DEPARTMENT OF THE INTERIOR
HUBERT WORK, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 769

THE GEOLOGIC TIME CLASSIFICATION OF THE UNITED STATES GEOLOGICAL SURVEY COMPARED WITH OTHER CLASSIFICATIONS

ACCOMPANIED BY

THE ORIGINAL DEFINITIONS OF ERA, PERIOD AND EPOCH TERMS

A COMPILATION

BY

M. GRACE WILMARTH

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
20 CENTS PER COPY

CONTENTS

ILLUSTRATION

PREFACE

By T. W. Stanton

With the intensive study of the geology of a country as large as the United States the stratigraphic classification has necessarily become very complex and the number of formation names has been greatly multiplied. However much this complexity and multiplicity may be deplored, it is the inevitable result of detailed study and especially of detailed mapping in disconnected regions. Further, as the geologic history and development of different areas have differed, so must the stratigraphic units recognized and their grouping differ.

In recent years the increased emphasis given by many geologists to the results of diastrophism—of the movements of the earth's crust—as the basis of classification has caused the proposal of several major changes in classification, both by interpolating new systems or periods and by changing the boundaries of those already recognized, but the geologists who have proposed innovations have differed among themselves, so that several American classifications are now current, all of which depart to a greater or less extent from that used in the publications of the United States Geological Survey. That the Geological Survey has been conservative, perhaps overconservative, in its classification is shown by the fact that it still uses essentially the same scheme that it adopted for the Geologic Atlas of the United States, as printed in the Twenty-fourth Annual Report of the Director in 1903. The classifications current in Europe also differ somewhat from one another and from those current in America.

With the rapid progress of detailed geologic investigation throughout the world and the shift in viewpoint as one phase or another of the complex subject is emphasized, changes in classification must necessarily be made as rapidly as enough evidence is presented to convince the majority of geologists that they are desirable.

In the accompanying chart (compiled by Miss M. Grace Wilmarth, secretary of the committee on geologic names) the United States Geological Survey's classification is compared with the classifications of Chamberlin and Salisbury, Ulrich, Schuchert, Clarke, and Grabau for the United States and of De Lapparent, Haug, and Geikie for Europe. The accompanying text quotes the original definitions of the major terms and gives brief statements showing the changes they have undergone, which, taken in connection with the correlation chart, give a fair general idea of the history of each term. The bulletin includes also a table showing several modern estimates of the measure of time included in the several geologic periods and epochs. It is believed that the material thus assembled in compact form will be useful to professional geologists, to students of geology, and possibly to that larger circle of readers who have an intelligent interest in general geology.

This chart will not fully meet the demand for correlation tables showing the relations of all the many hundreds of geologic formations in the United States that have been described and named, but when it is supplemented by a stratigraphic lexicon, which Miss Wilmarth now has in preparation, most of the information desired will be available in more useful and more accurate form than could be given in detailed correlation tables except those for restricted areas, which may be prepared from time to time.

THE GEOLOGIC TIME CLASSIFICATION OF THE UNITED STATES GEOLOGICAL SURVEY COMPARED WITH OTHER CLASSIFICATIONS AND ACCOMPANIED BY THE ORIGINAL DEFINITIONS OF ERA, PERIOD, AND EPOCH TERMS

By M. Grace Wilmarth

INTRODUCTION

Purpose of the work.—The United States Geological Survey receives many requests for its time classification, for information as to the relations of its time classification to those of other geologic authorities, and for the definitions of its time terms and of certain European time terms. The Survey has never published a comprehensive list of definitions of the time terms, nor any table or text explaining wherein its time classification differs from other time classifications. To supply the demand represented by these requests this bulletin is published.

Scope of the work.—In assembling the definitions of the time terms it became apparent that the original definitions should be published, in order that the reader might determine for himself wherein they differ from or agree with those that have grown out of studies made during more than a century and a half. The original definitions are quoted literally, except that those in foreign languages have been translated. In these definitions footnotes that have been inserted by the compiler are inclosed in brackets; other footnotes are part of the matter quoted. For practical reasons all footnotes, whether quoted or not, are numbered consecutively throughout the bulletin.

Most of the original definitions are founded on the geology of Europe, and in order that the reader may understand the relation of the Survey's time classification to that employed in Europe, the European classification, as interpreted by three European geologists, De Lapparent, Haug, and Geikie, has been incorporated in the accompanying chart, for comparison with that of the United States Geological Survey.

In recent years several American geologists and paleontologists have proposed important changes in the current time classification by introducing new periods and by changing the boundaries of old ones. The changes advocated by some of these geologists are also shown in the chart.

Builders of the time table.—The first time classification was that of Arduino, an eminent Italian scientist, who in 1760 divided the rocks of the earth into three major divisions, which he called Primitive (the oldest), Secondary, and Tertiary (the youngest). In this classification the more recent surficial deposits of the earth, to which the name Quaternary is now applied, were ignored. Of these earliest time terms "Primitive" (also called "Primary") and "Secondary" have long since fallen into disuse, but Tertiary is still in general use. The perpetuation of the term is a fitting tribute to a distinguished pioneer in geology as well as other sciences. Similarly, Quaternary remains, a relic of an early modification of Arduino's classification, by Desnoyers (1829) and Reboul (1833).

The names of some of the distinguished men who followed Arduino and helped to establish the geologic time classification now generally recognized in Europe and America are given in the following list:

Cenozoic era: Phillips (England), 1840 and 1841.
  Quaternary period: Desnoyers (France), 1829; Reboul (France), 1833.
    Recent epoch: Lyell (England), 1833.
      = "Modern Group" of De la Beche (England), 1831.
    Pleistocene epoch: Lyell (England), 1839; Forbes (England), 1846.
      = "Erratic Block Group" of De la Beche (England), 1831.
      = "Diluvium" of Buckland (England), 1823.
  Tertiary period: Arduino (Italy), 1760.
      = "Newest Floetz" of Werner (Germany), 1787–1817.
    Pliocene epoch: Lyell (England), 1833. (As originally defined included Pleistocene.)
    Miocene epoch: Lyell (England), 1833.
    Oligocene epoch: Beyrich (Germany), 1854.
    Eocene epoch: Lyell (England), 1833. (As originally defined included Oligocene.)
Mesozoic era: Phillips (England), 1840 and 1841.
      = "Secondary" of Arduino (Italy), 1760.
  Cretaceous period: Omalius d'Halloy (Belgium), 1822.
    Gulf epoch: R. T. Hill (United States), 1887.
    Comanche epoch: R. T. Hill (United States), 1887. Shasta epoch: Gabb (United States), 1869.
  Jurassic period: A. von Humboldt (Germany), 1799; Wm. Smith (England), 1815 and 1817; Conybeare and Phillips (England), 1822.
  Triassic period: Alberti (Germany), 1834.
Paleozoic era: Sedgwick (England), 1838. Included in "Primary" of Arduino (Italy), 1760.
  Carboniferous period: Conybeare and Phillips (England), 1822. (As originally defined included Devonian and excluded Permian.)
    Permian epoch: Murchison (England), 1841.
    Pennsylvanian epoch: H. S. Williams (United States), 1891.
      = "Coal Measures" of Conybeare (England), 1822.
    Mississippian epoch: A. Winchell (United States), 1869, and H. S. Williams (United States), 1891.
      = "Carboniferous limestone" of Conybeare (England), 1822.
  Devonian period: Sedgwick and Murchison (England), 1839.
      = "Old Red sandstone" of Conybeare (England), 1822.

Silurian period: Murchison (England), 1835. (As originally defined included all of Ordovician except the Beekmantown.)
Ordovician period: Lapworth (England), 1879.
Cincinnatian epoch: Meek and Worthen (United States), 1865; N. H. Winchell and E. O. Ulrich (United States), 1897.
Mohawkian epoch: Clarke and Schuchert (United States), 1899.
Cambrian period: Sedgwick (England), 1835. (As originally defined included the basal part of the Ordovician, or the rocks now known as Beekmantown, and some Archean rocks.)
Upper Cambrian epoch: Sedgwick (England), 1835.
= "Saratogan" of Walcott (United States), 1903.
= St. Croixan of Walcott, 1912, which replaces "Saratogan" (inappropriate name).
Middle Cambrian epoch: Sedgwick (England), 1835.
= Acadian of Dawson (Canada), 1868.
Lower Cambrian epoch: Sedgwick (England), 1835.
= "Georgian" of Walcott (United States), 1903.
= Waucoban of Walcott, 1912, which replaces "Georgian" (inappropriate name).
Proterozoic era: Emmons (United States), 1888, and Van Hise (United States), 1908. Included in "Primary" of Arduino (Italy), 1760.
= "Protozoic era," Sedgwick (England), 1838.
Algonkian period: Powell (United States), 1890; used but not defined by Walcott in 1889.
Keweenawan epoch: T. B. Brooks (United States), 1876.
Huronian epoch: Logan (Canada) and Hunt (United States), 1855.
Archean period: Dana (United States), 1872. (As originally defined included Algonkian.)
Laurentian epoch: Logan (Canada), 1854.
Keewatin epoch: Lawson (Canada), 1885.

Time terms and rock terms.—As shown in the accompanying chart, the geological *eras* of the earth's history are divided into smaller time units, generally called *periods*, and the periods are divided into still smaller time units called *epochs*. In the nomenclature adopted by the Geological Survey the rocks formed during a geologic period constitute a geologic *system*, and the rocks formed during a geologic epoch constitute a *series*. Or the explanation may be reversed, and we may say that the time covered by a geologic system constitutes a geologic period, and the time covered by a geologic series constitutes a geologic epoch. This technical usage of the terms period, system, series, and epoch is not, however, universal, as the headings in the chart will reveal. The rock element, and not the time element, appears to have been dominant in the minds of most of the geologists who defined the terms, for most of the subdivisions are defined as rock units rather than as time units. It is, therefore, the rocks themselves that are described in most of the definitions, rather than the time during which the rocks were formed. The rock idea and the time idea are, however, so interwoven that any description of a time unit almost automatically resolves itself into a description of the rocks of the interval. To this fact is due the seeming mixture of the two ideas in the quotations that follow.

For purposes of mapping and stratigraphy the series are divided into smaller units called *formations*, and many formations are divided into *members* and *lentils*. Several formations may also be assembled into a *group*. It might be useful to have a separate time term corresponding to each of these rock units, but no such terms have yet been adopted, and in Geological Survey publications the single term *epoch* is used for all subdivisions of periods, whether they correspond to series, groups, formations, or members.

The chart also shows that the epochs (or series) into which some of the periods (or systems) are divided have been given geographic names, while the epochs of other periods (or systems), equally important, are designated simply Upper, Middle, and Lower. The latter terms, however, have served to indicate quite as definitely the epochs of geologic history, which are based chiefly on changes in life as indicated by fossils, but in part on the character of the rocks and their relations to preceding and succeeding beds.

Length of the time divisions.—The age of the earth is an unsolved problem. Many geologists and physicists have, from time to time, worked on this problem, especially on estimates of the time represented in the geologic record since the earth attained approximately its present condition. Among them are such well-known European scientists as Lyell, Croll, Darwin, Sir William Thomson (Lord Kelvin), Tait, Geikie, Huxley, Harker, Mellard Reade, A. Holmes, Joly, Goodchild, Sollas, and Penck. Among American geologists who have contributed to the subject may be mentioned Clarence King, T. C. Chamberlin, R. D. Salisbury, W J McGee, J. M. Clarke, H. S. Williams, J. D. Dana, W. D. Matthew, G. K. Gilbert, G. F. Becker, C. D. Walcott, Charles Schuchert, F. W. Clarke, and Joseph Barrell. The problem has been attacked from different angles, and as the methods employed all involve unknown and imperfectly known elements they must give widely varying results. The calculations have been based on the rate of development of life on the earth throughout the ages, on the quantity of salt in the seas, on earth temperatures, on the rate of deposition of sediments of various kinds adjusted to the maximum known thicknesses of such sediments on the earth, on the rate of denudation or wearing away of the land, and on the heat delivered by the sun. More recent calculations have been based on radioactivity—that is, on estimates of the length of time required to produce given proportions of certain elements through the disintegration of the more complex elements uranium and thorium.

For purposes of comparison the estimates of Williams (1893), Sollas (1909), Schuchert (1910). and Matthew (1914), all of which are calculated on other bases than radioactivity, have been considered together, and the minimum and maximum mentioned by any one of them is given in the second column of the following table, which is adapted from a tabular statement published by Barrell in 1917. In the third column of the table the estimates made by Goodchild in 1896 are given. Goodchild's estimates, like some of the others, are based on a detailed study of the stratigraphic sequence of the rocks, but his results differ widely from the estimates of others on a similar basis and approach closely the figures derived by Barrell from the study of radioactivity. Barrell's figures are given in the fourth column of the table. The table shows that these modern estimates of the age of the earth since the geologic record began range from 48,380,000 years to 1,710,000,000 years. The estimates based on radioactivity have been considered by many scientists excessive, but recently published opinions [1] express the belief that readjustments and recalculations of the estimates based on geology, biology, and astronomy will greatly increase the figures heretofore obtained on those bases, and will tend to bring those results more into harmony with the results based on radioactivity.

Estimates of geologic time, in years

[Adapted from Joseph Barrell (Geol. Soc. America Bull., vol. 28, pp. 884–885, 1917)]

Time divisions	Figures obtained by methods other than radioactivity		Figures obtained by Barrell on radioactivity
	Composite of Williams (1893), Schuchert (1910), Sollas (1909), and Matthew (1914)	Goodchild (1896)	
Cenozoic era	2,100,000–10,800,000	93,400,000	55,000,000– 65,000,000
Quaternary period	100,000– 1,000,000		1,000,000– 1,500,000
Tertiary period	2,000,000– 9,800,000	16,000,000	54,000,000– 63,500,000
Pliocene epoch	500,000– 1,300,000		6,000,000– 7,500,000
Miocene epoch	500,000– 3,000,000		12,000,000– 14,000,000
Oligocene epoch	500,000– 2,000,000	77,400,000	16,000,000
Eocene epoch	500,000– 3,500,000		20,000,000– 26,000,000
Mesozoic era	6,300,000– 9,950,000	191,500,000	135,000,000–175,000,000
Cretaceous period	3,800,000– 4,700,000	------------	65,000,000– 85,000,000
Upper Cretaceous epoch	2,000,000– 2,700,000	31,400,000	40,000,000– 50,000,000
Lower Cretaceous or Comanche epoch	1,800,000– 2,000,000	72,600,000	25,000,000– 35,000,000
Jurassic period	800,000– 3,000,000		35,000,000– 45,000,000
Triassic period	1,700,000– 2,250,000	87,500,000	35,000,000– 45,000,000
Paleozoic era	12,480,000–45,860,000	419,300,000	350,000,000–470,000,000
Carboniferous period	4,700,000– 6,860,000	139,300,000	100,000,000–140,000,000
Permian epoch	1,200,000– 2,000,000	45,000,000	25,000,000– 40,000,000
Pennsylvanian epoch	1,500,000– 2,160,000	31,800,000	35,000,000– 50,000,000
Mississippian epoch	2,000,000– 2,700,000	62,500,000	40,000,000– 50,000,000
Devonian period	1,980,000– 5,000,000	125,000,000	50,000,000
Silurian period	1,500,000– 4,000,000	56,000,000	40,000,000
Ordovician period	1,700,000–15,000,000	57,000,000	90,000,000–130,000,000
Cambrian period	2,600,000–15,000,000	42,000,000	70,000,000–110,000,000
Sum of post-Proterozoic time	20,880,000–66,610,000	704,200,000	540,000,000–710,000,000
Proterozoic era	27,500,000 (Walcott)	------------	700,000,000–1,000,000,000
Algonkian period	17,500,000 (Walcott)	------------	
Archean period	10,000,000? (Walcott)	------------	
Total age of earth	48,380,000–94,110,000	------------	1,240,000,000–1,710,000,000

[1] Chamberlin, T. C., Clarke, J. M., and Brown, E. W., in a symposium on the age of the earth: Am. Philos. Soc. Proc., vol. 61, No. 4, pp. 247–285, 1922.

Thickness of the sedimentary rocks.—As an example of the kind of data used in estimates of geologic time the thickness of the sedimentary rocks may be considered. This thickness, to be sure, varies from place to place, for nowhere is there a complete section with all the geologic systems in complete development. Not only does the thickness of each system vary greatly, even within small areas, but in most places some of the systems are unrepresented. In addition, where the rocks of some systems are thickest the rocks of others are thinnest or absent, having either been deposited and afterward eroded away, or never deposited because the region at the time stood above the sea. In order to estimate the length of time required to form the sediments the scientist must consider the sum of the maximum known thicknesses of the various kinds of rocks deposited during each period, he must determine the average rate at which each kind of rock is deposited, and he must make allowances for erosion and for great time gaps. The following table showing the maximum known thicknesses of the sedimentary rocks of the earth is compiled from the estimates of several European and American geologists, supplemented for some units by more recently published sections:

Maximum known thicknesses of existing sedimentary rocks of the earth

	Feet
Cenozoic	70, 300
Quaternary system	4, 000
Tertiary system	66, 300
Pliocene series (California)	10, 500
Miocene series (California)	20, 800
Oligocene series (12,000 feet in Italy; 10,000 feet in California)	12, 000
Eocene series (23,000 feet in Wyoming, including the "Paleocene" rocks, which have an aggregate thickness of about 10,000 feet; 20,000 feet in Oregon)	23, 000
Mesozoic	74, 900
Cretaceous system	46, 400
Upper Cretaceous series (Wyoming)	20, 400
Lower Cretaceous series (California)	26, 000
Jurassic system (Alaska)	15, 000
Triassic system (Alps, Nevada, British Columbia)	13, 500
Paleozoic	161, 500
Carboniferous system	52, 500
Permian series (Australia)	13, 000
Pennsylvanian series (Oklahoma)	24, 500
Mississippian series (Britain)	15, 000
Devonian system (Britain)	37, 000
Silurian system (Scotland)	15, 000
Ordovician system (Britain)	17, 000
Cambrian system (British Columbia)	40, 000

	Feet
Proterozoic	(?)
Algonkian system (Superior region, 82,000 feet sediments, 22,000 feet volcanic rocks)	82,000
Keweenawan series	50,000
Huronian series	32,000
Archean system. Purely conjectural. Few sediments. Has been estimated at	94,000

Breaks in the geologic record.—Many time breaks occur in the geologic record, which is like a book in which leaves and even chapters are missing here and there. These time breaks mark boundaries between eras, between periods, and between epochs of both long and short duration. Some of them are of great magnitude and cover enormous periods of time, when the rocks that had already been formed were raised above the sea and subjected to the destructive action of the elements. Some of them are of smaller magnitude, and still others represent only minor oscillations of the sea. It is not always easy to determine the value of a particular time break. A break that is considered by one geologist of such magnitude as to form an appropriate boundary between periods or systems may seem to another equally competent geologist to be of minor importance. Hence the discrepancies shown in the classifications given on the chart.

Acknowledgments.—Most of the books cited in this bulletin are in the library of the Geological Survey. Two were loaned to the Survey by the Library of Congress, namely, Annales des sciences naturelles, volume 16, 1829, and Bulletins de la Société vaudoise des sciences naturelles, volume 4, 1856. The books mentioned in the following list are very rare, and no copies of them are known to be in the libraries of Washington, but copies were generously loaned to the Survey as follows:

John Crerar Library, Chicago, Ill.:
- Penny Cyclopædia, vol. 17, 1840.
- Ueber die Stellung der hessischen Tertiär-bildungen: K. preuss. Akad. Wis. Berlin Monatsber., November, 1854.

Library of the Museum of Comparative Zoology at Harvard College:
- Géologie de la période quaternaire, by Henri Reboul, Paris, 1833.

Yale University Library:
- French translation of Charles Lyell's Elements of geology, Paris, 1839, containing an appendix not in the original English edition.

Dr. George P. Merrill, Washington, D. C.:
- Geological essays, by Richard Kirwan, 1779.

The compiler is indebted to members of the United States Geological Survey for most of the translations and for valuable suggestions and criticism.

Use of quotation marks.—The terms printed with quotation marks in this compilation have not been adopted by the United States Geological Survey.

THE ERA TERMS

CENOZOIC ERA

J. Phillips, 1840 (Penny Cyclopædia, vol. 17, pp. 153–154).

Supposing, as we think likely, that general terms for stratified rocks, thus formed upon a consideration of their organic contents, which appear to follow a great law of succession, will be preferred to others based on a view of their mineral qualities, which are certainly subject to repetition, there will be no other difficulty in their construction or application than what may be overcome by the progress of investigation. As many systems or combinations of organic forms as are clearly traceable in the stratified crust of the globe, so many corresponding terms (as Palæozoic, Mesozoic, Kainozoic [Cenozoic], &c.) may be made, nor will these necessarily require change upon every new discovery. For instance, the term Palæozoic may be retained, though it should be found that the application of it ought to be extended so as to include the carboniferous rocks or even the magnesian limestone ("Zechstein" of Germany). This indeed is not unlikely, for the following reasons. * * *

J. Phillips, 1841 (Palæozoic fossils of Cornwall, Devon, and West Somerset: Great Britain Geol. Survey Mem., p. 160).

[See under *Paleozoic era, J. Phillips, 1841*]

It is probable that the terms "Kainozoic" and "Cainozoic" (Cenozoic) as introduced by Phillips in 1840 and 1841 included the "Newer Pliocene" of Lyell, although Lyell in 1839 replaced that term by Pleistocene and restricted Pliocene to his "Older Pliocene." The United States Geological Survey includes the Recent and Pleistocene in the Cenozoic era, but, as shown on the accompanying chart, some authorities exclude from it the Recent, and still others exclude both Recent and Pleistocene. The meaning of the word is recent life.

The Cenozoic era contains more loose and uncompacted rocks than the other geologic eras. Its fossils, which are animals and plants of modern types, as a rule differ from those of the preceding Mesozoic era, although some Mesozoic forms persist even to the present time. The Quaternary period of the Cenozoic era has been believed to mark the advent of man on the earth, and it is therefore popularly known as the "age of man." Although mammals made their first appearance early in the Mesozoic era they reached their maximum development, in numbers and in size, during the Eocene epoch of the Tertiary period. The Tertiary is therefore popularly known as the "age of mammals."

"PSYCHOZOIC ERA"

J. Le Conte, 1877 (Am. Jour. Sci., 3d ser., vol. 14, p. 114).

III. *Historic value of the Present time.*—Most geologists regard the Present as one of the minor subdivisions of the Cenozoic Era, or even of the Quaternary period. More commonly the Quaternary and Present are united as one age—the age of man—of the Cenozoic Era. The Cenozoic is thus divided into two ages; the age of mammals commencing with the Tertiary and the age of man commencing with the Quaternary; and the Quaternary subdivided into several epochs, the last of which is the Present or Recent. But if the views above expressed in regard to critical periods, be correct, then the Present ought not to be connected with the Quaternary as one age, nor even with the Cenozoic as one era, but is itself justly entitled to rank as one of the *primary divisions* of time, as one of the great eras separated like all the other eras by a critical period; less distinct it may be, at least as yet, in species than the others, the inaugurating change less profound, the interval less long, but dignified by the appearance of man as the dominant agent of change, and therefore well entitled to the name *Psychozoic* sometimes given it. The geological importance of the appearance of man is not due only or chiefly to his transcendent dignity, but to his importance as an agent which has already very greatly, and must hereafter still more profoundly modify the whole fauna and flora of the earth. It is true that man first appeared in the Quaternary; but he had not yet established his supremacy; he was still fighting for mastery. With the establishment of his supremacy the reign of man commenced. An age is properly characterized by the *culmination*, not the first appearance, of a dominant class. As fishes existed before the age of fishes, reptiles before the age of reptiles, and mammals before the age of mammals, so man also appeared before the age of man.

We, therefore, regard the Cenozoic and Psychozoic as two consecutive eras, and the Quaternary as the critical, revolutionary or transitional period between. But since the record of this last critical period is not lost and we must place it somewhere, it seems best to place it with the Cenozoic Era and the mammalian age, and to commence the Psychozoic Era and age of man with the completed supremacy of man, i. e. with the Present epoch.

The interval covered by the term "Psychozoic era" is treated by the United States Geological Survey as a part of the Cenozoic era.

MESOZOIC ERA

J. Phillips, 1840 (Penny Cyclopædia, vol. 17, pp. 153–154).

[See quotation under *Cenozoic era*]

J. Phillips, 1841 (Palæozoic fossils of Cornwall, Devon, and West Somerset: Great Britain Geol. Survey Mem., p. 160).

[See quotation under *Paleozoic era*]

As originally defined in the foregoing publications the Mesozoic era included the Cretaceous, "Oolitic" (later renamed Jurassic), and "New Red sandstone" (later replaced by Triassic and in part by Permian). In the same year that Mesozoic was thus defined by Phillips (1841) Murchison introduced the term Permian to include the lower "New Red sandstone" and the "Magnesian limestone" (the latter included in the Paleozoic by Phillips), and assigned the Permian to the Paleozoic era. This restricted the term Triassic to the upper part of the "New Red sandstone" and abbreviated Phillips's definition of Mesozoic by the exclusion of the lower part of the "New Red sandstone." This is the commonly accepted definition of the term to-day, but, as shown in the accompanying chart, there is some disagreement among geologists as to just where the Mesozoic should end and the Cenozoic begin.

The meaning of Mesozoic is middle life. The time covered by it marks the rise and culmination of shellfish with complexly chambered coiled shells, called ammonites, of huge land reptiles called dinosaurs, and of great swimming and flying reptiles. For this reason it is commonly known as the "age of reptiles." It also marks the first appearance of birds (in the Jurassic) and of mammals, and the great development of cycads, an order of palmlike plants (in the Triassic), and of angiospermous plants, to which belong palms and hardwood trees (in the Cretaceous). Mesozoic fossils differ greatly from those of the preceding Paleozoic era and the succeeding Cenozoic era, although some forms of life are common to all three eras.

PALEOZOIC ERA

Rev. A. Sedgwick, 1838 (Geol. Soc. London Proc., vol. 2, No. 58, pp. 684–685).

Class II., or *Palæozoic series*

This class includes all the groups of formations between Class I [see p. 25] and the old red sandstone; and is subdivided as follows:—

1. *Lower Cambrian System.*—All the Welsh series under the Bala limestone. The two great groups of green roofing slate and porphyry on the north and south side of the mineral axis of the Cumbrian mountains. A small part of the slates of Cornwall and South Devon? A part of the slate series of the Isle of Man, etc., etc.

2. *Upper Cambrian System.*—A large part of the Lammermuir chain on the south frontier of Scotland. A part of the third Cumbrian group, commencing with the calcareous slates of Coniston and Windermere. The system of the Berwyns and South Wales. The slates of Charwood forest? All the North Devon and a part of the South Devon series. The greater part of the Cornish series.

