision with which correlations may be made upon paleontologic evidence is determined by the knowledge possessed of the relations of the elements of organic form to geologic age, so that a fragment of a fossil in the hands of one who knows how to interpret the evidence may furnish a more correct diagnosis of the age of the formation than a bushel of fossils in the hands of one ignorant of the laws of organic life determining the form of the structures produced.

The lowest member of the Mississippian series in Illinois having been defined as the Kinderhook group, it was a matter of simple paleontologic correlation to fix the lower limit in Iowa at the base of the "Chemung group," in Missouri at the base of the formations later called Chouteau group, in Indiana at base of the Goniatite beds, in Ohio at the base of the Waverly, and in Michigan at the base of the Marshall group. Immediately underlying these formations or their evident equiv-

alents in several of the States of the interior a black shale is conspicuously constant. While the black shale was generally correlated as Devonian, its precise age has not up to the present time been certainly fixed.

That the black shale has not been satisfactorily correlated is shown by its retention of that general name in spite of its frequent correlation with other black shales of definite age, as the Marcellus and the Genesee formations of New York.

As the terrane separating Silurian from Carboniferous thins out to the southwest, it is finally restricted to a few feet of black shale, but it is not proved paleontologically precisely what part of the expanded series, called Devonian in New York and Ohio, is represented by this shale.

In the later work of the geologists of Ohio a certain symmetry in correlation is sought by uniting the black shales, up to and including the Cleveland shale, into a single group and calling it the Ohio shale, correlating this as the upper member of the Devonian system.[1]

Prof. Newberry, in his monograph on "The Paleozoic fishes of North America,"[2] classifies the deposits above the last prominent black shale as Carboniferous, thus conforming with the general principle of making the black shale the top member of the Devonian system. In the case of Prof. Newberry this correlation is not new, and was first advanced to make the classification conform to a theoretical order of deposits explained under the name "circles of deposition."[3] But the tendency on all hands has been to accept this structural line of demarkation between the Carboniferous and Devonian formations. Still further work upon the structural as well as the paleontologic features of these black shales will be needed to determine their true correlation.

The subdivision of the Mississippian series is a matter of classification rather than correlation proper. All through the province variations in the stratigraphy are seen in the development of the local geologic structure. The structural or lithologic formations distinguishable over most of the province are as follows:

Chester group, Worthen.	Burlington limestone, Hall.
St. Louis group, Worthen.	Kinderhook group, Meek and Worthen; or
Warsaw limestone, Hall.	Chouteau group, Broadhead.
Keokuk group, Worthen.	

These formations have been defined in their typical localities and the faunas as locally studied have been described, but in several cases difficulty has been experienced in attempting to extend the classification over the whole Mississippian province.

The difficulties have occurred most frequently in distinguishing between Burlington and Keokuk faunas in the formations in western and

[1] Geol. Survey of Ohio, vol. 6, by Edw. Orton, 1888.

[2] U. S. Geol. Survey, Monograph, vol. 16, 1889.

[3] See a theory of circles of sedimentation, by J. S. Newberry, Am. Ass. Adv. Sci., Proc., vol. 22, pt. 2, pp. 185–196, 1873, and on circles of deposition in sedimentary strata, Canadian Nat., new series, vol. 7, pp. 163–164.

southwestern Missouri and northern Arkansas, in distinguishing in some cases whether a fauna is a Warsaw or a St. Louis fauna. The Chester fauna may be associated with particular conditions of environment.

On considering these several facts, it has appeared to the writer that in classifying the formations of the Mississippian series the correlations from a *structural* point of view have been carried too far and that an increase in the number of lithologic formations will better express the facts as at present known; whereas from a *paleontologic* point of view the classification is too minute, and that a combination of some of the formations will best express our present knowledge regarding their true relations. The practical application of this suggestion will result in applying new local names to structural formations whenever the structural characters are so divergent from those of the typical section that the correlation depends upon stratigraphic position above or below some clearly recognized horizon for its validity.

Recent studies of the fossils, their original grouping into local faunas and their association in other parts of the province, have led me to recognize three fairly well differentiated faunas in the Mississippian series, the subdivisions of which are believed to be local, and therefore very unsatisfactory for purposes of correlation.