3. *The Silurian System.*—The upper part of the third Cumbrian group, chiefly expended in Westmoreland and Yorkshire. The flagstone series of Denbigh shire. The hills on both sides of Llangollen. The region east of the Berwyn chain. The regions described in the papers of Mr. Murchison, from which the types of the system are derived. The lowest part of the culmiferous series?

Over all the preceding comes the *Old Red Sandstone*—divided into three great natural groups in the country bordering the Silurian types of Mr. Murchison; in the northern counties developed in a less distinct manner, chiefly in the form of great unconformable masses of conglomerate, appearing at irregular intervals between the preceding groups and the carboniferous series.

Little notice is taken in the memoir of the crystalline unstratified rocks associated with the several series. Any questions of classification, bearing on their geological epoch, can only be determined by the effects, produced by them on the stratified series, which mark the period of their first protrusion; but for the present this subject is not touched on by the author.

J. Phillips, 1840 (Penny Cyclopædia, vol. 17, pp. 153–154).

PALÆOZOIC SERIES. The fossiliferous strata of earlier geological date than the carboniferous system, and the mountain limestone, are thus designated in the article ORGANIC REMAINS. One of the greatest impediments to a clear exposition of geological truths, is the difficulty of choosing proper general terms to suit classifications founded on limited researches. The ancient terms of Primary, Secondary, and Tertiary Rocks will probably retain their popularity and applicability, because of the simplicity of the truly general idea which they contain in common—the sequence of geological time. In characterizing and naming the subdivisions of these great groups of rocks, geologists have only partially followed out the same principle; every geological investigation of sufficient extent includes, as a principal point, the discovery of the relative antiquity of the subdivisions of Primary, Secondary, and Tertiary strata, but there is seldom an opportunity to frame a corresponding nomenclature, owing to the circumstance that general names, already and indeed long since proposed and adopted by the great body of geologists, cannot without great inconvenience be changed, even when new discoveries or wider generalizations demand their correction.

The term "Transition" was applied to a large section of the Primary rocks, or else used to designate them as a separate class, at a time when true characters could by no means be assigned to them. Among Transition rocks, "Grauwacke" was frequently seen. Hence the term Grauwacke System was commonly used to express a large portion (the upper) of the Primary series of strata.

In progress of rigorous investigation, the absence of organic fossils from the gneiss and mica-schist rocks, and the occasional or ordinary presence of them in the grauwacke series, became generally admitted, and hence the convenient classification of Mr. De la Beche of "Fossiliferous" and "Nonfossiliferous" Primaries, the former being in fact an equivalent term for "Transition Strata." Recent researches into the organization of the fossil plants and animals of those antient strata have produced very strong evidence for believing that, from the Snowdonian Slates, placed by Professor Sedgwick in the lower part of the Cambrian system, to the lower beds of the old redsandstone (at least), one system of organic life prevails—characterised by the preponderance of corals, such as Catenipora and Favosites, shells of Brachiopoda and Cephalopoda, and crustacea of the trilobitic types. It is true that when separate strata, included within the limits of geological time just stated, are compared in respect of their organic contents, distinctions more or less marked appear (as for example, conspicuously in the strata of the Silurian system), yet these mostly turn on nice differences of some of the analogous forms, and may perhaps have only a local value, as we know to be the case in the instance of the oolitic strata.

On the contrary, if we compare the whole series of organic forms found in these Palæozoic Strata, as they are exhibited in Wales or Cumberland, with the whole series of fossils discovered in the carboniferous system of the north of England or the border of Wales, we find not more than 1, 2, or 3 per cent.

of intimately related species. The distinction between the Silurian fossils and those of the mountain limestone is of the same order as that which obtains between the latter series and the fossils of the magnesian limestone. Struck with this fact, Mr. Murchison has suggested for the early groups of strata the title of "protozoic rocks," which (beside one chance of ambiguity from the meaning attached in zoology to the word "Protozoa") seems to assert more than is necessary, perhaps more than is known. We prefer therefore to apply to the same strata the title of Palæozoic, which seems liable to no objection, and which has, we believe, been occasionally employed by Professor Sedgwick.

Supposing, as we think likely, that general terms for stratified rocks, thus formed upon a consideration of their organic contents, which appear to follow a great law of succession, will be preferred to others based on a view of their mineral qualities, which are certainly subject to repetition, there will be no other difficulty in their construction or application than what may be overcome by the progress of investigation. As many systems or combinations of organic forms as are clearly traceable in the stratified crust of the globe, so many corresponding terms (as Palæozoic, Mesozoic, Kainozoic [Cenozoic], &c.), may be made, nor will these necessarily require change upon every new discovery. For instance, the term Palæozoic may be retained, though it should be found that the application of it ought to be extended so as to include the carboniferous rocks or even the magnesian limestone ("Zechstein" of Germany). This indeed is not unlikely, for the following reasons. First, it is the opinion of eminent living geologists (Professor Sedgwick, Mr. Murchison, and others) that in strata which correspond in age to the old red-sandstone, there occur groups of organic remains intermediate in forms and combinations between the types of the Silurian and carboniferous æras. Secondly, it is ascertained that a large proportion of the forms of zoophyta, mollusca, and fishes, which appear in magnesian limestone, are extremely analogous to or even identical with some of the more numerous species of the mountain limestone. At present the Palæozoic series of rocks includes the following formations, placed in the order of position, according to the most recent views:

Old Red-Sandstone.—This in whole or in part is supposed by Mr. Murchison and others to be represented by the calcareous, arenaceous, and argillaceous rocks of North and South Devon, Cornwall, part of Brittany, the Harz, Westphalia; and they prefer to call the series Devonian, from the country where it is supposed to be best developed.

Silurian Rocks.—Mr. Murchison ranks these in four formations, viz. Ludlow Rocks, Wenlock Rocks, Caradoc Rocks, Llandeilo Rocks.

Cambrian Rocks.—Professor Sedgwick subdivides them into Plynlymmon Rocks, Bala Limestone, and Snowdon Rocks.

It is supposed, but perhaps has not been perfectly ascertained, that the rocks of Skiddaw, &c., which come next in order below, are deficient of organic remains. May we propose for these and other lower stratified rocks the term "Hypozoic Series?"

J. Phillips, 1841 (Palæozoic fossils of Cornwall, Devon, and West Somerset: Great Britain Geol. Survey Mem., p. 160).

I have suggested[2] the propriety of extending the application of this term [Palæozoic] so as to make it include not only the "Silurian" group, but all the newer types of organization up to the magnesian limestone; and following out this plan of nomenclature, have presented an outline of a general classi-

[2] "Penny Cyclopædia," articles Geology, Palæozoic rocks, Saliferous system, etc.

fication on the evidence of organic remains, which fortunately clashes very little with the ordinary scheme founded on structural, mineral, and chemical analogies of the rocks.

As this classification will be employed in some of the following pages, it is here offered in the original form:—

Proposed Titles depending on the Series of Organic Affinities.		Ordinary Title.
Cainozoic [Cenozoic] Strata	Upper	=Pleiocene Tertiaries.
	Middle	=Meiocene Tertiaries.
	Lower	=Eocene Tertiaries.
Mesozoic Strata	Upper	=Cretaceous System.
	Middle	=Oolitic System.
	Lower	=New Red formation.
Palæozoic Strata	Upper?	= Magnesian Limestone formation. Carboniferous System.
	Middle?	= (Eifel and South Devon).
	Lower	= Transition Strata. Primary Strata.

(The terms are founded on the verb ζάω or ζώω—to live, combined with καινός—recent [Cenozoic], μέσος—medial or middle [Mesozoic], and παλαιός—ancient [Paleozoic].)

As originally defined, in 1838, the Paleozoic included only the Cambrian, Ordovician, and Silurian periods (or systems) of the present classification. The definition of 1840 added to it the "Old Red sandstone" (Devonian of the present day), and also suggested the inclusion of the overlying Carboniferous, but as the term Carboniferous was then used it did not include Permian. The definition given by Phillips in 1841 added to the Paleozoic not only the Carboniferous as then recognized but the overlying "Magnesian Limestone formation" as well. In 1841 and 1845 the term Permian was introduced by Murchison, De Verneuil, and Von Keyserling to include the "Magnesian limestone" and the lower part of the "New Red sandstone," and the Permian was assigned to the Paleozoic era. This definition of Paleozoic is the one almost universally employed to-day.

The meaning of the word is old or ancient life. In the rocks of the oldest, or Cambrian, period of the Paleozoic era no traces of land animals have been found, brachiopods and the marine crustaceans known as trilobites being the most characteristic animals entombed in the Cambrian rocks, but seaweeds were abundant. In the next period, the Ordovician, shell-forming sea animals, especially cephalopods and brachiopods, became abundant, the culmination of the trilobites was reached, and the first trace of insect life appeared. In the succeeding Silurian period shell-forming sea animals became dominant, especially those related to the nautilus (cephalopods). The Silurian also witnessed the rise and culmination of the marine animals sometimes known as sea lilies (crinoids), and of giant scorpion-like crustaceans (eurypterids), as well as the rise of fishes and reef-building corals. In the Devonian period fishes became abundant, and hence the Devonian is known as the "age of fishes." The Devonian also witnessed the rise of amphibians and land plants. In the closing period of the Paleozoic era, the Carboniferous, club mosses (lycopods) and plants of horsetail and fern types dominated the floral life, while primitive flowering plants and the earliest cone-bearing trees appeared. Among marine animals brachiopods were still the most common invertebrates, and primitive sharks were the most abundant fishes. Reptiles and insects also appeared, and amphibians increased to such an extent that the Carboniferous period is known as the "age of amphibians."

PRE-CAMBRIAN ERA TERMS

The pre-Paleozoic rocks have been classified in many ways, and opinion regarding their classification is still divided, as shown by the accompanying chart and by the pages that follow.

The classification of these rocks on a life basis has led to the introduction of many terms ending in "zoic," regarding the use of which there has been and still is great diversity of opinion. Each one of these zoic terms has, in fact, been applied to both the whole and to one or more parts of the pre-Paleozoic rock assemblage, as shown by the following quotations, which are arranged in the alphabetic order of the terms. Although these quotations have been assembled after considerable research, they are not offered as a complete résumé of the literature bearing on the subject. They will, however, serve to show the diverse usages of the pre-Cambrian zoic terms. The United States Geological Survey classifies all pre-Cambrian rocks under one zoic term, namely, *Proterozoic era.*

"AGNOTOZOIC ERA"

R. D. Irving, 1887 (Am. Jour. Sci., 3d ser., vol. 34, p. 373).

The general term to be used to cover the great pre-Cambrian interval should then express the existence of this early life, and our present ignorance with regard to its nature. During the year and a half that such an addition to geological nomenclature has been under discussion between myself and several of my fellow-geologists, many terms have been proposed and discussed. Some of these have been rejected because, though sufficiently appropriate, they have already been too generally used in other connections. Others again seemed inadmissible because, while expressing well the idea to be presented, they were made up of derivatives from the Greek not ordinarily met with in the English language, and were too cumbersome and pedantic in sound. Others again, like *Proterozoic* (*πρότερος, earlier*), suggested by Mr. Emmons, while simple and made from a Greek word of not too uncommon use, seemed to fail in covering the ground sufficiently. I have therefore been disposed to return to a term early proposed by Professor T. C. Chamberlin, to whom indeed is to be assigned the first suggestion of the use of a single name to cover all of the pre-Cambrian fragmentals. I would advocate, therefore, the use of the term *Agnotozoic* (*ἄγνωτος, unknown; ζωή, life*), to cover all of the geological interval lying between the base of the Cambrian and the summit of the Archean crystallines.

R. D. Irving, 1888 (U. S. Geol. Survey Seventh Ann. Rept., pp. 453–454).

It seems, therefore, desirable that a new term should be introduced of equal classificatory rank with Paleozoic, indicating that these great Pre-Cambrian and Post-Archæan series are zoic in character and that they cannot, as yet at least, be admitted to the Paleozoic series proper. In an article in the American Journal of Science for 1887 (page 373) I advocated the adoption of the term Agnotozoic (ἄγνωτος, unknown; ζωή, life), indicating at once the presence of life and its unknown character. A recognized objection to this term may be based upon the consideration that if definite faunas shall be discovered in these formations or in any of them the term Agnotozoic would be inapplicable. To this it may be replied that it is improbable that such discoveries will be made in all of the formations included under this term and that it will still be needed for the residue. If definite faunas are found in any of them and these prove to be Paleozoic in character, the formation containing them will simply be transferred to the Paleozoic series and the remainder of the formations left under the term Agnotozoic. If, on the other hand, the faunas prove to be diverse from the Paleozoic, a new zoic group bearing a name appropriate to the discovered life will be required in any case, whether the term Agnotozoic or any other imaginable term be now applied to the formation.

Some of my colleagues upon the survey, however, prefer the more noncommittal term Eparchæan, signifying simply the position of these formations upon the Archæan. To this term the same objection applies as to the preceding, that the discovery of a definite fauna would necessarily call for an appropriate zoic classification, under the canons of good nomenclature. In short, it may be safely remarked that, while there is an imperative demand for a separate term adapted to the present needs of the science, any term now proposed must be held subject to future limitation or entire replacement, if any sufficiently distinctive paleontological discoveries shall be made.

The following table shows the arrangement of formations suggested, in which the terms Agnotozoic and Eparchæan are both introduced:

Systems	Groups	Systems
Paleozoic	Carboniferous	Paleozoic
	Devonian	
	Silurian	
	Cambrian (Lower Silurian)	
Agnotozoic or Eparchæan	Keweenawan	
	Huronian	
	(other groups?)	
Archæan	Laurentian (including Upper Laurentian)	Archæan.

T. C. Chamberlin, 1888 (Am. Jour. Sci., 3d ser., vol. 35, p. 254).

Prof. R. D. Irving has advocated the adoption of the term "Agnotozoic" as a comprehensive designation for the fragmental rocks which lie between the base of the Cambrian formations and the summit of the Archæan crystallines, and has credited me with the authorship of the term and the early advocacy of the desirableness of a distinct name for these formations. Concerning this I wish to file a disclaimer; not that I do not fully concur with Professor Irving in this advocacy, for I do most cordially, nor because I suppose it to be a matter of consequence to Professor Irving, since I know that he holds all questions of priority or proprietorship in nomenclature in little esteem, if not in light contempt. I wish to file the disclaimer not because of this special case but out of respect for a general principle in nomenclature, which I hope to see adopted to the displacement of a purely technical and indiscriminative application of the law of priority. I hold that nomenclature of the class in question should rest, not with some individual, who, standing by and looking upon the work of others, may see, perchance before they do, whereunto their labors are growing; nor with some one, who, on the basis of superficial observation and hasty conjecture, throws out first to the world a tentative nomenclature, leaving it to the future and to the labors of others to justify or reject; but on the contrary, I hold it should rest with the patient and thoroughgoing investigator, who by careful and comprehensive study develops an adequate basis for nomenclature, properly sanctioned by a broad and trustworthy array of facts. I have been in some senses a student of the formations to be embraced under the proposed term, but in no such sense as to give me the right of nomenclature under this principle. If, therefore, this term shall be adopted, as I sincerely trust it may, I earnestly desire that it shall stand to the credit of some one who has had a larger part in the actual development of the facts upon which its adoption must rest, among whom I know of no one who has contributed more than Professor Irving.

J. W. Dawson, 1888 (Geol. Soc. London Quart. Jour., vol. 44, p. 803, footnote).

Irving has proposed to call all the formations between the Laurentian and the base of the Cambrian "Agnotozoic;" but the term Huronian seems sufficient at present for this purpose.

E. Kayser, 1893 (Textbook of comparative geology, translated and edited by Philip Lake, pp. 10, 13, 15).

[See quotation under "*Azoic era*"]

E. Haug, 1908 (Traité de géologie, tome 2, pp. 566–586).

Agnotozoic era:
- Algonkian period. In America divided into
  - Keweenawan.
  - Huronian.
- Archean period. In America divided into
  - Laurentian.
  - Keewatin.

C. R. Van Hise, 1908 (Geol. Soc. America Bull., vol. 19, pp. 27–28).

[Proposes *Proterozoic,* instead of *"Agnotozoic,"* to include all pre-Cambrian time. See quotation under *Proterozoic era*]

C. R. Van Hise and C. K. Leith, 1909 (U. S. Geol. Survey Bull. 360, pp. 19–21).

[Propose *Proterozoic,* instead of *"Agnotozoic,"* to include all pre-Cambrian time. See quotation under *Proterozoic era*]

"Agnotozoic" is derived from the Greek words ἄγνωτος (unknown) and ζωή (life). The time covered by it, in both its narrow and its broad sense, is included in the Proterozoic era by the United States Geological Survey. In its original (narrow) usage it corresponds to the Algonkian period. In its broad usage it includes both the Algonkian and Archean periods and corresponds to the Proterozoic era of the United States Geological Survey.

"ARCHEOZOIC ERA"

J. D. Dana, 1872 (Corals and Coral Islands, App., p. 373).

Geological history begins with what has been called *Azoic* time, *azoic* signifying the absence of all life. But the rocks supposed to be Azoic have been found to afford evidence of the existence of the simplest kinds of life during their formation; and the era they represent, is, therefore, more correctly styled the Archeozoic, from the Greek for *beginning* and *life*. The other grand subdivisions of geological time, are as follows: Palæozoic time (named from the Greek for ancient life) * * *.

K. A. von Zittel, 1880 (Handbuch der Palæontologie, Bd. 1, Abt. 1, p. 24).

Palæozoic period:
* * *
Silurian formation at base (including Cambrian).
Archeozoic period:
Primitive slate formation.
Laurentian gneiss formation.
Primitive gneiss formation.

J. D. Dana, 1892 (Am. Jour. Sci., 3d ser., vol. 43, pp. 460–461).

[Proposes the same classification as that given in the next quotation, from the 1895 edition of his Manual of geology. In addition he states:]

The *Algonkian* (or Agnotozoic) beds belong either to the Archæan or to the Paleozoic.

The Archæan division of geological time is of the same category with the Paleozcic, Mesozoic, and Cenozoic; all are grand divisions based on the progress of life, and they include together its complete range. There is no room for another grand division between Archæan and Paleozoic any more than for one between Paleozoic and Mesozoic. In contrast, the Algonkian division is not above the Cambrian in grade, it being based on series of rocks. Its true biological relations are in doubt, because fossils representing the supposed life of the period are unknown, or imperfectly so.

J. D. Dana, 1895 (Manual of geology, 4th ed., pp. 404–413, 440–453).

[Geologic time is divided into] four primary divisions, the Archæan, Paleozoic, Mesozoic, and Cenozoic. [Page 404.]

I. *Archæan Time.*—The beginning of Archæan time was without life; but before it closed conditions had been reached that admitted of the existence of protophytic and protozoic life. [Page 407.]

I. *Archæan Time.*—There are the two divisions, the *Azoic* and the *Archæozoic*, but they are not distinguishable in the rocks. The rocks have been divided into—

1. Laurentian. [Bottom.]
2. Huronian. [Top.] [Page 407.]

[Archæan time is divided as follows:]

Archæozoic æon. Life in its lowest forms of existence:
Era of first animal life.
Era of first plants.

Azoic æon. Without life:
Oceanic era.
Lithic era.
Astral æon, as it has been called, or that of the fluid globe having a heavy vaporous envelope containing the future water of the globe or its dissociated elements, and other heavy vapors or gases. [Pages 440–441.]

The subdivision of Archæan time into Azoic and Archæozoic, here used, is the same as that of the edition of 1874, except that Archæozoic is substituted for Eozoic. The limiting temperature of Archæozoic time is doubtful for several reasons, and especially because of the uncertainty as to the destructive excess of carbonic acid in the air and waters, and, therefore, as to the possibility of the existence of life. [Page 442.]

Subdivisions of the Archæan terranes, and the rocks. Two subdivisions have general acceptance:—

I. The Laurentian.
II. The Huronian era. [Page 445.]

The Keweenaw formation is without fossils, and hence is of uncertain age; but its relations appear to be probably Paleozoic. [Page 447.]

Although fossils, according to present knowledge, are absent from Archæan rocks, or are of questionable character, the existence during the later part of the Archæan of aquatic life in its simplest forms is rendered almost certain by the fact that the temperature of the waters was favorable to it, and by the occurrence among the stratified rocks of beds of limestone; by the abundance in many limestones, and other rocks, of graphite, which constitutes 20 per cent of some layers in Canada; and by the presence in the Huronian of carbonaceous shales or slates containing 40 per cent of carbonaceous materials. The life belonged to that division of Archæan time which is designated, on page 441, the Archæozoic æon; and the Huronian rocks represent the latter part of this æon, if not the whole of it. [Page 453.]

J. Le Conte, 1903 (Elements of geology, revised and partly rewritten by H. L. Fairchild, 5th ed., pp. 293, 294, 295).

Archæozoic era:
Algonkian age. Evidences of life.
Huronian period.
Archæan age. No evidences of life.
Laurentian period.

T. C. Chamberlin and R. D. Salisbury, 1906 (Textbook of geology, vol. 2, pp. 137–138, 162).

On the planetesimal hypothesis, the oldest rocks to which we might hope to gain access would be those referred to the Extrusive eon, during which more or less sedimentary rock was mingled with the volcanic. On this hypothesis, as on the preceding, no sharp line of demarkation would be expected between dominantly sedimentary rocks above, and dominantly non-sedimentary rocks below.

The rock-formations now most widely exposed at the surface are sedimentary, and were therefore formed during the time of atmospheric and hydrospheric dominance, that is, during the great Gradational eon. In not a few places, however, formations of dominantly extrusive-igneous or meta-igneous origin are found, either beneath the prevailing sedimentary rocks, or projecting up through them in such relations as to show their greater age. In many cases these inferior rocks were thoroughly metamorphosed, and in essentially their present condition, before the deposition of the overlying beds, for masses of metamorphic rock derived from them are included in the nonmetamorphic series above. These igneous and meta-igneous formations which antedate the oldest known series of rocks made up chiefly of sediments, are the oldest rock-formations known, and the era during which they were formed is therefore the first era of which there is definite record in the accessible formations of the earth.

These rocks consist of a very complex series of formations, embracing lava outflows, volcanic tuffs, igneous intrusions of various types and exceptional extent, together with some sedimentary deposits, all usually metamorphosed and notably deformed. Distinct fossils have not been found in these rocks, but the occasional presence of (1) carbonaceous shales very similar to younger shales which derived their carbon from organic sources, (2) iron-ore beds similar to those which owe their origin to plant action, and (3) occasional limestones and cherts which, as a class, are usually the products of organic action, are thought to imply the existence of life, and to warrant placing the era when these rocks were formed in the "zoic" group. This view is supported by the theoretical probability that life extended back through a vast period unrecorded by fossils, since the earliest fossils yet found imply a very prolonged antecedent evolution. The era during which, or during the later part of which, this oldest system of accessible rock formation was made, is the Archeozoic era.

Under the planetesimal hypothesis, the oldest known rocks may be confidently referred to the Archeozoic era. * * *

It has been thought by leading geologists especially engaged in the investigation of these formations, that the pre-Cambrian systems of dominantly sedimentary rocks should be separated from the dominantly igneous or meta-igneous complex below.[3] Following their lead, these pre-Cambrian systems of rock, composed chiefly of sediments, are here separated from the Archean, and designated *Algonkian* or *Proterozoic.* * * * [Pages 137–138.]

To the Proterozoic[4] era is assigned the time that elapsed between the close of the formation of the igneous complex and the beginning of the lowest system which is now known to contain abundant well-preserved fossils; or in other words, the time between the close of the Archean and the beginning of the Paleozoic. [Page 162.]

E. Kayser, 1911 (Lehrbuch der Geologie, p. 12).

Eozoic or Proterozoic group (Algonkian).
Azoic or Archeozoic group (Archean).

E. Kayser, 1912 (Lehrbuch der allgemeinen Geologie, 4th ed., p. 138).

Eozoic or Archæozoic rock group (Algonkian).
Azoic or Archean rock group (Urgebirge).

T. C. Chamberlin, 1914 (Cong. géol. internat., 12th sess., Toronto, Compt.-rend., p. 425).

[Explains the basis on which he divides pre-Paleozoic time into two eras—Proterozoic and Archeozoic. See quotation under *Proterozoic era*]

A. P. Coleman, 1915 (Problems of American geology, Yale University Pub., p. 90).

[See quotation under *Proterozoic era*]

[3] Irving, Seventh Ann. Rept., U. S. Geol. Surv., pp. 448–454, and Van Hise, Bull. 86, U. S. Geol. Surv., pp. 491–493.

[4] Proterozoic, as here used, is a synonym for *Algonkian* as used by the U. S. Geol. Surv.

C. Schuchert, 1915 (Textbook of geology, pp. 444–445, 540).

[See quotation under *Proterozoic era*]

H. F. Cleland, 1916 (Textbook of geology, pp. 384, 388).

[See quotation under *Proterozoic era*]

A. Grabau, 1921 (Textbook of geology, p. 20).

[See quotation under *Proterozoic era*]

J. Walther, 1921 (Geologie von Deutschland, 3d enlarged ed., p. 48).

Palæozoic:
* * *
Silurian at base.
Archæozoic:
Cambrian.
Algonkian.
Crystalline rocks.

K. A. von Zittel, 1921 (Grundzüge der Palæontologie, Abt. 1, chart opp. p. 8).

Palæozoic group:
* * *
Cambrian at base (Upper, Middle, and Lower Cambrian).
Archæozoic=Eozoic group (pre-Cambrian, Proterozoic, Algonkian).
Azoic group=Archæan, Urgebirge.

J. Stiny, 1922 (Technische Geologie, pp. 554–559).

Cambrian (Upper, Middle, and Lower).
Algonkian (Eozoic, Archeozoic).
Archæan (Urgebirge).

A. P. Coleman and W. A. Parks, 1922 (Textbook of geology, p. 154).

[See quotation under *Proterozoic era*]

C. Schuchert, 1924 (Textbook of geology, 2d ed., vol. 2).

[See quotation under "*Eozoic era*"]

"*Archeozoic*" is derived from the Greek words ἀρχαῖος (ancient, primitive) and ζωή (life). The time covered by it, as variously used by different authors (except those who include the Cambrian in it), is included in the Proterozoic era by the United States Geological Survey. As originally used it included all pre-Paleozoic time. In later usages it has been applied (1) to the Algonkian period only, (2) to the Archean period only, and (3) to the Cambrian, Algonkian, and Archean periods.