The following table sets forth the proposed classification and nomenclature:

	Structure scale.		Time scale.
Mississippian series	Chester stage		Genevieve age.
	St. Louis stage		
	Warsaw stage		
	Keokuk stage		Osage age.
	Burlington stage		
	Kinderhook stage, including	Chouteau limestone	Chouteau age.
		Vermicular shale and sandstone	
		Lithographic limestone	

The Chouteau age is the age of the Chouteau group of Broadhead. The Osage age is the age of the fauna of the Burlington and Keokuk formations, which are locally distinguishable, but in the sections on the northwestern, western, and southwestern flanks of the Ozark Uplift are so blended that it seems impracticable in most cases to differentiate them. The name is suggested by the fact that the Osage River drains the region in which this confusion of the two faunas is clearly exhibited. The Genevieve age is the age of the fauna of the Archimedes group of Shumard.[1]

The name is suggested by the fact that Shumard first called attention to the union of the several formations in which the common fauna prevails in his description of the geology of Ste. Genevieve County, Missouri. The name he applied was Archimedes group, but this is not a sat-

[1] Repts. Geol. Survey Missouri, 1855-1871, by G. C. Broadhead, F. B. Meek, and B. F. Shumard Ibid., 1873, pp. 292-293, by B. F. Shumard.

isfactory name, and in the county of Ste. Genevieve and on the eastern and northeastern margins of the Ozark Uplift, above and below this county, are found the typical outcrops of the individual formations included in the group.

This classification is used in reports already communicated to the State geologists of Arkansas and Missouri, and I give it here to expose the latest results of my attempts at correlation of these formations.

One of the most important results which such a review of the history of correlation emphasizes is the fact that all attempts to attain uniformity of classification or nomenclature have failed to a greater or less extent.

The extent of the artificiality of the correlation is in some measure proportionate to the distance separating the formations compared; but the experience of the geologists of the second geological survey of Pennsylvania shows how difficult it is to make satisfactory correlations even between the rocks of adjoining counties.

Amos Eaton, seventy years ago, attempted to make the classification and nomenclature of the New York formations uniform with that of Germany and England. He succeeded as well as anyone could in his time; but some young men, trained in his own school, went into the field a few years later to work up the geology of New York State. They began with the application of his system, but when they found it fettering the accuracy of their observations they cast it aside. They recorded the facts as they found them, gave independent names to the formations for the purpose of identifying them, and formed a New York system.

The classification and nomenclature of this system has been adopted as a standard in all respects except where uniformity with European usage was attempted.

The name "system" was lost because this is only part of a system; the divisions, Champlain, Ontarian, Erian, etc., have been discarded because they are purely artificial and have nothing to do with the natural classification of the rocks; the grouping of the formations into Devonian, Silurian, is still allowed, but it is applied both loosely and unsatisfactorily by all except the text-book user. After the New York survey was completed, the same men, satisfied with their success, and still remembering the philosophy of uniformity, thought it might be applied to all American geology. They went westward, tried to fit the New York and Pennsylvania systems to the geology of the Mississippian province. In the cases where they attempted to classify the Mississippian rocks on the Appalachian model the result proved unsatisfactory, because artificial and not expressing the facts as they are. In the cases where the nomenclature and classification have been built up independently and strictly according to the local expression of the facts they have been retained.

One after another of these early attempts to produce uniformity in

nomenclature have been discarded because the facts did not support the correlation when precision was applied. In the far West the anomalies were so great that defenders of the traditional geology have stood aghast. The Government geologists, who were chiefly concerned in developing the facts, have gained the reputation of disregarding precedent, European standards, and even the opinions of their brother geologists; but after one of these doubters has climbed the Rockies, trailed across the plateaus, and looked into the cañons, he has come back forced to confess that "the half was not told him," and paleontologists and geologists alike have been obliged to expand their systems to accommodate these bold geologists of the saddle.

Such has been the result of seeking uniformity for a single continent. Like results, we believe, will appear upon comparison of the formations of different provinces on other continents. The experience of European geologists who have not gone outside Europe has been mainly with the details of a single geologic province; a certain degree of uniformity is therefore practicable for them. It is no disrespect to the European system that has led Americans to think lightly of conformity to any uniform standard of geologic classification or nomenclature. The reason for the failure on the part of American geologists to adopt and apply the older standards of Europe to their formations is found in the fact that the supposed uniformity does not actually exist.

The literature of the first quarter of the century demonstrated that classification can not be based upon *uniformity of lithologic constitution.* The last twenty-five years has made it evident that *uniformity of stratigraphy* can not be relied on for correlations, and now the modern school of paleontologists are demonstrating the fact that the divisional lines marking the biologic or time scale do not correspond to those of the structural or stratigraphic scale, but are determined by independent factors. In the classification of rock formations the character of the formations should receive chief consideration, but the particular geologic period in which sediments are deposited has practically no relation to the nature of the sediments or their amount or their physical arrangement as geologic deposits. It is, hence, a grave question whether the development of our science does not demand that geographic factors should take precedence of time factors in all classifications of geologic formations.