"AZOIC ERA"

R. I. Murchison, E. de Verneuil, and A. von Keyserling, 1845 (The geology of Europe and the Ural Mountains, p. 10*).

To the crystalline masses which preceded that Paleozoic succession to which our researches were mostly directed, we apply the term "Azoic," not meaning thereby dogmatically to affirm, that nothing organic could have been in existence during those earliest deposits of sedimentary matter, but simply as expressing the fact, that in as far as human researches have reached, no vestiges of living things have been found in them, so also from their nature they seem to have been formed under such accompanying conditions of intense heat and fusion, that it is hopeless to expect to find in them traces of organization. * * * In the term Azoic rocks, we include all the crystalline masses belonging to the ancient group of gneiss, together with ancient granitic and plutonic rocks by which they have been invaded. * * * [In footnote:] Hypercritically, it may be said that this word might also be applied to other deposits of subsequent age, in which the organic remains are also obliterated, and thus be merged with *Hypogene* of Lyell. But in our sense the word *azoic* is synonymous with pro-zoic, or before the recognizable traces of life. Professor Phillips has applied the word *Hypozoic* to the same rocks which we term *Azoic*.

J. W. Foster and J. D. Whitney, 1851 (Am. Assoc. Adv. Sci. Proc., vol. 5, p. 4).

The term *Azoic* (from ἀ-, negative, and ζωή, life) was first applied by Murchison and de Verneuil, to designate a class of crystalline rocks, which occur around the Gulf of Finland, whose geological position is below the Silurian System. In it, they include not only gneiss and mica slate, but the igneous rocks, such as granite and diorite, by which they are invaded. We adopt the term, but limit its signification, by applying it to a class of rocks supposed to be detrital in their origin, and to have been formed before the dawn of animal or vegetable life. It comprises the most ancient of the strata which form the crust of the earth, and occupies a distinct position in the geological column; being below the Potsdam sandstone.

J. W. Foster and J. D. Whitney, 1851 (Report on the geology of the Lake Superior land district, pt. 2, p. 3).

Below all the fossiliferous rocks of this [Lake Superior] region, there is a class of rocks, consisting of various crystalline schists, beds of quartz and saccharoidal marble, more or less metamorphosed, which we denominate the *Azoic system*. This term was first applied by Murchison and de Verneuil to designate those crystalline masses which preceded the palæozoic strata. In it, they include not only gneiss, but the granitic and plutonic rocks by which it has been invaded. We adopt the term, but limit its signification to those rocks which were detrital in their origin, and which were supposed to have been formed before the dawn of organized existence.

A. d'Orbigny, 1852 (Cours élémentaire de paléontologie et de géologie stratigraphiques, tome 2, fasc. 2, pp. 263 et seq).

Paleozoic (Silurian at base).
Azoic. The Azoic stratified rocks preceded the appearance of animal life on the globe.

D. Page, 1854 (Introductory textbook of geology, p. 39).

Palæozoic period (ancient life):
* * *
Silurian at base. [Includes Cambrian.]
Azoic period (void of life):
Non-fossiliferous epoch, or Metamorphic system.

J. D. Dana, 1863 (Manual of geology, 1st ed., pp. 130, 131, 134, 142, 145–146; also editions of 1864, 1868, and 1869, same pages).

Preceding these [the "Age of Mollusks, or Silurian," including Potsdam at base], there is the *Azoic* era,—the name being derived from the Greek ἀ- and ζωή, life, and signifying the absence of life. The Azoic rocks are mostly crystalline. [Pages 130, 131.]

The Azoic age is the age in the earth's history preceding the appearance of animal life. The fact of the existence of the globe at one time in a state of universal fusion is placed beyond reasonable doubt. And whatever events occurred upon the globe from the era of the elevated temperature necessary to fusion, down to the time when the climate and waters had become fitted for animal life, are events in the *Azoic* age. The age must, therefore, stand as the first in geological history, whether science can point out unquestionably the rocks of that age or not. [Page 134.]

The Azoic rocks in North America at present include all that are older than the Potsdam sandstone of New York,—the first of the Silurian. [Page 134.]

The Azoic rocks of Canada are divided by Logan into the *Laurentian* [including Keewatin],—including the great part of the system, and embracing all the regions to which we have above particularly alluded,—and the *Huronian,* comprising a narrow band on the borders of Lake Superior and Lake Huron. [Page 142.]

The term "azoic," as here used, implies absence of life, but not necessarily of the lowest grades.

The reasons in favor of the existence of life of some kind are—

1. The formation of limestone strata in the Azoic age like those of the Silurian, in connection with the fact that Silurian and later limestones are known to be mainly made from organic relics. * * *

2. The occurrence of graphite in the limestone and other strata,—graphite being known to be a common result of the exposure of mineral coal or charcoal to a high heat, and, in certain rocks of Rhode Island and Massachusetts, having undoubtedly been made from vegetable remains. * * *

3. The occurrence of anthracite in small pieces in the iron-bearing rocks of Arendal, Norway, which rocks are probably Azoic in age. [Pages 145–146.]

E. Hitchcock and C. H. Hitchcock, 1868 (Elementary geology, pp. 41–43, 60, 63).

Palæozoic (ancient type of organic life):

* * *

Cambrian or Huronian series at base. [Pages 43, 63.]

Azoic (Interzoic and Hypozoic or Laurentian). The term *Azoic* signifies *unfossiliferous*, and is the most satisfactory appellation for these crystalline rocks, which are not only the oldest rocks upon the globe, but are also found among the higher groups. The term *Hypozoic* signifies that the rocks embraced in the system lie beneath those containing fossils. * * * The term Laurentian applies only to the lower part of the Azoic rocks, the upper part forming the Huronian system.

Unstratified or igneous rocks:

Below the Azoic series are the unstratified rocks, which extend to unknown depths.

H. Credner, 1872 (Elemente der Geologie, 1st ed., pp. 264–288).

Paleozoic group (Silurian the basal system).

Azoic group (Primitive, pre-Silurian, Eozoic):

Huronian slate formation (including Cambrian formation in part).

Laurentian gneiss formation.

H. Credner, 1876 (Elemente der Geologie, 3d ed., pp. 353–384); 1879 (Traité de géologie et de paléontologie, 3d ed., pp. 338–365); and 1887 (Elemente der Geologie, 6th ed., pp. 377–408).

Palæozoic group (Silurian the basal subdivision).

Archean group (Primitive, pre-Silurian, Azoic or Eozoic). The word Archean, which does not prejudice the question of the appearance of life on the earth, is preferred to the two others [Azoic and Eozoic]. It is composed of—

Huronian or formation of crystalline slates (including Cambrian formation in part).

Laurentian or formation of primitive gneiss.

J. D. Dana, 1875 and 1880 (Manual of geology, 2d ed., pp. 138–139; 3d ed., pp. 140–160).

The following subdivisions of geological time are here adopted:

I. *Archæan time.*—The beginning, including a very long era without life, and, finally, that in which appeared the earliest and simplest forms of plants and animals.

II. *Silurian age, or age of invertebrates.* * * * [Pages 138–139.] [According to table on p. 142 and the text his Silurian included Cambrian.]

The subdivisions of geological time are, then,—

I. Archæan time, including an Azoic and an Eozoic era, though not yet distinguished in the rocks.

1. Azoic age. [Bottom.]
2. Eozoic age. [Top.]

II. Paleozoic time. * * * [Page 140.]

Archæan time includes strictly, at its commencement, an *Azoic* age, or the era in which the physical conditions were incompatible with the existence of life. But this era, so far as now known, is without recognizable records; for no rocks have yet been shown to be earlier in date than those which are now supposed to have been formed since the first life began to exist. About this early era there is, therefore, little known. By following the lead of ascertained law in physics and chemistry, and the suggestion of astronomy, and also analogies from later geological history, some probable conclusions may be reached. But this is not the place for their discussion, except so far as to state the principal steps of progress. There must have been,—

I. A *first* era, after that of the original nebula, if such there was,—in which the earth was a globe of molten rock, like the sun in brightness and nature, enveloped in an atmosphere containing the dissociated elements of the future waters and whatever else the heat at the surface could throw into a state of vapor.

II. A *second* era, in which cooling went forward until the exterior became solid from cooling, and probably as a crust over a liquid interior. * * *

III. A *third* era, or a continuation of the preceding, carrying forward the cooling to 80° or 100° C. (175° to 212° F.), or *to a temperature admitting of the existence of the simplest forms of vegetable life.* * * *

IV. A *fourth* era, commencing with the beginning of life on the globe,—which beginning was possible, judging from known facts, when the temperature of the waters had cooled down at least to 200° F. It has been supposed that all the Archæan rocks open to view over the earth's surface are those of this last era. But more investigation is required, before it can be regarded as an established fact that none of earlier time are open to investigation. From these rocks in America, two principal periods have been indicated, with other subdivisions. * * * [Pages 147–148.]

This formation in North America was first distinctly recognized in its true importance in the Report of Foster and Whitney on the Lake Superior region, in which it was named the *Azoic system.* Dawson, after his announcement of the animal nature of the Eozoon, suggested the name *Eozoic* (from ἠώς, dawn, and ζωή, life). As the supposed Eozoon may be of mineral nature, its use here is objectionable. * * * [Page 148.]

II. *Periods of the Archæan era.* In Canada, where these rocks in North America are most fully represented, two periods have been recognized: 1, The *Laurentian,* the older, so named from the river St. Lawrence; and 2, the *Huronian.* The estimated thickness of the rocks of the Laurentian period is 30,000 feet; of the Huronian, from 10,000 to 20,000 feet. [Page 151.]

No distinct remains of plants have been observed. The occurrence of graphite in the rocks, and its making 20 per cent of some layers, is strong evidence that plants of some kind, if not also animals, were abundant. * * * [Page 157, under heading *life* (of Laurentian period).]

Animals of the lowest division of animal life, that of Rhizopods among Protozoans, were probably abundant. * * * [Page 158, under heading *life* (of Laurentian period).] Whatever may be the final decision with regard to *Eozoon,* there can be little doubt that Rhizopods existed in Archæan time. [Page 159, under heading *life* (of Laurentian period).]

As the original Huronian has no fossils, there is no basis for a satisfactory determination of its equivalents. It is quite possible that it is Cambrian or Primordial. [Page 160.]

C. Vogt, 1879 (Lehrbuch der Geologie und Petrefactenkunde, pp. 225–235).

Palæozoic group (Cambrian at base).
Lowest formation (Archæan system, Primitive formation, Azoic system, Laurentian and Huronian, Bottom-rocks).

K. A. von Zittel, 1883 (Traité de paléontologie, tome I, pt. 1, p. 22).

Palæozoic era or group:
  * * *
  Cambrian system at base.
Azoic era or group:
  System of primitive schists.
  System of Laurentian gneiss.
  System of fundamental gneiss.

J. D. Whitney and M. E. Wadsworth, 1884 (Mus. Comp. Zool. Harvard Coll. Bull., vol. 7, Geol. ser., vol. 1, No. 11, p. 562).

Proposed chronological arrangement of crystalline rocks:
Azoic:
  Pelodian (argillites).
  Glacian (conglomerates).
  Taconian (limestones).
  Crystallian (quartzites, quartz schists).
  Montalban (mica schists).
  Huronian (diorites, diabases, melaphyrs, chlorite schists).
  Porphyrian (porphyrites).
  Arvonian (felsite, quartz porphyry, petrosilex, jaspilite).
  Norian (gabbro, coarse diabases and diorites).
  Ophian (peridotites, including serpentines).
  Siderian (magnetite, hematite, menaccanite).
  Laurentian (granites, gneisses, syenites).

J. D. Dana, 1892 (Am. Jour. Sci, 3d ser., vol. 43, pp. 460–461) and 1895 (Manual of geology, 4th ed., pp. 440–441).

Archæan:
  Archæozoic æon (life in its lowest forms of existence):
    Era of first animal life.
    Era of first plants.
  Azoic æon (without life):
    Oceanic era
    Lithic era
  Astral æon, as it has been called, or that of the fluid globe having a heavy vaporous envelope containing the future water of the globe or its dissociated elements, and other heavy vapors or gases.

E. Kayser, 1893 (Textbook of comparative geology, translated and edited by Philip Lake, pp. 10, 13, 15).

Azoic or Archæan group: Under the head of Archæan we group together all those rocks which are older than the lowest beds of the Cambrian, and which extend from these as their upper limit to the deepest, so-called Laurentian, gneiss. The terms fundamental or Primitive (terrain primitif of the French), Azoic or Agnotozoic, and Pre-Cambrian have also been used with the same signification.

The Archæan rocks must be considered unfossiliferous, since it has been shown that the supposed fossils found towards the middle of the century in Canada and afterwards in Scotland, Scandinavia, and Bohemia, are of inorganic origin. These supposed fossils occur in crystalline limestone in the gneiss and form nodular masses consisting chiefly of serpentinous material divided by numerous tubes swelling out into cells. They were described as giant Foraminifers under the name *Eozoon*, but have been shown, thanks especially to the minute microscopic researches of Möbius, to be inorganic. On account of this absence of fossils the name Azoic (first used by Murchison in 1845 for the old crystalline mass of Scandinavia) has been applied to these rocks. * * * The strongest evidence of the existence of organized life during the Archæan period, is to be found in the relatively high organization of the oldest known fauna, the Cambrian. The high development of this fauna indeed necessarily forces us to the conclusion that it was preceded by one or more, probably a whole series, of older faunas, the remains of which we may expect in time to find in the Archæan. So long, however, as such remains have not been found, it is advisable instead of the as yet unwarranted term Eozoic, to keep to the expression Archæan introduced by Dana (1874).

K. A. von Zittel, 1903 (Grundzüge der Palæontologie, Abt. 1, pp. 5–6).

Palæozoic group (Cambrian system at base).
Archean (or Azoic) group:
  Primitive slate system.
  Gneiss system.

A. E. Törnebohm and A. Hennig, 1904 (Sveriges geologiska Undersökning, ser. Al, a, p. 6).

Palæozoic series (Cambrian at base).
Azoic series:
  Algonkian.
  Urberg.

K. A. von Zittel, 1910 (Grundzüge der Palæontologie, Abt. 1, pp. 5–6).

Palæozoic group:

* * *

Cambrian system (Upper, Middle, and Lower) at base.

Archean (or Azoic) group:

Primitive slate system.

Gneiss system.

E. Kayser, 1911 (Lehrbuch der Geologie, p. 12).

Eozoic or Proterozoic group (Algonkian).

Azoic or Archeozoic group (Archean).

E. Kayser, 1912 (Lehrbuch der allgemeinen Geologie, 4th ed., p. 138).

Eozoic or Archæozoic rock group (Algonkian).

Azoic or Archean rock group (Urgebirge).

H. Credner, 1912 (Elemente der Geologie, 11th revised ed., pp. 360–380).

Proterozoic group:

Algonkian complex.

Azoic or Archean group.

K. A. von Zittel, 1921 (Grundzüge der Palæontologie, Abt. 1, chart opp. p. 8).

Palæozoic group (Cambrian at base).

Archæozoic = Eozoic group (pre-Cambrian, Proterozoic, Algonkian).

Azoic group = Archæan, Urgebirge.

J. Stiny, 1922 (Technische Geologie, pp. 554–559).

Cambrian (Upper, Middle, and Lower).

Algonkian (Eozoic, Archeozoic).

Archæan (Urgebirge).

C. Schuchert, 1924 (Textbook of geology, 2d ed., vol. 2).

[See quotation under "*Eozoic era*"]

"Azoic" is derived from the Greek ἀ- (without) and ζωή (life) and means having no trace of life. The time covered by it in its different usages is included in the Proterozoic era by the United States Geological Survey. In its earlier and in some of its later usages the term was applied to all pre-Paleozoic time. In other later usages it has been applied (1) to all pre-Potsdam time, (2) to the Huronian epoch and the Archean period, (3) to the Archean period only, and (4) to a hypothetical interval preceding all known rocks.

"COLLOZOIC AGE"

A. C. Lane, 1917 (Am. Jour. Sci., 4th ser., vol. 43, p. 46, pl. 1).

For a time the early ocean might remain as acid as iron chloride is, and in such an acid or fresh ocean no animals would tend to secrete hard parts until the concentration of salts reached and passed the optimum for some cell activity, when the extra lime would be secreted as a pathological reaction. They would be jelly-like (colloidal) and this would be a Collozoic age,[5] but for that very reason might easily and rapidly evolve in various directions.

In the chart forming Plate I of the volume cited above the following subdivisions are given:

Collozoic:
- Animikian series.
- Algoman revolution (granite and gneiss).
- Huronian system.
- Laurentian revolution (granite and gneiss).
- Grenville series.

Azoic:
- Keewatin series.
- Coutchiching series.

"Collozoic" is derived from the Greek words κόλλα (glue or gelatine) and ζωή (life) and means protoplasmic life. The time covered by it is included in the Proterozoic era by the United States Geological Survey.

"EOBIOTIC ERA" AND "EOMORPHIC ERA"

C. H. Hitchcock, 1888 (Internat. Cong. Geol., American committee reports, Philadelphia, p. A14; P. Frazer, reporter).

Prof. Hitchcock suggests *Eobiotic* in place of Eozoic, as it is better to use the Greek word signifying animal life; and also because of a previous use of Eozoic. He thinks it would be better still to say *Eomorphic* in allusion to the fact that the Huronian beds are almost the first which show the existence of sedimentation.

Eo is derived from the Greek ἠώς (dawn); biotic from βιωτικός (pertaining to life); and morphic from μορφή (form). The time covered by these terms is included in the Proterozoic era by the United States Geological Survey.

"EOZOIC ERA"

J. W. Dawson, 1868 (Acadian geology, 2d ed., p. 658) and 1891 (4th ed., p. 658).

The Huronian and Laurentian periods. The formations last described carry us far back through the long ages of the earth's geological history to the beginning of the Palæozoic period; but still older rocks, indicating still earlier periods, are known to geologists. These, until lately, were regarded as azoic, or destitute of remains of life; but the discovery of *Eozoon Canadense* now entitles them to the name Eozoic, or those that indicate the morning of that great creative day in which the lower forms of animal life were introduced upon our planet. * * *

---

[5] Collozoic is a synonym for Huronian, or Eozoic, nearly, denoting the stratified rocks before the Cambrian in which the existence of life may be inferred, and connoting the supposition that the absence of ordinary fossil remains in them is due to the fact that the animals had not yet developed hard parts, (for the reason as I have supposed that the concentration of base had not passed the physiologic optimum, and the ocean water was soft or acid,) and were yet colloidal or jelly-like.

B. von Cotta, 1872 (Die Geologie der Gegenwart dargestellt und beleuchtet, pp. 89–98).

Cambrian.
Eozoic:
Crystalline schists (including, in Canada, quartzite and talc slates, Laurentian rocks, and crystalline schists interbedded with Eozoon-bearing granular limestone and serpentine).

J. D. Dana, 1875 and 1880 (Manual of geology, 2d ed., pp. 138–139; 3d ed., pp. 140–160).

Paleozoic time.
Archæan time:
Eozoic age.
Azoic age.

[See quotation under "*Azoic era*"]

J. Le Conte, 1882 (Elements of geology, pp. 280, 281, 282) and 1891 (Elements of geology, pp. 282, 283).

Archæan or Eozoic[6] era:
Huronian.
Laurentian.

J. W. Dawson, 1888 (Internat. Cong. Geol., American committee reports, Philadelphia, p. A6; P. Frazer, reporter).

Sir J. W. Dawson prefers the term "Eozoic" [to Archean], and would have it include all the Pre-Cambrian strata.

A. Winchell, 1889 (Geological studies or elements of geology, 3d ed., pp. 361–369).

Eozoic Great System. *Eozoic*, unlike *Azoic* (formerly employed), can never become inapplicable through the progress of discovery. The rocks next before the *Eozoic* were perhaps strata now melted away. The divisions of the Great System:

Keweenian system.
Huronian system.
Laurentian system.

J. Walther, 1910 (Lehrbuch der Geologie von Deutschland, p. 40).

Eozoic era:
Cambrian.
Algonkian.
Crystalline schists.

E. Kayser, 1911 (Lehrbuch der Geologie, p. 12).

Eozoic or Proterozoic group (Algonkian).
Azoic or Archeozoic group (Archean).

E. Kayser, 1912 (Lehrbuch der allgemeinen Geologie, 4th ed., p. 138).

Eozoic or Archæozoic rock group (Algonkian).
Azoic or Archean rock group (Urgebirge).

---

[6] Dawn of animal life.

A. Tornquist, 1913 (Grundzüge der geologischen Formations- und Gebirgskunde, p. 41).

Upper Eozoic:
- Jotnian formation.
- Jatulian formation.

Middle Eozoic:
- Kavelian formation.
- Lodogian and Bottnian formations.

Lower Eozoic (Azoic):
- Granite, gneiss, and crystalline schists.

J. Park, 1914 (Textbook of geology, pp. 306–307).

Eozoic[7] era. This group includes all the rocks of pre-Cambrian age that reach the surface or have been laid bare by denudation. * * *

In the Lake Superior region of North America, where the Eozoic has its greatest and perhaps most typical development, the succession recognized by American geologists is as follows, the name Archæan being restricted to the lower highly crystalline complex of altered rocks:—

Algonkian:
- (1) Keweenawan (Copper-bearing series).
- Unconformity.
- (2) Huronian:
  - Upper.
  - Unconformity.
  - Middle.
  - Unconformity.
  - Lower.

Unconformity.

Archæan:
- (3) Keewatin.
- Eruptive unconformity.
- (4) Laurentian.

A. Grabau, 1921 (Textbook of geology, p. 20).

[See quotation under *Proterozoic era*]

C. Schuchert, 1924 (Textbook of geology, 2d ed., vol. 2).

Proterozoic:
- Killarney revolution (granites).
- Algonkian:
  - Keweenawan series.
  - Huronian series.
- Timiskamian:
  - Algoman revolution (granites).
  - Sudburian-Doréan series. (The pre-Huronian position of these formations is not yet definitely established, according to Leith.)

Archeozoic or Archean:
- Laurentian revolution (granites).
- Loganian:
  - Keewatin-Coutchiching series.

---

[7] Gr. Eos=the dawn, and zoe=life.

Classification hypothetic; no known rock record.
Eozoic. (Dawn of unicellular life.)
Azoic. (Lifeless.) Includes oceanic era, lithic era, and astral era of Dana.
Cosmic or astronomic time.

The time covered by "Eozoic era," as thus variously used, is included in the Proterozoic era by the United States Geological Survey. As originally defined "Eozoic" was applied to all pre-Paleozoic time. In its later usages it has been applied (1) to all Cambrian and pre-Paleozoic time, (2) to pre-Paleozoic time only, (3) to the Algonkian period only, (4) to Huronian and Laurentian (including Keewatin) time, (5) to a part only of the Algonkian period, and (6) to a hypothetical pre-Keewatin interval.

"HYPOZOIC ERA"

J. Phillips, 1855 (Manual of geology, pp. 76–89).

In the following description of strata, we shall retain the general titles of Primary, Secondary, and Tertiary Strata, combining with them a parallel set of names—Hypozoic, Palæozoic, Mesozoic, and Cainozoic strata—and divide them into several systems and formations according to certain properties, or in agreement with their elective associations. [Page 76.]

Hypozoic Strata: These strata, which have the aspect of being derived from decomposed granitic rocks, with several subordinate and associated strata all devoid of organic remains, constitute, according to the concurring testimony of geological observers, the lowest group of the whole series of Neptunian deposits. [Page 80.]

The limestone associated with the truly ancient gneiss and mica slate is destitute of organic remains. The gneiss and mica system may therefore be considered as *hypozoic*, or beneath the strata which contain reliquiæ of *palæozoic* life. [Page 87.] There are strong grounds for believing that what we now call *hypozoic* strata were really formed when no organic life was manifested on the globe. [Page 88.]

[In table on page 624 the pre-Paleozoic is called *Prozoic? period.*]

Hypozoic: A term proposed in the former edition of this work for the lowest primary strata, such as gneiss, mica schist, &c., found below all those which contain organic remains. ὑπό, below [or under], ζωή, life=Azoic (Mur.). [Page 655.]

The time covered by the term "Hypozoic" is included in the Proterozoic era by the United States Geological Survey. The term was probably first published by J. Phillips in 1840, in the Penny Cyclopædia.

"PROGONOZOIC" AND "PROGONIC"

J. J. Sederholm, 1914 (Cong. géol. internat., 12th sess., Toronto, Compt.-rend., pp. 383–384).

POSSIBILITY OF THE USE OF GROUP NAMES WITH THEORETICAL MEANINGS

As long as it is impossible to correlate the Pre-Cambrian series in different parts of the world with approximate certainty, the introduction of terms of group rank and world-wide significance for divisions of this complex is more a theoretical than a practical question. Obviously, the name Algonkian, which is analogous in form to the names applied to systems, cannot always continue to be applied to a division of group rank. The Algonkian and Archæan are, no doubt, at least of the same magnitude as the younger groups, and may possibly even comprise several groups. Various names with theoretical meanings have been proposed, such as *Eparchæan, Proterozoic, Archeozoic, Eozoic, Agnotozoic,* etc. Chamberlin and Salisbury regard Archeozoic as an older group than the Proterozoic, while Van Hise and Leith, in their important work, "The Pre-Cambrian Geology of North America," the vade-mecum of every Pre-Cambrian geologist, recognize only one pre-Palæozoic group, the Proterozoic. If we add to the Palæozoic, which already means something old, an older Proterozoic, and an even more ancient Archeozoic, the form of this terminology, with almost as many comparatives as ultra-hyper-super-dreadnought, seems to violate the principles of good word-building. Why should the Pre-Cambrian be added as appendices to the classification of the younger groups, when they form a realm of no less chronological importance?

Moreover, the "zoic" character is proved in few cases, which makes a general use of most of these words difficult. This reason induced Irving to propose the word *Agnotozoic,* which has lately been adopted also by Haug. But, as I have pointed out before, this word implies a *contradictio in adjecto,* the organisms being either wanting, in which case the group is not *zoic,* or existing, in which case the term *agnotus* is not justified. I have tried to eliminate these difficulties by proposing the term *Progonozoic,* the group of the *ancestral* organisms; this can also be used in the modified form *Progonic.* However, I feel most inclined to propose the introduction of the latter term, not as a designation of the youngest Pre-Cambrian, but as an equivalent for Pre-Cambrian, that would mean a declaration of independence on the part of Pre-Cambrian geology against the geology of the younger groups. This seems justified by the fact that such different methods are employed in the investigation of these respective fields of inquiry. The Progonic could in such case be further subdivided, as I have proposed before, into Neo-Progonic, Meso-Progonic and Archeo-Progonic.

But these proposals are new and have not yet undergone the ordeal of criticism, hence it would be unwise to propose now the adoption of any such term. For my part I think it would be better to leave to the future the adoption of any theoretical names for the different Pre-Cambrian groups, or for the whole of the Pre-Cambrian. But if the Congress should prefer to take any action on this point, I hope that it will consider the terms which I have proposed.