The correlations between form, density, and composition of minerals are formulated in systematic mineralogy, the correlations between form structure and age are formulated in systematic paleontology, and a systematic geology will be attained when the relations between the composition, the stratigraphic order, and the geographic position of rock formation can be adequately formulated.

The experience of geologists in the past shows conclusively that composition and stratigraphic order of sequence are intimately associated with geographic locality. Each geographic province has its own

history and will ultimately require its own nomenclature and classification.

It was Kirwan,[1] I believe, who classified the rocks as "mountains," translating the German word "gebirge" into mountain, instead of formation, as we should do now; thus, "Steinkohlen gebirge," "grauwacken gebirge," he called "Carboniferous mountains," "Greywalcke mountains."

Although the double sense is at once evident to us, the conception of the German geologists expressed in applying the name "Gebirge" to a geologic formation is not so far wrong as at first it would appear. It was long ago learned that uniformity of nomenclature for mountains of different continents is absurd.

Although some relation exists between the position on the continent, the distance from coast, and the size of the adjacent sea, as Guyot has shown, geographic position of a mountain is the one thing distinguishing it from all other mountains, and no consideration of similarity in mountains dispenses with the necessity of separate names for every local mountain range. Although covered from sight, and with our present knowledge difficult to outline, it is altogether probable that geologic formations are as completely separated geographically as are mountains. Any classification of formations which does not recognize geographic position as of primary importance is artificial, and in the nomenclature regard for the geography must find a place if we would be scientifically accurate.

Having defined the geologic formations of a province, their correlation with those of another province can be made only by means of the fossil contents. This the experienced geologist has demonstrated.

History shows that the correlations which have best endured the test of time were made regarding formations whose structural and stratigraphic features were elaborated independently of the correlation, and the correlation of which was based upon carefully collected and exhaustively studied fossils. The records of structure, composition, and stratigraphic order, when based upon careful observation, are permanently valuable contributions to knowledge, and their value is not increased by attempts to fit them into some established classification upon scant paleontologic data or hasty paleontologic comparison.

The classification made by the field geologist should not be warped to conform to any standard, not even that of the adjoining county, unless there is structural evidence of identity of formations. Correlation by physical means, i. e., inference from general dip, altitude, thickness, when associated with likeness of composition, is practicable for short distances and when made by experienced geologists, but even then the determination is not absolute; contradictory paleontologic evidence in the hands of an equally expert paleontologist should always be given precedence.

[1] "Geological Essays," London, 1799.

The undisputed correlations from one province to another, as from the European sections to those of New York, from the Appalachian to the Mississippian provinces, or from either of these to the Acadian province, rest entirely upon biologic evidence—coal beds and masses of coral and crinoidal limestone are of biologic not geologic origin. Such correlations are generally satisfactory so far as they pertain to the general equivalency of systems or series; but all attempts to correlate with precision the limits of such divisions or to establish uniformity in the subdivisions of two separate provinces has proved forced and artificial, and the history of American geology shows that after the determination of the general equivalence of age, in matters both of classification and of nomenclature, little attempt has been made to attain uniformity with outside standards. Paleontologists have discussed the relations between the fossil faunas of America and the European standards, but the cases have been rare in which the differences have not been as conspicuous as the agreements.

The principles involved in correlations made by use of fossils are purely biologic and are intimately concerned with the laws of structure and growth of the individual, with the effects of environment and geographical distribution, with the laws of heredity and evolution, and with the laws of relationship of organisms to each other and to geologic time. The discussion of these matters would be out of place here; but it may be said that the great advance attained in the accuracy and in the general methods of geologic correlation during the last twenty years is mainly due to the changed conceptions regarding the nature of the organic species.

The Cuvierian notion of species was entirely consistent with the notion of sharply defined, uniform delimitations and "universal" formations. Each species was supposed to belong to one, and how it could appear in two formations was not explained. The Darwinian notion of species is not consistent with sharply defined lines in the classification either of organisms or of formations.

According to this notion the modification of organic form is conceived as not an arbitrary matter, but as correlated with difference of environment and of genetic relationship, so that the lesser variations of specific form are of as great value to the modern paleontologist for purposes of correlation as is the identity of species. Comparison of allied species in the same genus exhibits to him the rate and direction of modification taking place in the genetic history of the genus, and in the plastic or variable characters he finds a sensitive indicator of the stage of development attained by the race when the particular individual lived. Biological study shows him that fossils must contain intrinsic evidence of their geologic age independent of the formations in which they were buried, and his chief work is to learn what this evidence is and how to interpret it. To such evidence the final appeal must be made in all cases of the correlation of geologic formations.

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