No action was taken by the Congress. The United States Geological Survey's term *Proterozoic era* corresponds to the time interval for which Sederholm suggested the term "*Progonozoic*" or "*Progonic.*"

PROTEROZOIC ERA

S. F. Emmons, 1888 (letter to Persifor Frazer, dated May 25, 1887, published in Internat. Geol. Cong., American committee reports, Philadelphia, pp. A58–A60).

With Irving, Chamberlin, and Walcott I think that the Huronian, Keweenawian, and Grand Cañon series, and whatever other clastic formations occur between the Cambrian and the Archean, should be included in one grand group of equivalent rank with the Archean, Paleozoic, etc., and since the term Paleozoic has by long use become so indelibly impressed upon geological classification that it would be difficult to give it up, I would suggest that the name *Proterozoic* should be given to this new group, signifying that its life was earlier than that of the other groups, without committing ourselves as yet to the statement that it was the first to appear upon the earth. [Page 59.]

S. F. Emmons, 1888 (Internat. Geol. Cong., American committee reports, Philadelphia, p. 13; P. Frazer, reporter).

Dr. [S. F.] Emmons suggests that the beds referred to by Irving [those between the Cambrian and the Archean], be grouped together as " Proterozoic."

This name seems preferable to Agnotozoic, both because to select our ignorance of a terrane as a means of identifying it is to select that which all the terranes have most certainly in common; and also because the term Proterozoic is elastic and better adapted to serve as a temporary scaffolding until more of the true history of the earlier rocks becomes known. But *Eozoic* or *Eobiotic* seems better than either.

[On page 42 of the foregoing report, under the " Conclusions " of the Congress, it was provided that the name for the division between the Laurentian and the Cambrian should be one of the following: " Eozoic, Proterozoic, Eobiotic, Eomorphic, Agnotozoic, etc."]

C. R. Van Hise, 1892 (U. S. Geol. Survey Bull. 86, pp. 492–493) and 1896 (U. S. Geol. Survey Sixteenth Ann. Rept., pt. 1, pp. 761–762).

It is, however, necessary to recognize that the carrying downward of the term Cambrian to cover not only the great thicknesses of rocks which are now included in it, but all pre-Cambrian clastics, will probably make the Cambrian as great as or greater than all the subsequent periods put together.

That this is inadvisable is plain, and the clastic rock masses below the Olenellus fauna are so enormous that the proposal to introduce a general term like Agnotozoic as the equivalent of Paleozoic, Mesozoic, and Cenozoic, to cover this great group, is a conservative one. Irving foresaw that the term would be objected to, because sooner or later the life will become to a greater or less degree known, and he suggested as an alternative for Agnotozoic, Eparchean, in contradistinction to Archean, which was reserved by him to cover the Basement Complex. As the character of the life of this group is already beginning to be known, it seems to me that the term Proterozoic, considered for the place by Irving (7th Ann. Rept. U. S. G. S. for 1885–86, p. 454), but rejected, is preferable to either Agnotozoic or Eparchean.

In a conference of the members of the United States Geological Survey, called by the Director at Washington (Tenth Ann. Rept. U. S. Geol. Surv., for 1888–89, Report of the Director, p. 66) these terms were discussed with reference to atlas-sheet mapping, although there was no question on the part of anyone as to the necessity for some such term. Recognizing the impracticability of the certain correlation with one another of the one or more pre-Cambrian clastic series which occur in the various regions, and recognizing the fact that for use in mapping a uniform plan must be adopted, some one suggested that a term of the same class as Cambrian, Silurian, and Devonian should be selected for rocks here included, and to occupy this place the term Algonkian was proposed and accepted. The proposed general scheme of classification for the lower part of the geological column is as follows:

Paleozoic:
- Carboniferous.
- Devonian.
- Silurian.
- Cambrian.

Proterozoic:
  Algonkian.
Archean:
  Archean.

A. Geikie, 1893 (Textbook of geology, 3d ed., pp. 680, 684) and 1903 (Textbook of geology, 4th ed., pp. 867–868).

The Geological Record is classified into five main divisions: (1) Pre-Cambrian, also called Archæan, Azoic (lifeless), Eozoic (dawn of life), or Proterozoic (earliest life); (2) Palæozoic (ancient life) or Primary. [Page 680.]

Various terms have been proposed for this complex assemblage of rocks, such as Primitive, Proterozoic, Azoic, Agnotozoic or Archæan. * * * To prove that any region of crystalline schists may be "Primitive," "Azoic," or "Archæan" we must first find these rocks overlain by the oldest fossiliferous formations. Where no evidence of this kind is available, the use of precise terms, which are meant to denote a particular geological era, is undesirable. There seems good reason to believe that the asserted "Archæan" age of many tracts of schistose and granitoid rocks rests on no better basis than mere supposition, and that as the study of regional metamorphism is extended, the so-called "Archæan" areas will be proportionately contracted. Several distinct systems of mineral masses can be shown in some regions to exist beneath the base of the Palæozoic formations, differing so greatly in petrological characters, in tectonic relations, and probably also in mode of formation, that they cannot, without a very unnatural union, be arranged in one definite stratigraphical series. For the present it seems to me least objectionable to adopt some vague general term which nevertheless expresses the only homotaxial relation about which there can be no doubt. For this purpose the designation "Pre-Cambrian," already in use, seems suitable. The rocks which I would embrace under this epithet may include a number of separate systems or formations which have little or nothing in common, save the fact that they are all older than the base of the Cambrian rocks. Until our knowledge of these ancient masses is much more extensive and precise than it is at present I think it would be of advantage to avoid the adoption of any general terminology that would involve assumptions as to their definite place and sequence in the geological record, their mode of origin, their relation to the history of plant and animal life, or their identification in different countries. [Page 684.]

T. C. Chamberlin and R. D. Salisbury, 1906 (Textbook of geology, pp. 137–138, 162).

[See quotation under *"Archeozoic era"*]

A. P. Coleman, 1906 (Jour. Geology, vol. 14, pp. 62–63).

Now that it has been proved that water-formed sediments, sometimes in large amounts, belong to the basal complex and are older than the Laurentian eruptives in the Great Lakes region, where these rocks have been most widely studied, should not the western geologists revise their point of view and drop either the "Proterozoic" or the "Azoic," or both, from their nomenclature?

C. R. Van Hise, 1908 (Geol. Soc. America Bull., vol. 19, pp. 16–19, 26–28).

The wisdom of the conclusions of the geologists who selected the terms Algonkian and Archean for the two major divisions of the pre-Cambrian has since been confirmed by considerations which have developed since the adoption of the terms. As has been seen, when the terms Agnotozoic and Proterozoic were proposed by Irving in the sense now conveyed by Algonkian, it was known that the rocks there placed contained positive evidence of life, but it was supposed that the inferior group of the pre-Cambrian contained no evidence of the existence of life. It has since been ascertained that in the Archean all the evidences of life shown by the Algonkian exist, with the exception of the few imperfect fossils which are now known in the latter group. Thus there arises, if zoic terms are to be used, the necessity for the introduction of another zoic term for the Archean (and, as has been seen, Archeozoic has been suggested) ; or, if this be not done, it is necessary to extend one zoic term to cover all of the pre-Cambrian rocks to the base of the earth formations.

The objection to a dual zoic division for the pre-Cambrian rocks is that their life is not known to be different. When we say Paleozoic and Mesozoic, we understand the terms to indicate a great known faunal difference. We think not so much of the rocks, their lithological contrasts and the differences of the physical conditions of their formation. as of the life contrast. The rocks which contain a Paleozoic fauna are Paleozoic; those which contain a Mesozoic fauna are Mesozoic. The separation of the rocks of the pre-Cambrian into Proterozoic and Archeozoic premises a fundamental difference in the fauna of the two eras for which there is no evidence. In short, the zoic division is an unverified assumption which the future may or may not justify.

On the other hand, this objection can not be raised against the terms Algonkian and Archean. Their use is justified by the facts in the field, which inevitably lead to the dual classification of the pre-Cambrian formations on a physical basis. The above gives sufficient reason for continuing to adhere to them.

However, the great physical contrasts of the Archean and Algonkian and the profound unconformity separating the two, marking one of the greatest physical revolutions of the world, doubtless does correspond to great life changes. There has been a tendency to place more and more emphasis on the physical breaks between the Paleozoic and the Mesozoic, and the Mesozoic and the Cenozoic, and to regard the differences of life of these eras as largely due to physical revolutions; consequently we should expect the great physical revolution separating the Archean and Algonkian to have resulted in important life changes; and while I shall use the terms Algonkian and Archean because they correspond by definition to the physical facts on which the dual division of the pre-Cambrian is made, if others prefer the terms Proterozoic and Archeozoic, I shall not quarrel with them, after having pointed out that fossil evidence can not be given to justify this life classification, and that the use of these terms is based on faith in future progress rather than on achieved results.

The Archean is a series dominantly composed of igneous rocks, largely volcanic and for extensive areas probably submarine. Sediments are subordinate. The Algonkian is a series of rocks which is mainly sedimentary. Volcanic rocks are subordinate. * * *

To the dual division of the pre-Cambrian emphasized it has been objected that it can not everywhere be applied. To this objection instant agreement is made. It may be equally well said that the Paleozoic can not everywhere be separated from the pre-Paleozoic. * * *

In the classification of the Algonkian presented by Willis for China he introduces into the nomenclature of the pre-Cambrian the words "Neo-Proterozoic" and "Eo-Proterozoic." I wish to question this suggested practice, since I can see no philosophical basis on which such a division can be made; nor do the facts as described seem to me to require any such division. Indeed, no adequate reason is advanced or even suggested for the selection of one unconformity rather than another of those in the Algonkian as the basis of the division. If the use of these terms results in the practice becoming at all general, it will be believed by the students beginning geology and soon by the geologists themselves that Eo- and Neo-Algonkian or Proterozoic in one region correspond with those of the other, and this would be certain to lead to error. I know of no region in which emphasis on one break in the Algonkian more than others is justified, and if this be not the case, the division is purely theoretical rather than factitious. In short, I foresee confusion and no advantage in the arbitrary introduction of the two proposed terms which have no philosophical basis or definite facts in the field which justify them; for their use amounts to the introduction of zoic terms for the divisions of the Proterozoic, and thus the objection made (pages 16-17) to Proterozoic and Archeozoic for the major divisions of the pre-Cambrian applies with much greater force to Eo and Neo divisions of the Proterozoic.

CONCLUDING STATEMENT

In view of the foregoing considerations I present the following classification of the pre-Cambrian as representative of the best current views:

Algonkian	One or more series in various geological provinces separated by unconformities. To this series local names are applicable.
Unconformity.	
Archean	Keewatin. Eruptive unconformity. Laurentian.

Whether the physical contrasts which separate the Archean and Algonkian are such as to justify the belief that corresponding to them are two life groups which may be called the Proterozoic and Archeozoic, I leave the future to determine, and adhere to the terms which have arisen as a result of inductive studies of pre-Cambrian geology.

Those who decline to accept a dual zoic division of the pre-Cambrian may still favor a single zoic term to comprise the two groups. Thus Émile Haug, professor of geology in the University of Paris, in his textbook on geology, which has just appeared, so uses the term Agnotozoic. But if the consensus of opinion turns in this direction, it would be better, I think, to use Proterozoic rather than Agnotozoic as the life term. If the term Proterozoic be decided on for all pre-Cambrian rocks, for the two major divisions of the Proterozoic, the terms Algonkian and Archean clearly have precedence and right of way from every point of view, and this Haug recognized by making them the major divisions of his Agnotozoic. This clearly emphasized the standing these terms have gained and to which their clear definitions and general applicability entitle them.

It has also been suggested, but, so far as I know, never in print, that the term Proterozoic be extended to the bottom of the column, and that the two divisions of the Proterozoic thus defined be Earlier and Later. This proposal would amount to an indirect dual division of the pre-Cambrian emphasized in this paper. Such usages would simply introduce other terms for the major divisions of the pre-Cambrian having a meaning equivalent to that of Archean and Algonkian. The only result of the acceptance of the proposals, so far as I can see, would be the avoidance of these terms. The ideas of those who as a result of many years' work have formulated the fundamental principles upon which the division of the pre-Cambrian is based would be taken, but their

1146—25——4

terms rejected and other terms introduced in their stead, which, as terms merely, are very objectionable.

In closing I wish to express my strong belief that the dual division of the pre-Cambrian into two great groups of rocks seems now as firmly established as the division between any other two groups; indeed, the major contrasts between the Archean and Algonkian, in the character of the rocks and the earth conditions which they represent, are probably greater than between any other two. The only other two which have anything like such contrasts are the Algonkian and the Paleozoic, and this difference is not in the nature of the materials or the physical conditions obtaining during their depositions, but in the absence of definitely recognized life forms in the older and the presence of a highly developed fauna in the newer. Also the division of the Archean into Laurentian and Keewatin is firmly established, and Archean is entitled to a group place in the geological column.

It is also clear that the Algonkian should have the place of a group in the geological column.

C. R. Van Hise, 1909 (Jour. Geology, vol. 17, pp. 121–122). (Discussing F. D. Adams's paper in same journal.)

I fully discussed the major classification of the pre-Cambrian in my presidential address before the Geological Society a year ago, and gave reasons for the primary divisions of the pre-Cambrian into the Archean and Algonkian. In that address I gave objections to a zoic classification, similar to but not identical with that which Dr. Adams adheres to. His proposed major classification is eo-proterozoic, meso-proterozoic, and neo-proterozoic. These terms imply that the pre-Cambrian had three distinctive life periods, an *eo*, a *meso*. and a *neo*. This may be the case, but until fossils are found in the pre-Cambrian in sufficient abundance to justify a zoic classification, there can be no sufficient warrant for proposing that the major divisions of the pre-Cambrian be made upon a zoic basis.

C. R. Van Hise and C. K. Leith, 1909 (U. S. Geol. Survey Bull. 360, pp. 19–21).

The United States Geological Survey has since 1889 recognized a dual division of the pre-Cambrian into Archean and Algonkian. The senior author has favored the term Proterozoic (earlier life) as the era equivalent to the Algonkian. His proposed classification of the pre-Cambrian as given in the first edition of this bulletin (Bulletin No. 86) and repeated in the Sixteenth Annual Report of the United States Geological Survey, except that "Agnotozoic" is omitted, reads as follows:

Era or group.	Period or system.
Paleozoic	Cambrian and others
Agnotozoic or Proterozoic	Algonkian
Archean	Archean

When it was proposed to use "Agnotozoic" or Proterozoic as the equivalent of Algonkian it was not known that the Archean contained sediments.

A few fossils had been found in Algonkian rocks. Thus there was a certain basis for using the term Proterozoic as equivalent to Algonkian. But carbonaceous shales, limestones, and iron formation rocks extend to the very bottom of the known geological column, suggesting existence of life in the earliest rocks. However, the life remains of the pre-Cambrian are far too scant to warrant any attempt at subdivision of the pre-Cambrian on the "zoic" basis. The major classification of the pre-Cambrian has been made upon a physical and not a paleontological basis. For this reason, therefore.

the writers prefer to use the terms Archean and Algonkian, without separate "zoic" equivalents.

Our proposed classification of the pre-Cambrian is as follows:

Algonkian	One or more series in various geological provinces, separated by unconformities. To these series local names are applicable.
Unconformity.	
Archean	Keewatin. Eruptive unconformity. Laurentian.

Chamberlin and Salisbury, in their textbook of geology, have proposed the divisions Proterozoic and Archæozoic for the rocks which we here call Algonkian and Archean, but such "zoic" division is not founded on evidence furnished by fossils and represents a hope of the future rather than achieved results. It seems probable from the great physical contrasts in the Archean and Algonkian that this proposed "zoic" division would be justified if we could know the life of these two eras, though this is yet a speculative belief based upon general principles.

Émile Haug, realizing the difficulty of dividing the pre-Cambrian on the "zoic" basis, has proposed to use only a single "zoic" term for all of the pre-Cambrian rocks. For this term he has chosen the word "Agnotozoic," which he separates into Archean and Algonkian. If Professor Haug's plan be followed, it seems to us that the preferable term for this place is Proterozoic rather than "Agnotozoic."

However, since the proper choice of "zoic" terms can be made only by future development of knowledge, and there is no consensus of opinion on the matter, we shall avoid introducing the "zoic" nomenclature into this discussion, confining ourselves, as has been said, for the major subdivisions of the pre-Cambrian to the terms Algonkian and Archean, the forms of which correspond with the physical basis upon which the separation is actually made.

F. D. Adams, 1909 (Jour. Geology, vol. 17, p. 115).

- Pre-Cambrian:
  - Neo-Proterozoic:
    - Keweenawan-Athabasca series.
    - Upper Huronian or Animikie-Nastapoka series.
  - Meso-Proterozoic:
    - Middle Huronian.
    - Lower Huronian.
  - Eo-Proterozoic:
    - Keewatin series.
    - Laurentian system.

E. Kayser, 1911 (Lehrbuch der Geologie, p. 12).

- Eozoic or Proterozoic group (Algonkian).
- Azoic or Archeozoic group (Archean).

H. Credner, 1912 (Elemente der Geologie, 11th revised ed., pp. 360–380).

- Palæozoic group (Cambrian at base).
- Proterozoic group:
  - Algonkian complex.
- Azoic or Archean group.

T. C. Chamberlin, 1914 (Cong. géol. internat., 12th sess., Toronto, Compt.-rend., p. 425).

T. C. Chamberlin (Chicago), stated briefly the grounds on which the Pre-Cambrian is divided into Proterozoic and Archeozoic, to which allusion had been made. A portion of the Pre-Cambrian sediments present the products of mature disintegration, while the earlier portions are usually characterized by partial or immature disintegration. The former are best typified by the great beds of quartzite, that imply the complete disintegration of large quantities of quartz-bearing rock and the subsequent assortment and reduction of its quartz particles. The shales and schists imply the same process, but in their metamorphosed condition they are less easily and safely distinguished from pyroclastic and other material of different origin. Mature disintegration implies some restraining agency that held the rock in place while the slow weathering process completed its work; otherwise the products of incomplete disintegration would have mingled with quartz and given an arkose or equivalent product. In the later ages the chief restraining agency was the mantle of vegetation, so that this view favours the existence of a vegetal covering of the land as far back as great terranes of quartzite occur. By hypothesis the classification thus comes to have a semiorganic basis; but this is not essential to the classification which is based on the dominant processes attending the sedimentation. The Proterozoic is thus made to include terranes that bear great quartzite formations. The earlier formations not so characterized are grouped into the Archeozoic.

W. G. Miller and C. W. Knight, 1914 (Canada Bur. Mines Rept., vol. 22, pt. 2, pp. 3, 125).

The crystalline limestones and other Grenville sediments in southeastern Ontario constitute a series of great thickness, and are found to be of pre-Laurentian age. The great volume of the sediments older than the Laurentian appears not to justify the separation of the Laurentian and earlier rocks from those of later pre-Cambrian age. In other words, a dual subdivision of the pre-Cambrian into an upper characteristically sedimentary group above the Laurentian and a lower igneous complex, including the Grenville, is not logical. Hence the writers do not make use of the terms Algonkian and Archean, or Proterozoic and Archeozoic, employed by many authors. * * *

In the author's opinion there appears to be no logical reason for a dual subdivision of the pre-Cambrian into Archean and Algonkian, or Archeozoic and Proterozoic, either on the basis of proportion of sediments or on that of life development. As regards metamorphism, there is a normal progression downward from that of the younger to the older groups, Fig. 60 [photograph]. The Temiskamian rocks are more highly metamorphosed than are the Animikean, and less metamorphosed than the Grenville. Moreover, the thickness of the pre-Laurentian sediments is great.

C. Schuchert and J. Barrell, 1914 (Am. Jour. Sci., 4th ser., vol. 38, pp. 18–19).

To note in descending order certain of the problems presented in the present table: the attention may be turned first to the use of the names Proterozoic and Archeozoic, with their popular rendition as the Age of Primitive Marine Invertebrates and the Age of Unicellular Life. The reason for this usage is the desire for conformity with the system of classification used for the later geologic ages. The Proterozoic, however, is broken here into an early and a late division, separated by a period of profound diastrophism, following a use made by Coleman in the Dana Memorial Lectures on the Silliman Foundation, given at Yale University in December, 1913, and to be published during 1914 by the Yale University Press. The limitations of these divisions are thus structural rather than biologic, but this is true in a measure also of the later eras, as argued by Chamberlin.[8] As the names of successive great divisions of earth history, to be applied in widely separated regions, these terms Archeozoic and Proterozoic imply a less definite correlation than the more localized terms of Paleolaurentian, Neolaurentian, and Algonkian, used here for the Canadian Shield. For this reason these "zoic" names appear to have real value, as well as for the fact that by their use harmony is maintained through the whole scheme of geologic chronology. The nature of the faunas of the Proterozoic and Archeozoic is unknown, as is also the time in earth history when the Metazoa first rose to dominance over the Protozoa. The dividing line therefore cannot be drawn from biologic evidence; but even if a fair knowledge of the life of these times was possessed, it is probable that it would be found gradational to a considerable degree, and these broad names as here used could still apply without doing violence to the biotas of the Paleo and Neolaurentian.

W. G. Miller and C. W. Knight, 1915 (Jour. Geology, vol. 23, pp. 591–593).

A dual subdivision of the pre-Cambrian, as shown in Table II, is employed by many authors. It is purely arbitrary, and is now known to be based on a misconception as to the relations of the rocks. It was believed, or assumed, that the greatest unconformity within the pre-Cambrian is that at the base of the "Lower Huronian," as the term is used by the U. S. Geological Survey. Such, however, has not proved to be the case. There is no proof that the unconformity at the base of the Timiskamian is of less magnitude than that at the base of the Animikean, of the author's classification, or vice versa. According to Coleman, the various sedimentary series of the Timiskamian, his Sudbury series, where most fully developed, appear to have an approximate aggregate thickness of 29,000 feet. Elsewhere these sediments are also known to have great thickness.

The term "Eparchean Interval," concerning which there has been so much discussion in the past, should now be discarded. The so-called Lower and Middle Huronian rocks of the classic area of Lake Huron lie above and not beneath it. There are now known to be two great "intervals" in the pre-Cambrian, that beneath our Animikean and that beneath our Timiskamian, and not merely one as has been assumed.

Moreover, a dual subdivision of the pre-Cambrian cannot be justified on the basis of differences in metamorphism or other characteristics of the rocks. Normally there is a gradual increase in degree of metamorphism from the youngest to the oldest. In the province of Ontario the Animikean rocks are only slightly metamorphosed or disturbed, while the Timiskamian are disturbed and frequently rendered schistose, and the Loganian are highly metamorphosed.

Sediments, Grenville, occur in great volume in the Loganian. Hence the "Archean" cannot be said to be essentially igneous, as assumed at one time. Moreover, ordinary stratigraphic methods, which have been cited as a test as to whether certain groups of rocks should be classed as Archean or otherwise, can be applied in studying the Grenville. This has been shown by the author's work in southeastern Ontario.

---

[8] Van Hise and Leith, Pre-Cambrian Geology of North America, Bull. 360, U. S. Geol. Surv., 1909, p. 21.

Briefly, it may be said that the discovery of the true relations of the Timiskamian destroys the argument for a dual classification of the pre-Cambrian.

[They give (p. 598) the following classification for Ontario:]

Pre-Cambrian of Ontario:
- Keweenawan epoch (deposition).
- Animikean epoch (deposition).
- Algoman epoch (intrusive granites).
- Timiskamian epoch (deposition).
- Laurentian (granite intrusions).
- Loganian.
  - Grenville epoch (deposition).
  - Keewatin (largely basic volcanic rocks).

A. P. Coleman, 1915 (Problems of American geology, Yale Univ. Pub., p. 90).

Late Proterozoic:
- Keweenawan.
- Upper Huronian } Typical Huronian.
- Lower Huronian } Typical Huronian.

Early Proterozoic:
- Laurentian granite and gneiss.
- Sudburian=Temiscaming, Pontiac, etc.

Archæozoic:
- Granite eruptive through lower series.
- Keewatin and Grenville.

C. Schuchert, 1915 (Textbook of geology, pp. 444–445, 540–541).

Late Proterozoic era (primitive life):
- Algonkian major division:
  - Keweenawan period.
  - Animikian period.
  - Huronian period.

Early Proterozoic era (primitive life):
- Neo-laurentian major division:
  - Algomian revolution.
  - Sudburian period.

Archeozoic era (primal life; age of unicellular life):
- Paleo-laurentian major division:
  - Laurentian revolution and igneous invasion.
  - Keewatin period } Grenville.
  - Coutchiching period } Grenville.

In regard to the use of the names Archeozoic and Proterozoic, for the Age of Unicellular Life, and the Age of Primitive Marine Invertebrates, respectively, the following should be stated. As the post-Proterozoic eras are marked by an abundance of life preserved as fossils, it is highly desirable to bring out this fact in the names through the ending *zoic*, which means life. In the pre-Cambrian eras, however, fossils are exceedingly scarce and a classification of the formations on this basis cannot be developed, yet it is established that life existed throughout the Proterozoic and in all probability the Archeozoic as well. Therefore, the usage of *zoic* in these names is also desirable and harmonizes them with those used for the later ages, even though the classification of the rocks in the older eras is by geologic structure rather than by fossils. Because no direct and accepted evidence of life has been found in the Archeozoic era some geologists prefer to call it *Archean* (means very old), a noncommittal term once applied to all pre-Cambrian formations. *Azoic* (without life) and *Eozoic* (dawn life) are other terms which have been used, but in this book Archeozoic is preferred because it means oldest or primal life, a significance in harmony with our present conception.

A. C. Lawson, 1916 (California Univ. Dept. Geology Bull., vol. 10, No. 1, chart opp. p. 18).

Paleozoic? era.
- Algonkian (period, system).
  - Keweenawan (epoch, series).
  - Animikian (epoch, series).

Eparchean interval.

Archean era.
- Algoman revolution.[9]
- Huronian (period, system).
  - Temiskamian (epoch, series).
  - Bruce (epoch, series).
- Epilaurentian revolution.
- Laurentian revolution.[9]
- Ontarian (period, system).
  - Grenville (epoch, series).
  - Keewatin (epoch, series).
  - Coutchiching (epoch, series).

H. F. Cleland, 1916 (Textbook of geology, pp. 384, 388).

Paleozoic era and group.

Pre-Cambrian eras:
- Proterozoic era and group (early life).
  - Upper Proterozoic (Keweenawan).
  - Middle Proterozoic (Upper Huronian).
  - Lower Proterozoic:
    - Middle Huronian.
    - Lower Huronian.
- Archeozoic era and group (beginning of life):
  - Laurentian.
  - Keewatin.

A. Grabau, 1921 (Textbook of geology, p. 20).

Proterozoic era (Primary in part; Algonkian):
- Keweenawan system.
- Animikean system.
- Huronian system.

Eozoic era (Primary in part; Archæan in part):
- Algoman revolution.
- Sudburian system.

Archæozoic era (Primary in part; Archæan in part):
- Laurentian system.
- Keewatin system.

[9] Adams (Problems of American Geology, p. 63) takes exception to placing the Laurentian and Algoman granites in the sequence of formations on the ground that they are intrusive masses and not members of the stratigraphic succession. It may be urged, however, that the sequence is chronological as well as stratigraphic and in the standard scale we need a term for these two periods of batholithic development. Perhaps the terms Laurentian revolution and Algoman revolution used in the tabulation will meet the objection.

A. P. Coleman and W. A. Parks, 1922 (Textbook of geology, p. 154).

Archean or pre-Cambrian:
- Proterozoic era:
  - Late Proterozoic period:
    - Keweenawan epoch.
    - Animikie epoch.
    - Huronian epoch.
  - Early Proterozoic period:
    - Algoman epoch.
    - Sudburian or Timiskamian epoch.
- Archeozoic era:
  - Laurentian epoch.
  - Keewatin and Grenville epochs.

C. Schuchert, 1924 (Textbook of geology, 2d ed., vol. 2).

[See quotation under "*Eozoic era*"]

Proterozoic is derived from the Greek words πρότερος (earlier, former, anterior, fore) and ζωή (life). A shorter form ("Protozoic") was introduced by Sedgwick in 1838, to apply to all pre-Cambrian time in case the rocks should be found to contain organic remains. (See definition of "Protozoic era," which follows.) The term *Proterozoic* was originally applied to the Algonkian period only. In later usages it has been, by different authors, applied (1) to all pre-Paleozoic time and (2) to the Algonkian period only. The United States Geological Survey has since 1907 applied the term to all pre-Paleozoic time represented by rocks visible for study.

"PROTOZOIC ERA"

Rev. A. Sedgwick, 1838 (Geol. Soc. London Proc., vol. 2, No. 58, p. 684).

Class I. *Primary stratified groups.*—Gneiss, mica slate, etc. etc. Highlands of Scotland and the Hebrides. Crystalline slates of Anglesea and the S. W. coast of Carnarvonshire.

The series generally without organic remains; but should organic remains appear unequivocally in any parts of this class, they may be described as the *Protozoic system.*

Class 1. (a). The crystalline slates of central Skiddaw forest, and the upper Skiddaw slate series. The whole is inorganic and intermediate between Class I and Class II. [The Skiddaw slates are now known to be of Ordovician age, and not intermediate between the Paleozoic and the "Protozoic," as originally supposed.]

Class II., or *Palæozoic series.*—This class includes all the groups of formations between Class I. and the old red sandstone; and is subdivided as follows: * * * [See under *Paleozoic era.*]

J. Phillips, 1855 (Manual of geology, p. 658).

Protozoic. The strata containing the earliest of the forms of life; the supposed first series of animals and plants. πρῶτος (first), ζωή (life) = primordial.

A. Stoppani, 1873 (Corso di geologia, vol. 2, pp. 161–175).

Palæozoic era (Cambrian at base).
Protozoic era:
Huronian (strata with *Eozoon canadense*).
Laurentian
Azoic era:
Intermediate Azoic terrain.

The term "Protozoic," introduced by Rev. A. Sedgwick in 1838, was suggested as a name for the pre-Cambrian rocks in case they should be found to contain organic remains. The word is derived from the Greek πρῶτος (first) and ζωή (life). Since this term was introduced the younger pre-Cambrian rocks, or those in America now commonly called Algonkian, have yielded fossils, consisting of crustaceans, brachiopods, and seaweeds, but the older pre-Cambrian rocks, or those now commonly called Archean, have not yielded any indisputable fossils, although many geologists and biologists are of the opinion that a low order of life existed during the Archean period.

"PROZOIC ERA"

J. Phillips, 1855 (Manual of geology, p. 624).

[On pages 76–89 the term "Hypozoic" is applied to the pre-Paleozoic rocks, but in the table on page 624 the pre-Paleozoic is called "*Prozoic? period.*"]

F. M. Endlich, 1878 (U. S. Geol. and Geog. Survey Terr. Tenth Ann. Rept., p. 103).

Prozoic. In preference to the word "azoic," I use the term "prozoic." It presents a more ready definition than the former of the idea that it is intended to convey. Many groups of geological epochs are "azoic," but by no means was their genesis, as such, prior to the appearance of life upon the earth. * * * It often becomes a matter of considerable difficulty to discriminate between prozoic and metamorphic rocks.

"Prozoic" is derived from the Greek words πρό (before) and ζωή (life) and means "belonging to the period before the appearance of life on the earth." The time thus designated is included in the Proterozoic era by the United States Geological Survey.

THE PERIOD AND EPOCH TERMS

QUATERNARY PERIOD (OR SYSTEM)

J. Desnoyers, 1829 (Observations sur un ensemble de dépôts marins plus récens que les terrains tertiaires du bassin de la Seine, et constituant une formation géologique distincte; précédées d'un aperçu de la non simultanéité des bassins tertiaires: Annales sci. nat., vol. 16, pp. 171–214, 402–491).

What I wish especially to prove is that the series of Tertiary deposits continued, and even began in the more recent basins, a long time perhaps after the basin of the Seine had been entirely filled up, and that these later formations, Quaternary,[10] so to speak, should not retain the name alluvial any more than the true and ancient Tertiary formations from which they must also be distinguished.

The rocks described by Desnoyers in the foregoing paper included marine, diluvial, alluvial, lacustrine, and volcanic deposits, the most recent of which were said to belong to the "actual and contemporary period."

Henri Reboul, 1833 (Géologie de la période quaternaire, pp. 1–5, Paris).

The fossil remains of the Tertiary terranes almost all belong to extinct species. One encounters only a few analogues of species still living under other latitudes and in other places than those where fossil species are found. This is why we should call Quaternary[11] the subsequent period, the terranes of which are characterized by animal and vegetable species like those actually living in the same places. The names Néomastonian and Anthropéïan are suitable also to this period, since it is conspicuous principally by the appearance of new mammals and especially of quadrupeds and of man. * * *

This period, considered in its connection with the succession of time, is divided naturally into two epochs; one, pre-historic, which embraces all the time anterior to the most ancient monuments of human societies; the other, which commences with these monuments and merits alone the name historic. The geognosy of the times occupied by the history of peoples is very limited and of slight interest. But this science alone remains to throw some light on the series of events that took place during the pre-historic epoch when men lived without leaving other monuments of their presence than the osseous débris or the products of some rude industry.

---

[10] This expression is used here merely for the sake of brevity, and not to establish a sharp boundary between these more recent Tertiaries and the older, hitherto recognized; there being in my opinion no real boundary between them, and there being perhaps a more marked boundary between the lower and the middle group of deposits more recent than those of the Seine. For fear that my opinion in this respect may be considered as unsound, or exaggerated, I have abandoned the word Quaternary, which I wished at first to apply to all the deposits more recent than those of the Seine basin. [Page 193.]

[11] M. J. Desnoyers is, I think, the first who proposed the name "Quaternary terranes," but those to which he applied it (the shell marls, the crags, the terranes of Herault) are only a division of the Tertiary class. If this division was admitted the *Néomastonian or Anthropéian* sediments should be called *quinurius*. The Tertiary terranes are then reduced to a few isolated basins, analogous, or supposedly analogous, to that of Paris.

[Table opp. p. 1]

Table of geologic periods and epochs

Periods	Epoch		Subdivisions of terranes
4 Quaternary of Néomastonian	Historic		
	Anti-historic		
3. Tertiary or Palaio-mastonian		Alluvium	
		Upper	Lacustrine
			Marine
		Lower	Lacustrine Marine
2. Secondary or Ammonean		Upper	Cretaceous Oolitic or Jurassic
		Middle	Liassic Keuper Peneon Pœcilian
		Lower	Houiller [coal measures] Intermediate Protozoic
1. Primary		Upper	
		Lower	

A. Morlot, 1856 (Notice sur le quaternaire en Suisse: Soc. vaudoise sci. nat. Bull., vol. 4, pp. 41–45; read March 15, 1854).

In the paper cited above Morlot recognized the following subdivisions of the Quaternary period: First glacial epoch, diluvian epoch, second glacial epoch, and modern epoch.

These earliest definitions of Quaternary included in it the deposits now classified as Recent and Pleistocene or "Glacial," which is the definition adopted by the United States Geological Survey. The meaning of the word is "of the fourth order or rank." At the time of its introduction the preceding divisions of geologic time were called Tertiary, Secondary, and Primary. "Secondary" and "Primary" have long since become obsolete, but Tertiary and Quaternary are still in common use.

The Quaternary period is characterized by animals and plants of modern types, and is commonly called the "age of man."

The present practice of most geologists includes all of the glacial epoch in the Quaternary period, and recognizes in it five ice stages separated by four interglacial stages, or intervals when the ice retreated and vegetation returned. To these glacial and interglacial stages the following names have been given in America, from areas where the record left by the ice of each stage is well shown or the soils of the interglacial stages are well developed:

Wisconsin stage of glaciation (the latest).
Peorian stage of deglaciation.
Iowan stage of glaciation.
Sangamon stage of deglaciation.
Illinoian stage of glaciation.
Yarmouth stage of deglaciation.
Kansan stage of glaciation.
Aftonian stage of deglaciation.
Nebraskan stage of glaciation, also called pre-Kansan stage (the oldest).

The correctness of including all the glacial deposits of these successive ice stages in the Pleistocene epoch of the Quaternary period is not beyond question. In some unglaciated areas there have been found marine, fluviatile, and lacustrine deposits which appear to correspond in age to glacial deposits of glaciated areas but which contain fossils (Sicilian) that paleontologists are inclined to class as of upper Pliocene age.

The names applied to the ice stages of Europe are given in the classification of Haug, the third on the accompanying chart. In the present state of knowledge the authorities on glacial geology correlate the Wurmian stage of Europe with the last, or Wisconsin, stage of America, the Rissian stage of Europe with the Illinoian stage of America, the Mindelian stage of Europe with the Kansan of America, and the Gunzian of Europe with the pre-Kansan of America.

Some geologists who have made a specialty of glacial geology are now of the opinion that the Recent epoch, in which we are living, may be but an interglacial stage of the Pleistocene, and not a distinct epoch in the earth's history.

RECENT EPOCH (OR SERIES)

C. Lyell, 1833 (Principles of geology, vol. 3, pp. 52–53).

SUBDIVISIONS OF THE TERTIARY EPOCH

Recent formations.—We shall now proceed to consider the subdivisions of tertiary strata which may be founded on the results of a comparison of their respective fossils, and to give names to the periods to which they each belong. The tertiary epoch has been divided into three periods in the tables; we shall, however, endeavour to establish *four*, all distinct from the actual period, or that which has elapsed since the earth has been tenanted by man. To the events of this latter era, which we shall term the *recent*, we have exclusively confined ourselves in the two preceding volumes. All sedimentary deposits, all volcanic rocks, in a word, every geological monument, whether belonging to the animate or inanimate world, which appertains to this epoch, may be termed *recent*. Some *recent* species, therefore, are found *fossil* in various tertiary periods, and, on the other hand, others, like the Dodo, may be *extinct*, for it is sufficient that they should once have co-existed with man, to make them referable to this era.

Some authors apply the term *contemporaneous* to all the formations which have originated during the human epoch; but as the word is so frequently in use to express the synchronous origin of distinct formations, it would be a source of great inconvenience and ambiguity, if we were to attach to it a technical sense.

We may sometimes prove, that certain strata belong to the recent period by aid of historical evidence, as parts of the delta of the Po, Rhone, and Nile, for example; at other times, by discovering imbedded remains of man or his works; but when we have no evidence of this kind, and we hesitate whether to ascribe a particular deposit to the recent era, or that immediately preceding, we must generally incline to refer it to the latter, for it will appear in the sequel, that the changes of the historical era are quite insignificant when contrasted with those even of the newest tertiary period.

Although from the arrangement of headings in the foregoing quotation the Recent formations seem to be included in the Tertiary "epoch," on page 61 Lyell gives a "Synoptical table of Recent and Tertiary formations," in which the Recent is treated as distinct from and younger than the Tertiary. As above defined, however, Recent includes the Pleistocene and Recent of the present classification, as explained by Lyell in the 1873 quotation under *Pleistocene epoch*. The Pleistocene as now understood was removed from the Recent by Forbes in 1846 and by Lyell in 1873, as explained in the quotations from their papers that are given under *Pleistocene epoch*.

PLEISTOCENE EPOCH (OR SERIES)

C. Lyell, 1839 (Elements of geology, French translation, appendix, pp. 616–621, Paris, 1839).

[See Lyell's explanation below, which is essentially a translation of the French passage cited above]

C. Lyell, 1839 (Charlesworth's Mag. Nat. Hist., vol. 3, p. 323, footnote).

In the Appendix to the French translation of my "Elements of Geology," I have proposed, for the sake of brevity, to substitute the term *Pleiocene* for *Older Pleiocene*, and *Pleistocene* for *Newer Pleiocene*, from the Greek πλεῖστος, most, and καινός, recent. I have been induced to make this innovation, because in proportion as the progress of science calls for subdivisions of these periods, the longer terms have become more inconvenient. We have often for example, to speak of the *older* and *newer* portion both of the *older* and *newer* pleiocene epochs. To the pleiocene period I have referred those strata which contain between 40 and 70 per cent of recent species of shells; to the pleistocene those in which the percentage exceeds 70. [In introducing the term Pliocene in 1833 Lyell spelled the name *Pliocene*, and not as here quoted by him.]

Lyell's original definition of "Newer Pliocene" is quoted under *Pliocene epoch*. The above original definition of Pleistocene applied the term to older deposits than are now included in it, as explained by Lyell in 1873 (see quotation given beyond). The following definition by Forbes is the commonly accepted definition of the present day:

Edward Forbes, 1846 (On the connexion between the distribution of the existing fauna and flora of the British Isles, and the geological changes which have affected their area, especially during the epoch of the Northern Drift: Great Britain Geol. Survey Mem., vol. 1, pp. 402–403).

Throughout this essay I have used the epithet "glacial," in connexion with the words "epoch," "beds," and "formation," in a sense which purists in geological phraseology may consider objectionable. I have used it, however, for want of a better, and as an expression of convenience, always intending to express by the phrase "Glacial epoch" that section of geological time which was typically distinguished by the prevalence of severe climatal conditions through a great part of the northern hemisphere, and during which those marine accumulations, in part truly sedimentary deposits, which have been called "Northern drift," were formed. I have selected the word "glacial," in order to remind the geologists of the ice-charged condition of our seas during that epoch,—conditions which probably did not prevail during its earlier stage, and the gradual disappearance of which marked its conclusion. As, however, it appears almost certain that the "Glacial epoch," and that of the deposition of Sicilian and Rhodian tertiaries were synchronic it would be advisable to adopt some term to express that geological period as a whole, and by which to designate the formations of that period. Mr. Lyell's term, "pleistocene," would, perhaps, best serve the purpose, as that of "newer pliocene" is not sufficiently distinctive, and may lead to confusion. In this case, among English tertiaries, the coraline crag would rank as *meiocene*, the red crag as *pleiocene*, the glacial beds as *pleistocene*, and the megaceros freshwater marls and marine raised beaches as two stages of *post-tertiary.*

In 1873 Lyell withdrew his definition of Pleistocene (which applied to a late Pliocene division) and adopted Forbes's 1846 definition (which applied to deposits of early post-Tertiary age), as shown in the following quotation:

C. Lyell, 1873 (Antiquity of man, 4th ed., pp. 3–4).

Nomenclature.—Some preliminary explanation of the nomenclature adopted in the following pages will be indispensable, that the meaning attached to the terms Recent, Pleistocene or Post-Pliocene, and Post-Tertiary may be correctly understood. In the first edition of my "Principles of Geology," in 1830 [vol. 3, first published in 1833] I divided the whole of the Tertiary formations into three groups; the Eocene, Miocene, and Pliocene, characterized by the percentage of extinct shells, or shells then unknown as living, which they contained. I then again subdivided the Pliocene into Older and Newer Pliocene. All strata of later age than these, or such as contained none but recent shells, I termed "Recent," and these strata were subsequently subdivided into Recent and Post-Pliocene, united under the general term Post-Tertiary.

In 1839 I proposed the term Pleistocene as an abbreviation for Newer Pliocene, and it soon became popular, because adopted by the late Edward Forbes in his admirable essay "On the Geological Relations of the existing Fauna and Flora of the British Isles;" but he applied the term almost precisely in the sense in which I have hitherto used Post-Pliocene, and not as short for Newer Pliocene. In order, therefore, to prevent confusion, I thought it best entirely to abstain from the use of Pleistocene in future; but in a note to my "Elements of Geology," I advised such geologists as wished to retain Pleistocene to use it as strictly synonymous with Post-Pliocene. This was done by many, and has been found so convenient that it has now been very generally adopted; therefore, as the term Post-Pliocene has many inconveniences, especially that of being often confounded with Post-Tertiary, I propose, in this volume, to adopt the term Pleistocene for the lower subdivision of the Post-Tertiary, retaining only sometimes in brackets the word Post-Pliocene, to remind the reader who is accustomed to that term that Pleistocene is used as its synonym.

As recognized by the United States Geological Survey and most other geologic authorities, the pre-Recent or Pleistocene epoch includes the deposits of the Great Ice Age, as it is popularly known, and contemporaneous marine, fluviatile, lacustrine, and volcanic rocks. In some areas it also probably includes some preglacial deposits and some postglacial deposits older than those of the Recent epoch. (See further explanation under *Quaternary period*, where the names of the ice stages of the Pleistocene epoch are given.)

TERTIARY PERIOD (OR SYSTEM)

Giovanni Arduino, 1760 (Nuova raccolta di opuscoli scientifici e filologici del padre abate Angiolo Calogierà, tom. 6, pp. 142–143, Venice, 1760).

To the most illustrious Sig. Cav. Antonio Valisuieri, Professor of Natural History in the University of Padua; second letter from Giovanni Arduino, Veronese-Vicentino:

On his various observations made in diverse parts of the territory of Vicenza and elsewhere, concerning the theory of the earth and mineralogy.

* * *

The tertiary mountains, or rather hills, are formed of a succession of strata of hard limestone of consolidated or unconsolidated sand and gravel, and of rock, and vitrified earth (but different from that of the primary mountains) and of earth of various colors.

These especially ought to be called tertiary, not only because they are seen in superposition on the slopes of the secondaries where the same hills terminate, but also because the greater part of their materials are shells, fragments, and comminuted sea shells; and fragments, flints, sand and mud derived from the disintegration of a great part of the primary and secondary mountains that evidently were once much higher and much less or perhaps not at all dissected and free from so many gullies, valleys, and ravines that are formed by the running of water.

As shown by the foregoing quotation, the original definition of the Tertiary system was contained in a letter written by Arduino to Antonio Valisuieri, professor of natural history in the University of Padua, and published in 1760, in vol. 6 of the "New collection of the scientific and philologic tracts of Father Abbot Angiolo Calogierà," a copy of which is in the Royal Library Vittorio Emanuele, at Rome, Italy, shelf number 79, A 15.

Arduino's pioneer researches were followed by those of Cuvier, Brongniart, and Deshayes in the Paris Basin, of D'Halloy in Belgium, and of Webster, Buckland, and Lyell in England. Large numbers of fossils were collected by these geologists in the different regions in which they worked. Upon the basis of their combined fossil studies Lyell in 1833 (see quotation under *Pliocene epoch*) divided the Tertiary into three "periods," to which he applied the names Eocene (the oldest), Miocene, and Pliocene (the youngest). The latter he divided into "Newer Pliocene" and "Older Pliocene." In 1839 Lyell restricted Pliocene to his "Older Pliocene," and introduced the new name Pleistocene for his "Newer Pliocene." (See quotation under *Pleistocene epoch.*) In 1846 Forbes adopted the term Pleistocene for the glacial deposits, evidently in the belief that Lyell had included these deposits in his Pleistocene "period." (See quotation from Forbes's report, under *Pleistocene epoch.*) Lyell, however, intended the term Pleistocene to apply to the latest Tertiary marine, lacustrine, and fluviatile deposits. But Forbes's application of the name to the glacial deposits became so popular that Lyell ceased to use Pleistocene for the "Newer Pliocene" sediments for which he had proposed it, and in 1873 (see quotation under *Pleistocene epoch*) he withdrew the name in that sense and adopted Forbes's application of it to the glacial deposits.

Lyell's subdivisions of the Tertiary (Eocene, Miocene, and Pliocene) continued to be the recognized divisions until 1854, although as studies of the Tertiary had progressed it was found that contemporaneous deposits were being called upper Eocene by some workers and lower Miocene by other workers. In 1854, therefore, Beyrich introduced the name Oligocene for the time interval covered by this series of transitional deposits. Thus a fourth term came to be added to the time divisions of the Tertiary period. These four epochs of the Tertiary are now recognized the world over.

As the Eocene deposits came to be better known the fossil plants contained in their basal part were believed by Schimper to differ sufficiently from those found higher in the Eocene to justify the separation from the Eocene of the rocks containing them. In 1874, therefore, he introduced the term "Paleocene" for the time interval covered by these rocks. Whether these deposits should be separated from the Eocene, and, if separated, whether they should be included in whole or only in part in the Tertiary, are questions upon which geologists and paleontologists are not even to-day fully agreed.

Although Lyell's names Eocene, Miocene, and Pliocene and Beyrich's Oligocene are recognized and used the world over, the modern conception of these Tertiary subdivisions is not strictly in accord with Lyell's conception of them. Most modern geologists and paleontologists do not draw the boundaries between these epochs on the basis of percentages of living species contained in the deposits, but on the general character of the fossils and on the stratigraphic and structural relations of the rocks containing them.

The Tertiary period was characterized by the great numbers and large size of its mammals, for which reason it is commonly known as the "age of mammals." It also witnessed the rise and development of the highest order of plants, and was distinguished by great volcanic activity, as shown by the occurrence of great masses of Tertiary volcanic rocks in all parts of the world.

PLIOCENE EPOCH (OR SERIES)

C. Lyell, 1833 (Principles of geology, vol. 3, pp. 52–55, 57–58).

SUBDIVISIONS OF THE TERTIARY EPOCH

Newer Pliocene period.—This most modern of the four subdivisions of the whole tertiary epoch we propose to call the *Newer Pliocene*, which, together with the *Older* Pliocene, constitute one group in the annexed tables of M. Deshayes.

We derive the term Pliocene from πλείων, major, and καινός, recens, as the major part of the fossil testacea of this epoch are referable to recent species.[12] Whether in all cases there may hereafter prove to be an absolute preponderance of recent species, in every group of strata assigned to this period in the tables, is very doubtful; but the proportion of living species, where least considerable, usually approaches to one-half of the total number, and appears always to exceed a third; and as our acquaintance with the testacea of the Mediterranean, and some other seas, increases, it is probable that a greater proportion will be identified.

The newer Pliocene formations, before alluded to, pass insensibly into those of the *Recent* epoch, and contain an immense preponderance of recent species. It will be seen that of two hundred and twenty-six species, found in the Sicilian beds, only ten are of extinct or unknown species, although the antiquity of these tertiary deposits, as contrasted with our most remote historical eras, is immensely great. In the volcanic and sedimentary strata of the district round Naples, the proportion appears to be even still smaller.

Older Pliocene period.—These formations, therefore, and others wherein the plurality of living species is so very decided, we shall term the *Newer* Pliocene, while those of the tertiary period immediately preceding may be called the *Older* Pliocene. To the latter belong the formations of Tuscany, and of the Subapennine hills in the north of Italy, as also the English Crag.

It appears that in the period last mentioned, the proportion of recent species varies from upwards of a third to somewhat more than half of the entire number; but it must be recollected, that this relation to the recent epoch is only *one* of its zoological characters, and that certain *peculiar species* of testacea also distinguish its deposits from all other strata. The relative posi-

[12] In the terms Pliocene, Miocene, and Eocene, the Greek diphthongs *ei* and *ai* are changed into the vowels *i* and *e*, in conformity with the idiom of our language. Thus we have Encenia, an inaugural ceremony, derived from ἐν and καινός recens; and as examples of the conversion of *ei* into *i*, we have icosahedron. * * *

tion of the beds referable to this era has been explained in diagrams Nos. 3 and 4, letter *f*, chapter II.

Miocene period.—The next antecedent tertiary epoch we shall name Miocene, from μείων, minor, and καινός, recens, a minority only of fossil shells imbedded in the formations of this period, being of recent species. The total number of Miocene shells, referred to in the annexed tables, amounts to 1021, of which one hundred and seventy-six only are recent, being in the proportion of rather less than eighteen in one hundred. Of species common to this period, and to the two divisions of the Pliocene epoch before alluded to, there are one hundred and ninety-six, whereof one hundred and fourteen are living, and the remaining eighty-two extinct, or only known as fossil.

As there are a certain number of fossil species which are characteristic of the Pliocene strata before described, so also there are many shells exclusively confined to the Miocene period. We have already stated, that in Touraine and in the South of France near Bordeaux, in Piedmont, in the basin of Vienna, and other localities, these Miocene formations are largely developed, and their relative position has been shown in diagrams Nos. 3 and 4, letter *e*, chapter II.

Eocene period.—The period next antecedent we shall call Eocene, from ἠώς, aurora, and καινσό, recens, because the extremely small proportion of living species contained in these strata, indicates what may be considered the first commencement, or *dawn*, of the existing state of the animate creation. To this era the formations first called tertiary, of the Paris and London basins, are referable. Their position is shown in the diagrams Nos. 3 and 4, letter *d*, in the second chapter.

The total number of fossil shells of this period already known, is one thousand two hundred and thirty-eight, of which number forty-two only are living species, being nearly in the proportion of three and a half in one hundred. Of fossil species, not known as recent, forty-two are common to the Eocene and Miocene epochs. In the Paris basin alone, 1122 species have been found fossil, of which thirty-eight only are still living.

The geographical distribution of those recent species which are found fossil in formations of such high antiquity as those of the Paris and London basins, is a subject of the highest interest. * * * [Pages 52–55.]

If intermediate formations shall hereafter be found between the Eocene and Miocene, and between those of the last period and the Pliocene, we may still find an appropriate place for all, by forming subdivisions on the same principle as that which has determined us to separate the lower from the upper Pliocene groups. Thus, for example, we might have three divisions of the Eocene epoch,—the older, middle, and newer; and three similar subdivisions, both of the Miocene and Pliocene epochs. In that case, the formations of the middle period must be considered as the types from which the assemblage of organic remains in the groups immediately antecedent or subsequent will diverge. * * * [Pages 57–58.]

In 1839 Lyell[13] restricted the term *Pliocene* to the "Older Pliocene" of his 1833 definition, and introduced the term *Pleistocene* for the "Newer Pliocene." But the use of Pleistocene for the "Newer Pliocene" was abandoned by him in 1873 (see quotations under *Pleistocene epoch*, *p.* 48), and he, as well as others, returned

[13] Lyell, C., On the relative ages of the Tertiary deposits commonly called "crag" in the counties of Norfolk and Suffolk: Charlesworth's Mag. Nat. Hist., new ser., vol. 3, p. 323, footnote, 1839.

to his original definition of Pliocene, and adopted Forbes's definition of Pleistocene (1846) for the early post-Tertiary glacial deposits. (See further explanation under *Tertiary period.*)

MIOCENE EPOCH (OR SERIES)

C. Lyell, 1833 (Principles of geology, vol. 3, pp. 52–55, 57–58).

[See quotation under *Pliocene epoch* and explanation under *Tertiary period*]

OLIGOCENE EPOCH (OR SERIES)

E. Beyrich, 1854 (Ueber die Stellung der hessischen Tertiär-bildungen: K. preuss. Akad. Wiss. Berlin Monatsber., November, 1854, pp. 664–666).

In conclusion I list below in a schematic summary the accepted sequence of the corresponding observed German and Belgian Tertiary beds. I consider it expedient to introduce a new name to designate the Tertiary time interval whose beds are primarily the subject of the discussion, that is, for the Tertiary deposits which exist between the two Tertiary time intervals which are generally known by the names introduced by Lyell; Eocene and Miocene. The need to associate under one common designation, as a narrow unit related within itself, the particular aggregate lying within these boundaries has often been felt by those who have devoted their attention to the Tertiary beds. To fill the need sometimes the name Lower Miocene and sometimes Upper Eocene has been used. Lyell uses Upper Eocene; I myself heretofore have used Lower Miocene. In a memoir on the Tertiary formations of the Basin of the Mayence, Hamilton, of the English geologists, has declared himself against Lyell for the name Lower Miocene. The new name Oligocene may be interposed between the older Eocene and younger Miocene.

SUMMARY OF TERTIARY BEDS OF MAYENCE BASIN, MIDDLE AND NORTH GERMANY, AND CORRESPONDING BEDS OF BELGIUM

A. *Miocene*

Belgium: *Bolderian system.*

North Germany: Dark sandy loams near Winterswyk in Holland and near Bocholt in Westphalia; at Bersenbrück north of Bramsche on the Hase; at Eversen and Feuerschützenbostel near Celle; at Lüneburg; Reinbeck; Sylt. Eastern occurrence near Gühlitz north of Perleberg in the Priegnitz region.

Middle Germany: None.

Mayence Basin: None.

B. *Oligocene*

1. Belgium: None.
   North Germany: Sands, in which occur the "mussel rocks" of Sternberg, not yet definitely identified in eastern portion. Loamy sand rich in mussel shells known from borings near Crefeld.
   Middle Germany: Upper yellow marine sands near Cassel, Güntersen, Luithorst, Alfeld, Hildesheim, Bünde, Osnabrück.
   Mayence Basin: None.
2. Belgium: *Upper rupelian system.* Loam of Boom.
   North Germany: Septaria loam of Walle near Celle; Hohenwarthe on the Elbe below Magdeburg; Burg; Görzig near Köthen, in the Mark province near Hermsdorf, Freienwalde, Bukow, Joachimsthal; on the Oder River near Stettin.
   Middle Germany: The same loam at Ober-Kaufungen near Cassel; Eckardroth west of Schlüchtern.
   Mayence Basin: None.

3. Belgium: *Lower rupelian system.* Sand with scallops and clay with Nucula near Kleyn-Spauwen.
   North Germany: None.
   Middle Germany: Clay with iron ore near Rheinhardtswalde.
   Mayence Basin: None.
4. Belgium: *Upper tongrian system.* Brackish-water deposits.
   North Germany: None.
   Middle Germany: Fresh-water deposits with lignite.
   Mayence Basin: Entire succession of brackish-water and fresh-water beds (Cyrene marl, limestone containing land mollusks [snails] and Cerithia; Littorinella limestone, lignite beds, sandstone bearing fossil leaves, bone sand of Eppelsheim).
5. Belgium: None.
   North Germany: None.
   Middle Germany: None.
   Mayence Basin: Lower marine sand of Absei.
6. Belgium: *Lower tongrian system.*
   North Germany: Glauconitic loamy sands and sandy loams above the lignite near Westeregeln, Biere, Calbe a. S.; Osterweddingen.
   Middle Germany: None.
   Mayence Basin: None.
7. Belgium: None.
   North Germany: Lignite-bearing Tertiary beds of the lowlands of northeast Germany.
   Middle Germany: None.
   Mayence Basin: None.

C. *Eocene*

Belgium: From the *Laekenian system* downward.
Absent in Germany north of the Alps and farther east north of the Carpathian Mountains.

The Oligocene deposits were originally included in the Eocene epoch, as explained on page 50, under *Tertiary period.* The word is of Greek derivation, from ὀλίγος (small, little) and καινός (new, recent).

EOCENE EPOCH (OR SERIES)

C. Lyell, 1833 (Principles of geology, vol. 3, pp. 52–55, 57–58).

For the original definition of Eocene see the quotation under *Pliocene epoch.* As originally defined by Lyell the term applied to all pre-Miocene Tertiary deposits. The recognition of *Oligocene* and "*Paleocene*" is mentioned under *Tertiary period*, on page 50.

"PALEOCENE"

W. P. Schimper, 1874 (Traité de paléontologie végétale, vol. 3, pp. 680–682).

VIII. Tertiary epoch.
I. Paleocene period.

Sands of Bracheux, ancient travertines of Sezanne, lignites and sandstones of Soissonais (Suessonian).

I have grouped all the vegetation of the Tertiary into five distinct floras, which does not mean that I consider the five floras as independent of one another. All these floras are interrelated in time as our local floras are in space. But in spite of the evident continuity in the evolution of the organic kingdom through the geologic ages there can nevertheless be distinguished in this continuous and progressive movement a constant change in the grouping and relative development of types, a change which enables us to identify for each epoch, and even for each geologic period, a group of forms constituting what we call the organic character of the epoch or of the period.

The group of plants or the flora of the period now under discussion, although allied closely with the Heersian flora, which is the continuation of the Cretaceous flora, and still more directly with the Eocene, has, nevertheless, an aspect peculiar to itself, which distinguishes it at a glance. It has in common with the preceding Cretaceous period the tropical and subtropical types of ferns (*Cyathea, Alsophila, Hemitelia*), to which are united others resembling more closely our types of temperate climates, such as *Blechnum, Asplenium, Athyrium.* The Pandanaceæ are represented by the genus *Nipadites* and a new type, which perhaps has its analogy in the *Carludovica,* which exists at the present time in the tropical regions of America. Palm trees are also found, but they resemble more closely the sabals than those of the Cretaceous terrane. The Myricaceæ, Cupuliferæ, Saliciaceæ, Lauraceæ, Ampelideæ, Araliaceæ, Magnoliaceæ, and Juglandaceæ persist, but with more or less pronounced specific modifications; the Tiliaceæ, under a form analogous to the *Grewia,* a genus indigenous to the tropics of the Old and New World; genera of Malvaceæ, the *Pterospernum,* an Indian type, and the *Sterculia,* which inhabit the same zones as the *Aralia,* constitute a new element, the same as the Moraceæ, with the genera *Protoficus* and *Artocarpoides,* and the Sapotaceæ with the type *Symplocos.* Some of the families which have made their appearance during the last period are in process of development, as the Cupuliferæ, which are enriched by the genera *Carpinus* and *Quercus,* not to mention the genera *Fagus* and *Castanea,* whose right of citizenship is not yet beyond doubt; the Saules are becoming more numerous and the family itself is augmented by the genus *Populus.* The figs and the laurels already show rather varied types; the latter are even represented by five genera, of which four have their principal representatives in Asia, and one, the *Sassafras,* in North America. The *Araliaceæ,* which in the Eocene flora showed such great development, enrich the tropical aspect of this luxuriant vegetation by more numerous forms. I say luxuriant because nearly all the trees of this first Tertiary flora, even some of those which have remained European, such as *Viburnum, Juglans,* and *Cornus,* are distinguished by an extraordinary richness of foliage. It is true that we know only the remnants of two local floras, that of Sezanne and that of the Soissonnais Basin, and it is possible that these forests owed their exceptional splendor to local circumstances only—much humidity coupled with tropical temperature. This humidity appears to be proved at least for Sezanne, where there was a lake on the banks of which were deposited the travertines which have transmitted to us the imprints of the leaves derived from the surrounding vegetation.

An interesting thing to note for this flora is the considerable number of plant types now belonging to the Northern Hemisphere and in part to the European flora; in the Cretaceous flora, on the contrary, the types of the Southern Hemisphere predominate; the forms of the most extreme points of our globe are assembled in it, while the Paleocene flora already shows a tendency to differentiation, in the sense that it concentrates more on the types which must later dominate in the Northern Hemisphere. A glance at the plate which follows will suffice to convince one of this curious fact.

I have said that the Paleocene flora is represented only by fragments in two rather restricted localities, one of which is at the Grottos near Sezanne (Champagne) and the other in the neighborhood of Soissons (sands of Bracheux, lignites and sandstones of Soissonnais). Perhaps the lower *lignites* of Provence (lower Ventabren, Belcodeme, Auriol) form a part of the same geologic horizon; the small number of determinable plant remains known of this formation does not permit a decision of this question. [Flora listed.]

The status and limits of "Paleocene" as now understood by vertebrate paleontologists were briefly stated by W. D. Matthew[14] in 1920, as follows:

The term Paleocene has been revived by several vertebrate paleontologists in recent years to cover the faunal zones previously known as Basal Eocene. Upon evidence of the vertebrate faunas it is entitled to rank as a distinct epoch, coordinate with the Eocene and Oligocene. It includes the Puerco, Torrejon, Fort Union, and probably certain less known vertebrate faunas in this country, and the Cernaysian in France. Its upper limit is marked by the first appearance of the principal modern orders of mammals and of certain modern groups of reptiles simultaneously in Western America and in Western Europe. The lower limit is more doubtfully fixed by the first appearance of placental mammals. The evidence of marine invertebrates and of plants does not at present appear to support the distinction of the Paleocene as a separate epoch. It is possible, however, that it covers the gap between the Cretaceous and Tertiary insisted upon by many stratigraphers and paleobotanists, and there are other possible interpretations that might reconcile the evidence. The writer believes that the epoch may also prove to include the Lance and certain other dinosaur-bearing formations, and that it may belong rather to the Cretaceous than to the Tertiary period. No final conclusions are in order until the evidence in different fields has been satisfactorily reconciled.

"Paleocene" is derived from the Greek παλαιός (ancient) and καινός (recent). The United States Geological Survey has not yet adopted the term.

CRETACEOUS PERIOD (OR SYSTEM)

J. J. d'Omalius d'Halloy, 1822 (Observations sur un essai de carte géologique de la France, des Pays-Bas et des contrées voisines: Annales des mines, vol. 7, pp. 373–374).

Here, then, are the names that I propose to give to the five groups that I have thought best to establish in the Secondary terrains.

I would call the first Peneen terrains, words which are only, so to speak, the translation of Todteliegende, and which may also be considered as recalling the circumstance that the most characteristic beds are ordinarily poor in fossil remains.

The second group will be designated by the name of Ammoneen terrains, words which will recall that all the systems of which it is composed have been formed during one epoch, in which existed the remarkable animals known as ammonites.

[14] Matthew, W. D., Status and limits of the Paleocene: Geol. Soc. America Bull., vol. 31, p. 221, 1920.

The third, which corresponds to what has already been called the chalk formation, will be designated by the name of Cretaceous terrain.[15]

The name Mastozootic, applied to the fourth group, will recall that in the midst of these terrains there are found the bones of mammals, the study of which has given birth to the beautiful work which has, as it were, created geology among us.

Finally, the fifth group will be designated by the name of Pyroide, which, without indicating anything definite as to the manner in which these terrains were formed, implies that they all resemble those that have a demonstrated igneous origin.

The essay above cited was reprinted in 1823 as a separate volume, accompanied by a geologic map, the explanation of which is as follows:

Pyroide terrains, comprising the products of present volcanoes, as well as the basaltic and trachytic terrains.

Mastozootic terrains, comprising all the terrains later than the chalk, the aqueous origin of which is undisputed.

Cretaceous terrains, corresponding to the formation of the chalk, with its tufas, its sands, and its clays.

Ammoneen terrains, comprising the Jurassic limestone, the Quader sandstone [now assigned to Cenomanian], the Muschelkalk [now assigned to Middle Triassic], the mottled sandstone, and the Zechstein [now included in Permian].

Peneen terrains, comprising the Macigno, the red sandstone, and the Todteliegende.

Primordial terrains, comprising the transitional terrains and the primitive terrains.

As thus defined D'Halloy's Cretaceous terrain applied to all deposits between the Tertiary and the Jurassic, and thus became a general term to include the French "craie," the English "chalk," and the German "Kreide" or "Kreidegebirge." It excluded the Quader sandstone of Germany, which was soon transferred to the Cretaceous, after its fossils had become better known. With that exception the original definition of Cretaceous corresponds with the definition generally used to-day.

The term was introduced into the geology of America by S. G. Morton, in 1834, in his "Synopsis of the organic remains of the Cretaceous group of the United States," a book of more than 100 pages, with descriptions of fossils and 19 plates of figures of the fossils. On pages 7–8 of this book Morton says:

CRETACEOUS GROUP OF THE UNITED STATES—EQUIVALENTS IN EUROPE

Ferruginous Sand. Mr. Vanuxem was the first to detect the analogy between this deposit and the chalk formation of Europe; although, as mentioned in the

---

[15] It is to be remarked that in a division less appropriate to the physical geography of France there might be reason to unite this little group to the preceding, and that in this case the denomination Ammoneen terrains may all the better be preserved, as there still existed ammonites when the chalk was formed. This name and that of Peneen terrains may also be preserved in case the Zechstein and the mottled sandstone should pass into the first group; because these two systems are not ordinarily very rich in animal remains.

preface, he did not refer it to any particular division of the chalk. My first essay (Journ. Acad. Nat. Science, Vol. VI, p. 97, 1827), published simultaneously with Mr. Vanuxem's, suggests its analogy to the *lower mass* of the cretaceous group, called by the French *la craie inferieure ou ancienne*, which in England is designated as the *Green Sand Formation*, or *Ferruginous Sand Series*.[16]

My subsequent researches during seven years have fully confirmed the preceding opinion.

Calcareous Strata. These were first noticed by myself in the year 1829. A careful examination of a great number of organic remains has induced me to consider these beds as of the same age as the white chalk of Europe: but as the American strata contain, as will be shown hereafter, some Tertiary shells, a positive decision must be deferred, until sanctioned by further observation.

In Europe two major divisions of the Cretaceous were early recognized, but the boundary between them has been placed differently from time to time and by different geologists. At first only the White Chalk was assigned to the Upper Cretaceous, and all the underlying rocks were called Lower Cretaceous; but later the boundary between Upper and Lower Cretaceous most generally accepted by continental geologists has been the boundary between Cenomanian and Albian, or Gault. In England it has been customary to refer the Gault to the Upper Cretaceous. To some geologists a threefold division of the Cretaceous has seemed more satisfactory. For example, Haug has grouped Albian, Cenomanian, and Turonian together to form Middle Cretaceous.

It was long supposed that the marine Cretaceous of the United States is all of Upper Cretaceous age, but in 1869 Gabb recognized the Lower Cretaceous age of the rocks in California which he named the Shasta group, now called the Shasta series. In 1887 R. T. Hill proved that a thick series of Cretaceous rocks in Texas, which he named the Comanche series, is older than the previously better known Cretaceous of the Gulf and Atlantic Coastal Plain, which he named the Gulf series. The two series are characterized by distinct faunas, and are at least locally separated by an unconformity, which Hill believed to be important. On account of this unconformity and the distinctness of the fauna Chamberlin and Salisbury later raised Comanchean to the rank of a system, in which they included the Shasta series and other Lower Cretaceous rocks. They have been followed in this method of treatment by a considerable number of geologists. The United States Geological Survey, however, still uses Comanche as the name of a provincial series of early Cretaceous rocks in Texas and neighboring regions. The name *Cretaceous* is derived from the Latin creta (chalk) and the suffix -aceus (of the nature of).

[16] Conybeare and Phillips describe the Ferruginous sand of England as composed of these four subdivisions, counting from below:—1, Ironsand; 2, Weald clay; 3, Green sand; 4, Chalk Marl. (Geol. pp. 60, 120, &c.) The whole series, embracing the White Chalk, is now very generally called the Cretaceous Group.

GULF EPOCH (OR SERIES)

R. T. Hill, 1887 (Am. Jour. Sci., 3d ser., vol. 33, pp. 298, 300).

As shown in the table on page 298 of the volume above cited, the Gulf series included Upper Cretaceous and so-called Middle Cretaceous deposits unconformably overlying the Comanche series (Lower Cretaceous). On the same page Hill subdivided the Gulf series from Elmo, Kaufman County, to Millsap, Parker County, Tex., as follows, in descending order: Navarro beds, Dallas limestone, Eagle Ford shales, and Timber Creek group. In 1889 [17] and in later reports, however, Hill made the term synonymous with Upper Cretaceous, Upper Cretaceous being extended to include the "Middle Cretaceous" deposits of his earlier report. Since 1889 the recognition of a so-called "Middle Cretaceous" has been almost universally discontinued, and all Cretaceous deposits overlying the Comanche series of the Gulf Coastal Plain have been recognized as belonging to the Gulf series, or Upper Cretaceous. The importance of the unconformity between the Gulf and Comanche series is also now questioned.

The name *Gulf series*, as now recognized, is a provincial series term applied to the upper part of the marine Cretaceous rocks of the southwestern part of the United States, the lower part of the Cretaceous rocks of that region being known as the *Comanche series*. The Gulf series was named for its extensive development along the Coastal Plain of the Gulf of Mexico. For additional explanation see under *Cretaceous period*.

COMANCHE EPOCH (OR SERIES)

R. T. Hill, 1887 (Am. Jour. Sci., 3d ser., vol. 33, p. 298, April, 1887).

Comanche series (Lower Cretaceous). This series is one of unbroken sedimentation and faunal continuity from base to top. Subdivisions are temporarily designated by horizons of prominent fossils. Many species continue throughout the entire series.

On the page cited above Hill divided the series into the Upper or Washita division and the Lower or Fredericksburg division, with subdivisions temporarily designated by horizons of prominent fossils, and showed it resting on "Dinosaur sand" and unconformably overlain by the Gulf series. The importance of this unconformity is, however, now questioned.

In April, 1887,[18] C. A. White included the "Dinosaur sand" (Trinity group of later reports) in the Comanche series, and that

---

[17] Hill, R. T., Relation of the uppermost Cretaceous beds of the eastern and southern United States: Am. Jour. Sci., 3d ser., vol. 38, p. 469, 1889.

[18] White, C. A., On the Cretaceous formations of Texas and their relation to those of other portions of North America: Acad. Nat. Sci. Philadelphia Proc., vol. 39, p. 40, 1887.

extended definition was adopted by Hill in October, 1887,[19] and has since been used by all writers. The series was named for Comanche, Comanche County, Texas, as stated by Hill in the First Annual Report of the Texas Geological Survey, page 117, 1890.

T. C. Chamberlin and R. D. Salisbury, 1906 (Geology, vol. 3, pp. 107–137).

The formations of the Cretaceous system are commonly divided into two main series, the Lower and Upper. To the former are referred the deposits of the earlier and lesser submergence, and to the latter, those of the later and more extensive submergence. The distinctness of the Lower and Upper Cretaceous is however so great that it seems, on the whole, in keeping with the spirit of the classification here adopted, to regard the two series as separate systems, and the corresponding divisions of time as separate periods. From the physical standpoint, the distinction between the Upper and Lower Cretaceous is greater than that between the different parts of any Paleozoic system, as commonly classified, if the Mississippian and the Pennsylvanian be regarded as separate systems, and greater than that between the Cambrian and the Ordovician, or between the Devonian and Mississippian. The paleontological phase of the question is discussed elsewhere. If the Lower Cretaceous be separated from the Upper, it may be called the Comanchean or Shastan system.[20] The propriety of this classification becomes the more striking, since it is equally applicable to other continents.

This classification involves no new idea. Hill, who has made a special study of the North American Cretaceous where both the Lower and Upper systems are developed, has repeatedly emphasized their distinctness, and Neumayer, after reviewing the relevant evidence, drawn chiefly from the phenomena of the old world, concludes that if the distinctness of the Lower and Upper Cretaceous had been known when the accepted time-divisions were established, they would have been made separate divisions of equal rank with the Triassic, Jurassic, etc. The Lower and Upper Cretaceous are therefore here considered as two somewhat associated periods, coordinate with the Triassic and Jurassic.

THE COMANCHEAN (SHASTIAN, LOWER CRETACEOUS) SYSTEM

The warping which marked the opening of the Comanchean period occasioned the development of extensive lakes or other basins of non-marine deposition in some parts of the continent, while other parts were depressed beneath the sea. The Comanchean deposits of the Atlantic and Eastern-Gulf coastal plains, and in certain parts of the western interior, are non-marine; those of the western Gulf region, extending as far north as the Ouachita Mountains and even a little beyond, are chiefly marine, while those of the Pacific coast are wholly so. From the distribution of the marine strata of the system, it is clear that by far the larger part of the continent was above sea level during the period, unless the deposits have been extensively removed by erosion, and this does not appear to be the case. * * * [Pages 107–108.]

The later Cretaceous period (which will herafter be called the Cretaceous) may be said to have been ushered in, so far as North America is concerned, by a notable encroachment of the sea on the land. [Page 137.]

The name *Comanche series* is applied to a provincial series of marine deposits constituting the lower part of the Cretaceous rocks of

---

[19] Hill, R. T., The Texas section of the American Cretaceous: Am. Jour. Sci., 3d ser., vol. 34, p. 288, 1887.

[20] The first of these terms has been applied to the Lower Cretaceous of Texas (Hill), and the second, by Le Conte and others, to the Lower Cretaceous of California.

the southwestern part of the United States, the overlying Cretaceous rocks of that region being known as the *Gulf series.* The lower part of the marine Cretaceous rocks as developed along the Pacific coast comprises another provincial series, to which the name *Shasta series* has been given. The reason for the use of the two names, Comanche series and Shasta series, for approximately contemporaneous deposits in western America is that they were deposited in different seas, between which there was no known connection, and their faunas and floras are so different that exact correlation has not been established. The Comanche sea covered parts of the States of Texas, Oklahoma, Arkansas, Kansas, Colorado, New Mexico, and Arizona. (See additional explanation under *Cretaceous period.*)

SHASTA EPOCH (OR SERIES)

W. M. Gabb, 1869 (California Geol. Survey, Paleontology, vol. 2, pp. vii, xiv, 129, 133).

In the preface J. D. Whitney states:

The present volume is devoted to the Tertiary and Cretaceous paleontology, and is entirely the work of Mr. Gabb. [Page vii.]

The Shasta Group is a provisional name, proposed to include a series of beds of different ages, but which, from our imperfect knowledge of the subject, can not yet be separated; it includes all below the Chico Group. It contains fossils, seemingly representing ages from the Gault to the Neocomien. inclusive, and is found principally in the mountains west and northwest of the Sacramento Valley. Two or three of its characteristic fossils have been found in the vicinity of Monte Diablo, and one of the same species has been sent from Washington Territory, east of Puget Sound. Few, or none, of its fossils are known to extend upwards into the Chico Group. [Page xiv.]

Gabb states:

Shasta Group. For reasons which will be detailed in their proper place, I consider the group, for which I here propose this name, to be the equivalent, or at least the nearest representative, of the Neocomien. It has been heretofore included, for want of positive grounds for separation, as a provisional member of the "Division A," of the California Cretaceous. * * * [Page 129.]

The absolute age of the Cretaceous strata of the northern part of the State has not yet been fully determined, but, as will be explained in the proper place, it seems not improbable that representatives of both the Gault and Lower Green Sand will be found included in what has here been provisionally termed the Shasta Group. [Page 133.]

The fauna of the Shasta "group" is described on succeeding pages of the book cited. Most of the fossils were collected in Shasta County, Calif., whence the derivation of the name.

The name *Shasta series* is a provincial series term, applied to the lower part of the marine Cretaceous rocks as developed on the Pacific coast.

JURASSIC PERIOD (OR SYSTEM)

A. von Humboldt, 1799 (Ueber die unterirdischen Gasarten, p. 39).

No copy of the above book is known in this country, but in Kosmos, volume 4, page 632, Stuttgart, 1858, Humboldt makes the following statements:

Upon a geological trip which I made in 1795 through southern France, western Switzerland, and northern Italy, I became convinced that the Jura-Kalkstein [Jura limestone], which Werner assigned to his Muschelkalk [the middle division of the Triassic], was a distinct formation. In my paper "Ueber die unterirdischen Gasarten," which my brother Wilhelm von Humboldt published in 1799, during my absence in South America, the formation is for the first time mentioned as the Jura-Kalkstein (p. 39). The establishing of this new formation was at once made known in the widely read Karsten's Mineralogische Tabellen (1800, p. 64 and introduction, p. vii). I named none of the fossils which characterize the Jura formation, and which Leopold von Buch described in 1839; but I erred in the age which I attributed to the Jura formation; on account of their proximity to the Alps, which were regarded as Zechstein, I regarded them as older than the Muschelkalk. In Buckland's first tables of the superposition of strata in the British Islands the Jura limestone of Humboldt is placed as Upper Oolite. [Refers to Humboldt, Essai géognostique sur le gisement des roches, 1823, p. 281.]

Although the name Jurassic had its inception with the Jura limestone of Humboldt (first published in 1799), Humboldt applied that name to only a small part of the Jurassic system of present usage, or to a part of the "Upper Oolite." (See accompanying chart.)

The following quotations from Zittel[21] give, briefly, the origin of the definition as it is now understood:

In the very beginning of the nineteenth century the fundamental features of the Jurassic succession had been so securely established by William Smith [of England] that subsequent observers had little to amend. The Jurassic deposits have attained a remarkably typical and perfect development in England. No serious obstacles of any kind are interposed in the path of the observer; no great tectonic disturbances, foldings, fractures, or high inclinations of the strata; no sudden changes of facies, and no gaps in the sedimentary series. The straightforward aspect of the stratigraphical relations, together with the characteristic lithological development of each individual member of the series, and the extraordinary wealth of fossil remains, has rendered England the classic ground of the Jurassic system.

William Smith at first treated the successive strata as equal in rank, and although he afterwards (1815 and 1817) united them into groups, these were not well defined and underwent modifications before they were received into the literature. Conybeare and W. Phillips [[22]] comprised under the name of Oolitic series all the strata between the ferruginous sand (lowest Cretaceous) and the red marl (Triassic). The same geologists classified the Lias as an independent basal formation in the Oolitic series and sub-divided the Oolitic formation above the Lias into three groups—the *Lower Oolites*, beginning with the

---

[21] Zittel, K. A. von, History of geology and paleontology, pp. 497–502, 1901.

[[22] Conybeare, Rev. W. D., and Phillips, William, Outlines of geology of England and Wales, pp. 59, 165–277, 1822.]

marly sandstone and concluding with the Cornbrash; the *Middle Oolites*, embracing the rocks from the Kellaways sandstone to the Coralrag; the *Upper Oolites*, embracing the rocks from the Kimmeridge Clay to the Purbeck marls and limestones [both inclusive]. * * * [Pages 497–498.]

In 1795, when Humboldt travelled through Bavaria and Switzerland on his way to Upper Italy, he described a thick series of limestones "between the old Gypsum (of the Zechstein formation) and the newer sandstone (Bunter sandstone)," both in the Franconian Alps and the Swiss Jura Chain, and he applied the name of "Jura Limestone" to this massive development. Ami Boué in 1829 defined the stratigraphical position of the "Jura Limestone" more accurately; he limited the term to the limestone above the Lias and below the Wealden formation. In the same year Brongniart had selected the term *Terrain Jurassique* for the sedimentary deposits comprised within almost the same limits. * * * [Page 499.]

In two memoirs, published 1832 and 1836, Thurmann gave an admirable exposition of the stratigraphy of the Bernese Jura. Voltz in Strasburg rendered willing assistance in identifying the fossils and determining the parallelism of the rocks with foreign equivalents.

Thurmann distinguished the following sub-divisions in the Terrain Jurassique:

C. *Upper Jurassic or Portland Group.*
- 15. Portland Limestone with *Exogyra virgula*, etc.
- 14. Kimmeridge Marl of Le Banné, very fossiliferous (*Exogyra virgula, Pteroceras Oceani, Mytilus Jurensis*, etc.).

B. *Middle Jurassic.*
- (b) Corallian group.
  - 13. Astarte Limestone.
  - 12. Nerinea Limestone.
  - 11. Coral Oolite.
  - 10. Coral Limestone.
- (a) Oxford group.
  - 9. Terrain à chailles.
  - 8. Oxford Clay and Kellaways Rock.

A. *Lower Jurassic or Oolite Group.*
- 7. Dalle nacrée (=Cornbrash?).
- 6. Calcaire roux sableux (=Forest Marble?) with *Ostrea Knorri.*
- 5. Great Oolite (Plagiostoma elongata, etc.).
- 4. Marls with *Ostrea acuminata* (=Fullers' Earth?).
- 3. Compact Oolite.
- 2. Ferruginous Oolite.
- 1. Grès superliasique (marly Sandstone). * * * [Pages 500–501.]

The *General Survey of the Orographic and Geognostic Relations of North-Western Germany*, a work published in 1830 by Friedrich Hoffmann, described the Jurassic succession in that district in greater detail than a previous contribution by Hausmann (1824). Roemer, Koch, and Dunker made the German Jurassic fossils the subject of palæontological monographs, and their results, taken in conjunction with the geological map and sections of Hoffmann, showed that the equivalents of the English Jurassic formations were well represented in North-Western Germany. Thus it seemed as if the English development of the Oolitic and Liassic formations could be regarded also as a standard for the leading features of the *Terrain Jurassique* in France, Switzerland, and North Germany. [Page 502.]

The present boundaries of the Jurassic (see accompanying chart) are as described in the foregoing quotation, except that geologists and paleontologists are not all in agreement as to whether the Rhætic should be included in the Jurassic or the Triassic. The United States Geological Survey and many other authorities still include Rhætic time in the Triassic period.

The name is derived from the development of the rocks in the Jura Mountains of France and Switzerland.

TRIASSIC PERIOD (OR SYSTEM)

F. von Alberti, 1834 (Beitrag zu einer Monographie des Bunten Sandsteins, Muschelkalks, und Keupers und die Verbindung dieser Gebilde zu einer Formation, pp. 323–324 and columnar section forming pl. 2).

Whoever examines more closely the foregoing analysis and tabulates all the fossils of the three hitherto separate formations; whoever examines, further, the transition of the different forms one into the other, and, indeed, considers the entire structure of the mountains and the decidedly different character of the fossils of the Zechstein [late Permian] from those of the Lias [Lower Jurassic], will realize that the Bunter sandstone, Muschelkalk and Keuper are the result of one period, their fossils, to use E. de Beaumont's words, being the thermometer of a geological period; that their separation into three formations is not appropriate, and that it is more in accord with the concept of a "formation" to unite them into a single formation, which I shall provisionally name *Trias.*

The columnar section in the publication cited above divided the Triassic into (descending order) Keuper group, Lettenkohlen group, Muschelkalk group, and Bunter sandstone group, and gave in detail the lithologic description of each group and the fossils from many different horizons of each division. The fossils of each group are also listed in the text. The Lettenkohlen group is the lower part of the Keuper.

As shown by the accompanying chart, the Triassic period and system as generally recognized to-day correspond with this original definition, for Alberti included in the Keuper, and hence in the Triassic, the deposits later named Rhætic (or Rhetian). Some geologists, however, especially the French, assign the Rhætic to the Jurassic.

In America there are three facies of the Triassic, namely, (1) the marine facies of the Pacific coast, extending as far east as Idaho and Utah in early Triassic time; (2) the red beds continental facies of the Interior; and (3) the continental Newark facies of the Atlantic border.

The name is derived from the three divisions that were originally included in the period, as explained in the above quotation.

CARBONIFEROUS PERIOD (OR SYSTEM)

Some encyclopedias credit the first use in geology of the term Carboniferous to Kirwan's "Geological essays," 1779. Kirwan, however, did not use the term in a stratigraphic or time sense; but in view of the fact that his "Geological essays" is a very rare book, and difficult to obtain, the following brief quotation from it is here given, in order to show the sense in which he did use the term.

Richard Kirwan, 1779 (Geological essays, pp. 290–291).

Chap. I, § 1. Of Carboniferous Soils and their attendant circumstances. By carboniferous soils I mean the various sorts of earth or stone among or under which coal is usually found. These soils are either chiefly argillaceous or arenilitic, or both together, or of the trap kind, or calcareous.

Rev. W. D. Conybeare and W. Phillips, 1822 (Outlines of the geology of England and Wales, pp. vii, 278, 320–364).

A synoptical and comparative view of the arrangement proposed in the present work and those of former writers is subjoined.

Character	Proposed names	Wernerian names	Other writers
1. Formations (chiefly of *sand & clay*) *above the chalk.*	*Superior order.*	Newest flœtz class.	Tertiary class.
2. Comprising *a. Chalk.* *b.* sands & clays *beneath the chalk.* *c.* calcareous freestones (*oolites*), & argillaceous beds. *d. New red sandstone, conglomerate & magnesian limestone.*	*Supermedial order.*	Flœtz class.	Secondary class.
3. Carboniferous rocks, comprising *a. Coal-measures.* *b. Carboniferous limestone.* *c. Old red sandstone.*	*Medial order.*	Sometimes referred to the preceding sometimes to the succeeding class by writers of these schools; very often the coal-measures are referred to the former —the subjacent limestone and sandstone to the latter.	
4. *Roofing slate, &c. &c.*	*Submedial order.*	Transition class.	Intermediate class.
5. *Mica slate.* *Gneiss.* *Granite, &c.*	*Inferior order.*	Primitive class.	Primitive class.

[Page vii.]

RED MARLE, OR NEW RED SANDSTONE

[Permian and Triassic of the present classification]

This Chapter will conclude our view of the formations above the great and important deposits of coal, and comprise the beds between the lias and those deposits: these are entirely referable to two formations very intimately connected together, viz. 1st. a series of marly and sandy beds intermixed with conglomerates derived from older rocks, containing gypsum and rock salt, and in one instance amygdaloidal trap: and 2ndly, a calcareous formation often brecciated and characterized by containing a considerable portion of magnesia: this lies beneath, or at least in the lower portion of the above series. The former deposits are commonly known by the name of Red marle or New red sandstone; the latter as the Magnesian limestone. * * * [Page 278.]

MEDIAL OR CARBONIFEROUS ORDER

Chapter I

General view of the formations comprised in this order

Section I. *Introductory notice*

It is intended to comprise, in the present book, an account of the rocks associated together in the districts which afford the principal deposit of fossil-coal, and indeed the only one capable of being applied to purposes of extensive utility which appears to exist in the whole geological series.

The class of rocks thus constituted will contain not only the great coal-deposit itself, but those of the limestone and sandstone also on which it reposes; which, though entitled to the character of distinct formations, are yet so intimately connected with the above, both geographically and geologically, that it is impossible to separate their consideration.

This series of rocks is by some geologists referred to the floetz, by others to the transition class of the Wernerians: we have preferred instituting a particular order for its reception, a proceeding justified by its proportional importance in the geological scale, its peculiar characters, and the many inconveniences arising from following either of the above conflicting examples. For this order we have proposed the name of *Medial,* wishing to adopt an appellation entirely free from theory, and indicating only the central place of this groupe in the five-fold division of the geological series which results from assigning to it a separate class. The epithet *carboniferous* is of obvious application to this series.

Had we been obliged to refer it either to the floetz or transition class of the Wernerians, we should not have hesitated in preferring the latter branch of the alternative; since at least ten characters will be found in common between the carboniferous and transition class, for one which would lead to an opposite arrangement: for instance,—1st, in those countries (as England and the Netherlands) where all the beds above this series really deserve, from their generally horizontal position, the name of floetz rocks, the carboniferous strata are most frequently much inclined, and exhibit every variety of contortion and disturbance,—agreeing in these respects with the transition rocks, but being entirely unconformable with the more recent. * * * [Pages 323–324.]

The following general principles may be laid down, to guide us in our order of treating this subject. In the first place, the series of rock formations which ought to be considered together with coal-measures, should be taken as including the four following subordinate series. I. *Coal-measures.* II. *Mill-stone grit and shale.* III. *Carboniferous* or *Mountain limestone.* IV. *Old red sandstone.* These are so much associated together in the same districts (entering as component parts into the same chain of hills, &c.), that in describing any extensive tract of country, they must be kept together under the view, or an inextricable confusion will result. * * * [Pages 325–326.]

Section II. *Of the Coal-Measures, or Great Coal-Formation*

Preliminary remarks on the limitation of this term, and the relations of this and other carbonaceous deposits

In speaking of the coal-formation, we must be understood as applying that term emphatically to the great and principal deposit of that mineral, interposed between the newer red or saliferous sandstone, and the great carboniferous limestone and older sandstone formations; or, where these are absent, resting on transition rocks. This is the deposit distinguished by the Wernerians as the *Independent* coal-formation.

It may be useful here to observe that, besides this great deposit, thin seams of carbonaceous matter may be traced in several other geological positions, and that such are sometimes, though very rarely, sufficiently productive to be worked for fuel; yielding however generally a coal of very inferior quality. * * * [Pages 326–327.]

Section III. *Millstone-grit and shale*

(a) *Chemical and external characters.* The coal-measures generally repose on a series of beds which are usually designated by the name of Millstone-grit and Shale. The millstone-grit is most commonly seen under the form of a coarse-grained sandstone, consisting of quartzose particles of various sizes (often sufficiently large to give the rock the character of a pudding-stone) agglutinated by an argillaceous cement. This sandstone differs from those which accompany the coal-measures, principally by its greater induration. It has every appearance of a rock mechanically formed from the detritus of pre-existent materials; and rounded particles of felspar may occasionally be traced in it. It sometimes, however (though comparatively seldom), assumes a finer texture, in which the mechanical structure becomes less evident, and even passes into a hard and solid cherty rock. * * * [Page 349.]

Section IV. *Carboniferous or mountain limestone*

(a) *Chemical and external characters.* The series just described reposes on that important assemblage of calcareous strata (occasionally alternating with beds of a different composition, e. g., shale-grit and amygdaloid) which has been often described by the name of mountain limestone, from its usually forming considerable hills; of metalliferous limestone, from its mineral riches; and of entrochal or encrinal limestone, from its organic remains. We prefer to all these that of *carboniferous limestone,* derived from its association in the coal districts, as expressing a character more constant and more peculiar than any of the former. * * * [Page 352.]

Section V. *Old Red Sandstone*

[Devonian of present classification]

The Carboniferous limestone is sometimes separated from this rock by a thick shale much resembling that associated with the millstone-grit; this may be distinguished as the *lower limestone shale.*

(a) *Chemical and external characters.* The old red sandstone is a coarse-grained, micaceous sandstone, evidently of mechanical origin, constituted apparently of abraded quartz, feldspar and mica, and containing fragments of quartz, clay-slate, flinty-slate, &c.; sometimes passing into the state of a quartzose conglomerate, sometimes possessing a structure coarsely schistose (and thus affording slates for paving), and sometimes, particularly towards its lower regions, becoming finely schistose, and passing into a fine-grained micaceous sandstone slate. It alternates with argillaceous beds, sometimes soft but more usually indurated and often slaty; the colour is usually dirty iron-red or dark brown, but sometimes passing into grey. It approaches in its lowest beds very nearly to the characters of the greywacke upon which it reposes, and indeed graduates insensibly into that rock; so that the line of separation between them is frequently only an imaginary and arbitrary demarcation. This rock contains in several places calcareous concretions, which produce a rock of a pseudo-brecciated appearance, known by the name of *Cornstone;* and has also some unimportant beds of limestone subordinate to it.

The superior consolidation of many of the beds of this rock will generally serve to distinguish it without much difficulty from the newer red sandstone, when a tract of any extent is examined; for although doubt may often remain from the examination of a single quarry, more extensive observation of the general features of a district will seldom leave any. Rock formations usually bear external marks of their relative antiquity, which the eye of the experienced geologist readily perceives. It is more difficult to distinguish this rock from the sandstones of the millstone-grit series, and those alternating with mountain limestone; and in fact it can only be considered as a lower link in the great chain of beds to which those belong; its prevalent and characteristic colour forms its best distinction. * * *

(c) *Organic remains.* It is generally destitute of organic remains; but towards its lower regions, where it approaches the limestone of the transition series, some beds of micaceous sandstone-slate occur, containing anomiae and encrinites similar to those in the transition limestone, which will be described hereafter. Vegetables similar to those of the coal are said in some instances to occur. [Pages 362–363.]

As thus defined the Carboniferous excluded the Permian rocks and included the "Old Red sandstone." The rocks now known as Permian, together with the rocks now known as Triassic, were included in the "New Red sandstone" and "Magnesian Limestone," which were said to overlie unconformably the Carboniferous in England and the Netherlands, and the "Old Red sandstone" was said not to have any sharp line of demarcation from the overlying Carboniferous limestones. The typical locality of the Carboniferous system of rocks is in the Pennine Range of England, and it is not fully represented in any other section of England. In the Pennine Range the "New Red sandstone" (a part of which belongs to the Permian) caps the "Coal Measures."

In 1839 the "Old Red sandstone" was, because of its fossil contents, excluded from the Carboniferous by Sedgwick and Murchison, and made a distinct system, under the name *Devonian system.* In 1841 Murchison introduced the name *Permian system* for the rocks between the Triassic above and what was then called Carboniferous below. Although in England, Germany, and the Netherlands the Permian rocks usually unconformably overlie the "Coal Measures," in some sections of England and America there is no sharp division line between them, and in India their relations are so close that

William Waagen introduced the term "Anthracolithic" to include his Carboniferous and the Permian.

An examination of the chart will show that geologists do not agree in the use of the term Carboniferous, and that some would abandon the name altogether. In America there is a widespread time break between the upper Mississippian and the Pennsylvanian, but this break is much greater in some areas than in others, and geologists are not agreed as to its time value. It is more frequently represented by the absence of early Pennsylvanian rocks than by the absence of late Mississippian beds. Whether the absence of the rocks is due to nondeposition or to erosion is not yet established. And whether this break represents a systemic boundary or a boundary of less importance is a debated question.

Many paleontologists regard the invertebrate fossils contained in the Mississippian, Pennsylvanian, and Permian rocks as constituting a major life unit, of the order of a period (or system), and comparable in rank to the Devonian life unit, although the rocks deposited during Carboniferous time are of much greater thickness than those deposited during Devonian time. Some other paleontologists would separate the Carboniferous into three life units, each of which they regard as of the rank of a geologic period (or system), but which the Survey classifies as of the rank of a geologic epoch (or series). Still others would separate the Mississippian into two geologic periods (or systems).

Regarding the invertebrate life of the Carboniferous rocks of America, paleontologists who use Carboniferous in the sense that the Survey uses it state that the early Mississippian invertebrates are naturally rather closely related to the late Devonian invertebrates, but that the late Mississippian (Chester) invertebrates are much more closely related to the Pennsylvanian invertebrates than they are to those of the late Devonian, and that there is a progressive evolution from the early Mississippian invertebrates to those of the late Mississippian; also that the Pennsylvanian invertebrates are closely related to but still distinct from the Permian invertebrates, which are without question more closely related to the Pennsylvanian invertebrates than they are to those of the succeeding Triassic period.

The Mississippian, Pennsylvanian, and Permian floras of America are reported to be related, but reasonably distinct. The late Mississippian (Chester) floras are more closely related to the Pennsylvanian floras than they are to the late Devonian floras, but the early Mississippian floras are rather closely related to the late Devonian floras, and the early Permian floras are more closely related to the Pennsylvanian floras than to those of the Triassic.

Carboniferous rocks the world over are characterized by the abundance and great variety of brachiopods of the genus *Productus.* Brachiopods of this genus occur in all three subdivisions of the Carboniferous—the Mississippian, the Pennsylvanian, and the Permian—and they became extinct with the Permian epoch. *Productus*, therefore, is a reliable indicator that the rocks containing it are of Carboniferous age, but the genus alone does not determine to which epoch of the Carboniferous period they belong. It frequently happens that other evidence of the age of the rocks is not obtainable in the allotted time, and the most definite opinion the geologist or paleontologist can form, therefore, is that they are of Carboniferous age.

The meaning of Carboniferous is coal-bearing, from the Latin carbo (coal, carbon) and fero (bear). The Pennsylvanian rocks in many parts of the world contain large quantities of commercial coal. The Permian rocks of many regions also yield coal, and the Mississippian rocks of northern England, Scotland, and certain parts of the United States and other countries contain some productive coal seams.

PERMIAN EPOCH (OR SERIES)

R. I. Murchison, 1841 (Philos. Mag., 3d ser., vol. 19, p. 419).

The carboniferous system is surmounted, to the east of the Volga, by a vast series of beds of marls, schists, limestones, sandstones and conglomerates, to which I propose to give the name of "Permian System," because, although this series represents as a whole, the lower new red sandstone *(Rothe todte liegende)* and the magnesian limestone or *Zechstein*, yet it cannot be classed exactly (whether by the succession of the strata or their contents) with either of the German or British subdivisions of this age. Moreover the British lithological term of lower new red sandstone is as inapplicable to the great masses of marls, white and yellow limestones, and gray copper grits, as the name of old *red* sandstone was found to be in reference to the schistose black rocks of Devonshire.

To this "Permian System" we refer the chief deposits of gypsum of Arzamas, of Kazan, and of the rivers Piana, Kama and Oufa, and of the environs of Orenbourg; we also place in it the saline sources of Solikamsk and Sergiefsk, and the rock salt of Iletsk and other localities in the government of Orenbourg, as well as all the copper mines and the large accumulations of plants and petrified wood, of which you have given a list in the "Bulletin" of your Society (anno 1840). Of the fossils of this system, some undescribed species of *Producti* might seem to connect the Permian with the carboniferous æra; and other shells, together with fishes and Saurians, link it on more closely to the period of the Zechstein, whilst its peculiar plants appear to constitute a Flora of a type intermediate between the epochs of the new red sandstone or "trias" and the coal-measures. Hence it is that I have ventured to consider this series as worthy of being regarded as a "System."

The overlying red deposits which occupy a great basin in the governments of Vologda and Niijni Novogorod, have not as yet been found to contain any organic remains except minute *Cyprides* and badly preserved Modiolæ; but when we take into consideration their thickness, geological position, and mineral-characters, we are disposed to think that they may at some future day be identified with a portion of the "Trias" of German geologists. I am strengthened in this opinion by Count Keyserling's discovering, during our tour at Monte Bogdo, certain fossils which are unknown in other parts of Russia, but which are associated with the *Ammonites Bogdoanus* already described by Von Buch, and which that distinguished geologist refers to the type of the muschelkalk.

R. I. Murchison, E. de Verneuil, and A. von Keyserling, 1845 (Geology of Russia in Europe and the Ural Mountains, pp. 7*–8, 140–141).

* * * and thirdly, after describing a peculiar form of the carboniferous system and giving a detailed account of the coal-bearing tracts in the empire, by establishing under the name of "Permian" a copious series of deposits which form the true termination of the long palæozoic periods.

This last-mentioned system has not hitherto obtained the attention to which it is entitled. In France it is known only as a deposit of red sandstone with a few plants; in Belgium it is a mere conglomerate (the "Péneen" or sterile group of M. d'Omalius d'Halloy). In England and Germany, where its members are much more expanded in the form of red sandstone and conglomerate, magnesian limestone, copper slate, etc., the strata have never received a collective name, nor have they till recently been united as a natural group,[23] distinguishable from the inferior formations by peculiar species, though connected with them by the general aspect of their fauna, and entirely different in all their organic contents from the overlying or triassic system.

Finding that this supracarboniferous group was not only spread over a region of enormous dimensions in Russia, extending from the Volga to the Ural Mountains on the east, and from the Sea of Archangel to the southern steppes of Orenburg, but that among certain fossils characteristic of the Zechstein in other parts of Europe, it also contained many new species of shells and a fauna somewhat differing from that of the carboniferous age, we have ventured to apply to it a collective name derived from the ancient kingdom of Permia, which was situated in the centre of the vast territories overspread by these deposits. * * * [Pages 7*–8.]

Such then is our apology for the introduction of a new synonym, and in the ensuing chapters we shall support our reasons for its use. To render, however, the term Permian acceptable to German and English readers, we have placed the words Zechstein and Magnesian Limestone as equivalents in the Table and Map, thus to point out, that beds similar in structure to them, form part of the diversified "Permian System."

In our first announcement of this system we believed[24] that it might comprehend the rothe-todte-liegende of Germany; but we have since seen reason to modify this view, and to exclude (for the present) that German deposit from our Russian natural group. For, if the rothe-todte-liegende should be found to contain (and we believe this to be the case) some of the same species

[23] Professor Phillips was the first to maintain, that the fossils of the magnesian limestone of England ought to be classed with those of the palæozoic rocks, and our Permian researches confirm his view.

[24] See Murchison's letter to Dr. Fischer, Moscow, Sept. 1841, when the term "Permian" was first proposed; also Phil. Mag. vol. XIX, p. 417. In suggesting this name, we had, we confess, forgotten that our distinguished friend M. D'Omalius D'Halloy had employed the word "Péneen" to characterize all the strata between the "terrein houiller" and the "bunter sandstein." We adhere, however, to our geographical name, not only because it was adopted on the same principle which led to the use of "Silurian" and "Devonian", but also from our having found in the Permian deposits undescribed organic remains and much mineral wealth (copper, sulphur, salt, etc.); thus rendering the word "Péneen" or "sterile" quite inapplicable in the present state of our knowledge.

of plants as the coal-fields of the surrounding countries, that deposit must certainly be considered the representative of the Carboniferous system in that portion of Northern Germany, where no other coal-fields exist. At all events, English geologists have not yet been able to point out any natural distinctions between the plants of their Lower Red Sandstone and those of the subjacent coal measures; and as the identification of this red sandstone with the rothetodte-liegende has been admitted, we are compelled to avow, that a deposit so characterized can form no part of a system in which the plants belong to a *peculiar type.* In a word, therefore, our Permian system embraces everything which was deposited between the conclusion of the carboniferous epoch, and the commencement of the Triassic series. [Pages 140–141.]

As stated in the preceding quotation, the name *Permian* is derived from the ancient kingdom of Permia, Russia. (See further explanation under *Carboniferous period* and *Pennsylvanian epoch.*)

PENNSYLVANIAN EPOCH (OR SERIES)

H. S. Williams, 1891 (Arkansas Geol. Survey Ann. Rept., vol. 4, p. xiii).

The formations of Washington County

System	Series	Group	Approximate Equivalence. (H. S. Williams)	Washington County
Carboniferous or Pennine.	Coal Measures or Pennsylvanian (H. S. Williams)			Millstone grit.
	Lower Carboniferous or Mississippian (H. S. Wms.)	Boston (Branner). Genevieve (H. S. Wms).	"Chester." "St. Louis." "Warsaw."	Kessler limestone (Simonds). Coal-bearing shale (Simonds). Pentremital limestone (Simonds) Washington shale and sandstone (Simonds). Archimedes limestone (Simonds). Marshall shale (Branner).
		Osage (H. S Wms).	"Keokuk." "Burlington."	Batesville sandstone (Branner). Fayetteville shale (Simonds). Wyman sandstone (Simonds). Boone chert and limestone (Branner).
Devonian?				Eureka shale (Branner).
Silurian.				(Sandstones).

The foregoing table contains the original use of *Pennsylvanian.* The term was introduced, as the table shows, as a geographic name to replace the descriptive term "Coal Measures." The book cited does not contain any further explanation of the term.

H. S. Williams, 1891 (U. S. Geol. Survey Bull. 80, pp. 83–108).

Chapter IV. The Coal Measures or Pennsylvania[n] series. [Heading on p. 83.]

The term "Coal Measures" as in use in 1891 in Pennsylvania, the typical area of the Pennsylvanian series, included, in descending order, the following subdivisions: "Upper Barren Measures," "Upper Productive Coal Measures," "Lower Barren Coal Measures," "Lower Productive Coal Measures," and Pottsville conglomerate ("Millstone grit"), the Pottsville resting on the rocks commonly called "Lower Carboniferous." In the Mississippi Valley region the "Coal Measures" included the coal-bearing rocks above the Chester group (of Mississippian age). The "Upper Barren Coal Measures" of Pennsylvania are the Dunkard group (Dunkard Creek series of I. C. White, 1891), and they contain some workable beds of coal. The Dunkard rocks are present only in the southwestern part of Pennsylvania and in adjacent parts of Ohio, West Virginia, and Maryland. In 1880 they were, on the basis of the fossil plants they contain, assigned to the Permian by Fontaine and White.[25] According to the statements on pages 81–82 and 108 of Bulletin 80 of the United States Geological Survey, Williams excluded the Permian rocks from his Pennsylvania[n] series and included in it, at the base, the so-called "Coal Measure Conglomerate or Millstone grit" (Pottsville formation of present usage). That is the definition adopted by the United States Geological Survey.

The division line between the Permian and Pennsylvanian in the United States is in general a purely paleontologic boundary, though in some sections it seems to coincide with an unconformity. In most areas its precise location remains to be determined.

MISSISSIPPIAN EPOCH (OR SERIES)

A. Winchell, 1869[26] (Am. Philos. Soc. Proc., vol. 11, p. 79).

I propose the use of this term ["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.

H. S. Williams, 1891 (U. S. Geol. Survey Bull. 80, p. 135).

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

[25] Fontaine, W. M., and White, I. C., The Permian or Upper Carboniferous flora of West Virginia and southwestern Pennsylvania: Second Pennsylvania Geol. Survey Rept. PP 1880.

[26] The date of publication of Winchell's paper has been variously stated. The paper was read March 5, 1869, and according to a footnote on page 245 of the American Philosophical Society Proceedings No. 83, volume 11 (which part of vol. 11 was published in 1870), also according to a footnote on page 385 of volume 11, the first part of Winchell's paper (the part in which he proposed the term "Mississippi group") appeared in No. 81 of the Proceedings of the Society and was published in 1869.

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," "Sub-carboniferous," 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[27] [1869].

(See explanation under *Carboniferous period.*)

"TENNESSEAN SYSTEM"

E. O. Ulrich, 1911 (Geol. Soc. America Bull., vol. 22, pp. 581–582).

Revision of methods as well as facts of stratigraphic classification.—It will have been observed that my revision affects the methods as well as the facts of stratigraphic correlation. By method, I mean the manner of determining what constitutes a geologic period or system, an epoch or series, or a stage or group, and, more particularly, how the boundaries of these time and stratigraphic divisions are to be drawn. Concisely stated, the method followed is to divide the stratigraphic sequence at the first plane beneath the introduction of a new fauna or beneath a marked faunal change that exhibits evidence of diastrophic movements. If the plane marks a great faunal break, providing the compared faunas invaded from the same oceanic basin, and especially when the plane corresponds also to a considerable change in the provincial boundaries that had prevailed during the greater part of the preceding period, then it seems to me it marks the beginning of a new system. It is on such grounds that the old Mississippian is divided into two systems—the Waverlyan and the Tennessean—also, that the Eopaleozoic is divided into four systems instead of but two.

Why the Waverlyan and Tennessean are systems and not series.—A system is divided into series on similar grounds, only in these cases the breaks are commonly of a lower order and the change in provincial boundaries less extensive. We may illustrate the difference by comparing the relations of the Waverlyan to the Tennessean on the one hand and the interrelations of the series divisions of these two systems on the other. Thus, during the Waverlyan, the continental seas were developed in southeastern North America in three fairly well distinguished basins or faunal provinces. Each of these provinces, furthermore, is characterized by its own lithological sequence. At times, also, the seas shifted so that only two or perhaps but one of the basins was submerged. Named from their characteristic formations, the eastern basin, with its shales and sandstones, may be called the Cuyahoga basin; the middle area, with its shales and cherty limestones, may be called the Fort Payne basin; the western province, with shaly beds beneath and at the top and rather pure crystalline limestone in the middle, may be called the Burlington province.

It may be questioned whether all three of these basins contained marine waters at any one time during this period. I believe this occurred during the Chattanoogan and, to a considerable extent also, in the New Providence-Fern

[27] The Marshall group, etc., Am. Phil. Soc., Proc., vol. 11, p. 79.

Glen-upper Cuyahoga age, and again in the Keokuk-Fort Payne-Logan-Grand Falls age. The point is not of vital importance here. It is enough to know that, as a rule, the Waverlyan seas occupied considerable parts of at least two of the basins, and that the greatest shifting during the period occurred at times marking the close of the series into which the system is divided. Thus, as shown in the Waverlyan correlation table, the Chattanoogan ends with its most widely distributed stage; the Kinderhookian is characterized by frequent oscillations and ends with its smallest (Chouteau) stage; the Osagian begins with the extensive Fern Glen stage, continues with the restricted Burlington stages, and ends with another eastward tilt, during which the Keokuk was deposited in Iowa and Illinois, the Grand Falls in Missouri and the cherty Fort Payne limestone in areas to the southeast of these States.

As indicated, the Waverlyan oscillations merely shifted the seas about within the area covered by the three basins. The movements consisted almost entirely of simple tilting of the area as a whole. The break between the Keokuk and the Warsaw stage of the succeeding Tennessean period, however, is marked less by tilting than by warping of the surface. The Warsaw, and to a greater extent the Spergen, disregarded the boundaries of the faunal and lithological provinces which prevailed during the Waverlyan and spread with surprising uniformity of expression from Missouri to Alabama and thence northeastward in the Allegheny basin to west Virginia and perhaps to Maryland. There was a change, also, in the northward extent of the seas, none of the Tennessean stages reaching as far in that direction as did certain Waverlyan formations. In short, a new set of conditions was introduced in southeastern North America with the Warsaw that thereafter prevailed—with minor oscillations and tilting—to the close of the Chesterian.

"WAVERLYAN SYSTEM"

C. Briggs, jr., 1838 (Ohio Geol. Survey First Ann. Rept., pl. 1, pp. 74, 79–80).

WAVERLY [ALSO WAVERLEY] SANDSTONE SERIES

The rocks superimposed upon the argillaceous slate (vide D, fig. 4, of the plate) appear to have been deposited under conditions no less remarkable than the two preceding divisions. Instead of the uniformly tranquil state of the two preceding periods ["Great limestone deposit" overlain by 200 to 300 feet of "Argillaceous slaty rock, or shale stratum"], the strata bear evidence of having been formed in waters alternately quiet and disturbed. Under these circumstances, were deposited the whole series of this division, which consists of alternate layers of fine-grained sandstone and shale, attaining a thickness of not less than three hundred feet. The layers of sandstone appear to have been formed in a gradually shoaling bay, estuary, or sea, for they are characterized by ripple marks, which, it has been stated by Mr. Conrad, can only be made in shallow waters. These markings are sometimes so surprisingly regular and beautiful as to appear artificial, rather than natural, slightly resembling the flutings on some ornamental columns. But in proof of this, reference need only be made to the aquatic vegetables which are found on the surfaces of some of the layers; and which were apparently entombed in the place of their growth. [Pages 74 to 75.]

Superimposed upon the stratum above described [200 to 300 feet of "Argillaceous slaty rock, or shale stratum"], occurs a series of alternations of sandstone and shale, the thickness of which has not yet been ascertained, but which will not probably vary far from 250 to 300 feet. The lower part of this stratum caps the highest elevations near Chillicothe, and it can be studied with great advantage on either side of the Scioto valley, from Chillicothe to Portsmouth. * * * The fine grained sandstones of this series have been quarried at Portsmouth, Piketon, Waverley, Chillicothe, and other places; and are favorably known in most of the principal towns in the State. Quarries without number may be opened, so that all demands, however great, may be supplied. The limits within which these quarries may be opened, will be determined by subsequent detailed surveys.

As some of the most beautiful stones that have been obtained were quarried at Waverly, we may, for the present, denominate these rocks the *Waverly sandstone series.*

CONGLOMERATE

Resting on the series last described [Waverly Sandstone Series], occurs a stratum which is composed of siliceous sand and pebbles; it varies in thickness, where it has been observed, from 40 to 80 feet. [Pages 79 to 80.]

E. O. Ulrich, 1911 (Geol. Soc. America Bull., vol. 22, pp. 581–583, pl. 29).

[See quotation under "*Tennessean system*"]

For many years the following was generally accepted as the correct sequence of the Mississippian and late Devonian formations of Ohio, in descending order:

Maxville limestone.
Logan formation (top formation of Waverly group).
Black Hand formation.
Cuyahoga formation.
Sunbury shale.
Berea grit.
Bedford shale (bottom formation of Waverly group).
Cleveland shale. }
Chagrin ("Erie") formation. } =Ohio shale.
Huron shale. }

Briggs's report, from which the foregoing original definition of Waverly is quoted, covered an area in southern Ohio that included "the counties of Scioto, Lawrence, Gallia, Athens, Hocking, and Jackson," and during the course of their field work he and his assistants extended their observations into Pike, Ross, Adams, and Highland counties. According to later reports of the Ohio State Survey the Waverly rocks of the area covered by these counties include at the top the Logan formation; they are underlain by the black Ohio shale, and are overlain in some places by the Maxville limestone and in other places by the Pottsville rocks.

The base of the Waverly and the boundary between the Mississippian and the Devonian are still debated questions. Briggs's original definition of the Waverly placed its lower limit at the top of the black to gray slaty argillaceous rocks which, according to Orton, were later named Ohio shale. In 1870 Newberry drew the base of the Waverly of northern Ohio at the base of the black Cleveland shale, which has long been believed by many geologists to correspond to the upper part of the Ohio shale of southern Ohio. Newberry's boundary was subsequently followed by Read (1873, 1878), Winchell (1874), Ulrich (1911), and Bassler (1911). Orton, however, in 1879 excluded the Cleveland from the Waverly and drew the base of the Waverly at the base of the Bedford shale. In this he was followed by Prosser (1901, 1903, 1905, 1912, 1915), Stauffer (1909, 1911), Hubbard and Bownocker (1911), Hyde (1912), Morse and Foerste (1912), Stout (1916), Burroughs (1913), and other geologists. Herrick in 1893 expressed the opinion that the Berea grit "is the real floor of the [Waverly] series." In 1911 Ulrich, for the reasons given in the quotation under "Tennessean system," elevated the Waverly to the rank of a system—the "Waverlyan system"—the base of which he placed at the base of the Cleveland shale, and the top at the base of the Maxville limestone, which he included in his Tennessean system. He divided his Waverlyan system into (descending order) Osagian, Kinderhookian, and Chattanoogan. With the Osagian he correlated the Logan, Black Hand, and upper part of the Cuyahoga; with the Kinderhookian he correlated the lower and major part of the Cuyahoga; and with his Chattanoogan he correlated the Sunbury, Berea, Bedford, and Cleveland. Subsequent studies, however, led him, in 1912, to publish the following as the true sequence of the early Mississippian and late Devonian rocks of Ohio:

Waverlyan system:
- ***
- Berea grit.
- Bedford shale.
- Cleveland shale.
- Olmsted shale (new name suggested by Chadwick).
- Huron shale. "Most probably younger than Chagrin."

Devonian:
- Chagrin formation.

In 1912 Girty, also Kindle, assigned the Bedford fauna to the Devonian. The same year Prosser expressed himself as undecided whether the Bedford fauna belonged to the Devonian or the Carboniferous, but stated that the evidence favored drawing the Carboniferous-Devonian boundary at the base of the Berea grit. Kindle's studies also led him in 1912 to the conclusion that the Huron shale and basal part of the Cleveland shale are contemporaneous with the Chagrin formation. In 1916 and 1917 Verwiebe placed the Mississippian-Devonian boundary at the unconformity at the base of the Berea. In 1921 Butts published the opinion that the Bedford shale is of Kinderhook age, and in this opinion Ulrich also concurs.

Because of the differences of opinion regarding these matters the United States Geological Survey classifies the Bedford shale as Devonian or Carboniferous.

"ANTHRACOLITHIC"

Waagen's definition of "Anthracolithic," a term synonymous with Carboniferous as used by the United States Geological Survey, is given below.

William Waagen, 1891 (Salt Range fossils: Palæontologia Indica, ser. 13, vol. 4, pt. 2, p. 241).

The two systems [Carboniferous and Permian] must be kept separate. At the same time, however, it is very desirable that the intimate connection between the two systems should also find an expression in the nomenclature. This can only be done by comprising the two as a group of a higher order under one name. The term "carboniferous" cannot here be used again, as with this the old confusion [meaning the different senses in which Carboniferous had been used] would again be sanctioned; and yet the most characteristic feature of the two systems is the frequent occurrence of coal-seams. Thus, I venture to propose for the whole, for the Carboniferous and Permian systems together, the name "Anthracolithic Epoch" * * * My "Anthracolithic Epoch" corresponds now to Neumayr's "Upper Palæozoics."

The word is derived from the Greek ἄνθραξ (coal) and λίθος (stone).

DEVONIAN PERIOD (OR SYSTEM)

Rev. A. Sedgwick and R. I. Murchison, 1839 (Geol. Soc. London Proc., vol. 3, No. 63, pp. 121–123, abstract).

A paper was then read on the classification of the older rocks of Devonshire and Cornwall, by the Rev. Professor Sedgwick, F. G. S., and Roderick Impey Murchison, Esq., F. G. S.

In a communication read in 1837 [and published in 1840[28]], the authors explained their general views respecting the older rocks of Devon and Cornwall, but having recently changed one part of their classification, they have hastened to place their reasons for doing so upon record, before the Geological Society. On three out of four of the essential points in their former communication, the authors' views remain unchanged; they adhere to the belief, which they were the first to put forth, that the greater portion of Devonshire belongs to the true carboniferous system, and that the succession and lithological characters of the different mineral masses in North and South Devon, which they then pointed out, remain unaltered. In proof of this there were suspended, during the reading of the paper, the same sections as were exhibited at Bristol in 1836. The change, therefore, which they propose, is to remove the lowest rocks from the Cambrian and Silurian systems to the old red; and their reason for making this alteration is founded on zoological evidence recently obtained, which shows that the organic remains of these deposits are of a peculiar character, approaching in the upper division, the fossils of the carboniferous strata, and in the lower, those of the Silurian system; as well as upon the previously ascertained regular sequence or pas-

[[28] Geol. Soc. London Trans., new ser., vol. 5, pt. 3, pp. 633–687, 1840.]

sage from the carboniferous strata, through all the subjacent series of deposits.

The fossil plants of the culm basin having been formerly determined to be, as far as recognizable, true coal measures remains, and the deposit having been therefore assigned to the era of the carboniferous system, the order of superposition being also clear, the strata underlying the coal basin might naturally be referred to the old red sandstone, if the organic remains found in them, belonged to a natural group, intermediate between the fossils of the carboniferous and Silurian systems. Subsequent examination has proved that such is the case, but this distinction could not have been ascertained had not Mr. Murchison published his work on the Silurian system. * * *

The authors next gave an approximate list of the fossils, collected by themselves or placed at their disposal by the Rev. R. Hennah, Major Harding, and the Rev. D. Williams, referring them to the great mineral groups to which they belong, both in North and South Devon. * * *

South Devon.—Having thus shown that in North Devon there is a regular succession of strata characterized by distinct fossils differing more and more in descending order from the organic remains of the mountain limestone, and approaching those of the Silurian system; the authors proceed to enumerate the order of the groups and the imbedded fossils in South Devon and the North of Cornwall. They show a similarity of succession of deposits and of organic remains in the upper groups, but they state that in consequence of the protrusion of the granite, there is in the lower a considerable difference in mineral type, especially south of Dartmoor. They refer, however, to their former memoir for ample details respecting these counties, and for proofs that they were correct in placing the great calcareous masses of Plymouth and Chudleigh on the same parallel as the lowest calcareous strata of North Devon.

In conclusion, the authors show, that the variation in Devonshire and Cornwall from the ordinary type of the old red sandstone in Herfordshire and adjoining counties, cannot be admitted as a valid argument against assigning the slates and sandstones of these counties to that system, because the variations in composition of other formations within limited areas is equally great. They show also that the absence of the true carboniferous limestone in Devonshire cannot disprove their present classification, because in Western Pembrokeshire that limestone is wanting, and the coal measures rest on older formations.

In consequence of mineral character being no longer indicative of age, and the term greywacke being lithologically applicable to beds of every class of rocks, and as Devonshire affords the best type of the fossils of this intermediate system, the authors propose to substitute the term *Devonian* for old red sandstone; and they hope that the organic remains, discovered in that county, will enable continental geologists to detect in their own country, a system of strata hitherto supposed to be almost peculiar to the British Isles.

The authors acknowledge the assistance they have received from Mr. J. Sowerby; and that Mr. Lonsdale first suggested, from their fossil contents, that the limestones of S. Devonshire might prove to be the representatives of the old red sandstone.

Rev A. Sedgwick and R. I. Murchison, 1840 (Geol. Soc. London Trans., 2d ser., vol. 5, pt. 3, pp. 701–702; read April 24, 1839).

Though the term old red sandstone, when designating great groups of rocks like the Cornish *killas* and Devonian slates should involve no error of classification, still it would, mineralogically, be most inappropriate. We purpose therefore, for the future, to designate these groups collectively by the name *Devonian system*, as involving no hypothesis, and being agreeable to analogy.

Thus the terms Carboniferous system, Devonian system, Silurian system, and Cambrian system, will represent a vast and apparently uninterrupted sequence of deposits; each having, as a whole, zoological and (often also) mineralogical characters of its own, yet each passing into the system next in order by almost imperceptible shades of difference. The old *palæozoic* rocks appear, therefore, notwithstanding their enormous scale, and the wide diffusion of the same organic types, to have been formed in subordination to the same laws which, in after periods, produced the more clear succession of our secondary formations.

SILURIAN PERIOD (OR SYSTEM)

R. I. Murchison, 1835 (London and Edinburgh Philos. Mag. and Jour. Sci., 3d ser., vol. 7, pp. 46–52).

The names finally adopted, and which will be incorporated in a work now in preparation on this subject are,

1. *Ludlow rocks*, divided into upper and lower Ludlow rocks, with a central zone of limestone: in this formation no change of name is proposed.
2. *Wenlock limestone* and shale (*equivalent, Dudley*).
3. *Caradoc sandstones.* This name, supplying the place of the Horderley and May Hill rocks, has been derived from the striking and well-known ridge of Caer Caradoc, on the eastern flanks of which, and lying between it and the Wenlock Edge, are exhibited those peculiar strata which are the equivalents of the shelly sandstones of Tortworth.
4. *Llandeilo flags* (preferred to "Builth and Llandeilo"). When this table is reprinted, there will naturally be found many additions to the organic remains, some identifications of British with foreign species, and numerous corrections.

Notwithstanding the adoption of these names, there was still required a comprehensive term by which the whole group could be designated, and at once distinguished from the *old red sandstone* above, and *the slaty rocks* below. * * * [Page 47.]

To return, however, to the system under review, I was urged by leading geologists both at home and abroad to propound an entirely new name for it. In consonance, therefore, with those views which have rendered the names used by English geologists so current throughout the world, I venture to suggest, that as the great mass of rocks in question, trending from south-west to north-east, traverses the kingdom of our ancestors the Silures, the term "*Silurian system*" should be adopted as expressive of the deposits which lie between the old red sandstone [above] and the slaty rocks of Wales [Tremadoc slate and Lingula flags], including, as above detailed, the Ludlow, Wenlock, Caradoc, and Llandeilo formations. One of the largest of these formations, to which, indeed, the Llandeilo flags are frequently subordinate, has been named after the bold and picturesque ridge of Caer *Caradoc* in Shropshire.

I further propose that the system be subdivided into "Upper" and "Lower Silurian rocks," the former embracing the deposits of "Ludlow" and "Wenlock," the latter those of "Caradoc" and "Llandeilo." [Pages 48–49. For explanation of the formation names see column by A. Geikie in accompanying chart.]

As thus defined the Silurian included the rocks later separated and named Ordovician. Until within recent years the rocks in the United States known as the Richmond group were considered to be the top subdivision of the Ordovician, but some geologists now consider the Richmond rocks and fauna more closely related to the Silurian than to the Ordovician, and include them in the Silurian, for both faunal and diastrophic reasons. The United States Geological Survey and other authorities have, however, not yet removed the Richmond from the Ordovician.

Some authors use the name "Ontaric system" instead of Silurian system. (See definition below.)

"ONTARIC SYSTEM"

E. Emmons, 1842 (Geology of New York, pt. 2, div. 4, Geol. 2d dist., pp. 100–101, 429).

Following out the plan of nomenclature for the rocks of New-York, I have considered that, for purposes of study, they [the rocks of the New-York Transition System] might be arranged in four groups, as follows: Champlain group, at the base of the Transition system; Ontario group, comprehending the rocks which lie upon its southern border for about fifteen or twenty miles; the Helderbergh series; and lastly, the Erie group, which completes the whole of the system, extending up to the old red sandstone. * * * The valley of Lake Ontario, at its southern extremity, is excavated out of the shales, sandstones and shaly limestones which compose the Ontario group. * * * The Ontario group is well developed all along the southern shore of that lake, particularly at Rochester, Lockport, and on the Niagara river. * * * [Pages 100-101. On page 429 the *Ontario group* is defined as underlying the Helderberg series (including at base the Pentamerus [Coeymans] limestone), as overlying the Champlain group, and as including Manlius limestone at top and Medina sandstone at base.]

As above defined the term "Ontario group" is essentially synonymous with Silurian system of present usage.

J. D. Dana, 1890 (Geol. Soc. America Bull., vol. 1, pp. 40–41).

The Upper Silurian may conveniently take a new name, but it is not necessary to go for it to the same little land of Wales that has supplied the two, Cambrian and Silurian, in honor of Sedgwick and Murchison. We may better look elsewhere for the third name. There is the land of Bohemia, where Barrande worked out his Silurian and Primordial systems, and there is the area of New York and Canada where were laid the foundations of American Paleozoic geology, and where our honored president, James Hall, has carried on his paleontological labors.

The term Bohemian has been already used for the Upper Silurian by the French geologist, M. de Lapparent, in his Treatise of 1883. The name Ontarian is suggested by the actual use of the term "Ontario Division" for the lower portion of the Upper Silurian by Mather, in his New York Geological Report of 1843, and by Emmons, in his Report of 1846. And it is in its favor that Upper Silurian rocks prevail over much of Ontario, Canada.

Cambrian, Silurian, Ontarian, would make a satisfactory triplet. Whatever name shall be adopted for the Upper Silurian, the working ground of Barrande, or that of Hall, Billings, and others should some way be recognized, and to this even the distinguished author of the term Ordovician would not, I am sure, enter his dissent.

J. M. Clarke and C. Schuchert, 1899 (Science, new ser., vol. 10, pp. 875–876).

[*Ontaric or Siluric era or system* is defined, in the table, as including all rocks between the top of the Manlius limestone and the base of the Oneida conglomerate or Shawangunk grit.]

Ontaric.—Vanuxem placed the base of the Ontario division at the "gray sandstone," Hall and Emmons at the [base of the] Medina, Mather at the Shawangunk grit. Vanuxem and Hall terminated the division above with the Niagara, Emmons included the Salina and waterlime. Any rational grouping of these formations must recognize as its base the predominance of coarse sedimentation installing a new cycle. Growing evidence fully endorses Emmons' view as to the termination of the group and period with the clearing of the Salina sea.

"ALEXANDRIAN SERIES"

T. E. Savage, 1908 (Am. Jour. Sci., 4th ser., vol. 25, pp. 433–434, 442–443).

MIDDLE SILURIAN SYSTEM

Alexandrian.—The beds referred to this formation are exposed in Alexander county to a thickness of 44 feet. They include the Cape Girardeau limestone and the overlying beds containing *Dalmanites danae* and *Whitfieldella billingsana.* The Cape Girardeau limestone is well exposed about two miles south of Thebes, in the bank of the river and along the streams in that immediate vicinity. It is also seen in a cut along the Illinois Central railroad, and in the river's bank, one and one-half miles north of Thebes. In the former locality this limestone is nearly 40 feet thick, and consists of black, fine-grained, brittle limestone, in thin layers which are often separated by narrow partings of dark, calcareous shale. This zone has a rich fauna which appears abruptly at this horizon. [Fossils listed.]

At the exposure north of Thebes the Cape Girardeau limestone rests directly upon the fossiliferous blue shale (2*b* of section). This member is succeeded by a bed of dark gray limestone, oolitic in the upper part. [Fossils listed.]

There are here no diagnostic fossils of the Richmond. The genera *Favosites, Stromatopora; Atrypa, Whitfieldella, Homœospira, Schuchertella* and *Clorinda* do not occur in American Ordovician strata, while *Atrypa rugosa* and *Lichas breviceps clintonensis* are indicative of the Silurian. On the other hand, the fauna is not directly related to that of the Clinton, from which formation it is separated by a marked erosional unconformity. Schuchert[20] cites a fauna from Edgewood, in eastern Missouri, collected by Ulrich, which corresponds closely with the above. Since there seems to be no direct time equivalent of these beds in the Ordovician or in the Silurian as generally defined, the horizons 3*a* to 3*c* are classed as Middle Silurian strata that more or less completely bridge the lost interval between the Cincinnatian and the Clinton. For these beds the time term Alexandrian is proposed, from Alexander county, Illinois, where they are well exposed; the term to have the same rank as Cincinnatian, which it immediately follows.

On pages 442–443 of the volume cited above the rocks of southwestern Illinois are classified as follows:

Devonian system:

* * *

Helderbergian.

A long break in sedimentation.

[20] Jour. Geol., vol. xiv, pp. 728, 729, 1906.

Upper Silurian or Silurian system:

Niagaran. Correlated with Clinton-Dayton, Ohio Clinton,[80] Interior or Western Clinton. 75 ft. [Details of beds given and fossils listed.]

A short break in deposition.

Middle Silurian system:

Alexandrian:

3c. Coarse-grained, somewhat oolitic limestone, in layers 12–18 inches thick. *Atrypa rugosa*, *Rhynchotreta* sp., *Schuchertella subplanus*, *Whitfieldella billingsana*, and *Lichas breviceps clintonensis* are common. 3½ ft.

3b. Fine-grained, dark colored shaly limestone, in layers 4–10 inches thick, characterized by *Rafinesquina mesacosta*, *Schuchertella subplanus* and *Dalmanites danæ*. 2½ ft.

3a. *Cape Girardeau limestone:* Fine-grained, black, brittle limestone, layers 1–4 inches thick, separated from each other by thin lenses or partings of calcareous shale on the surface of which are exposed Crinoids, *Rafinesquina mesacosta*, *Rhynchotrema* sp., *Schuchertella missouriensis* and *Cornulites tenuistriata*, etc. 33–38 ft.

A probable short break in sedimentation.

Lower Silurian or Ordovician system:

Cincinnatian:

Richmond-Maquoketa. 91 ft.

ORDOVICIAN PERIOD (OR SYSTEM)

C. Lapworth, 1879 (Geol. Mag., London, new ser., vol. 6, pp. 12–14).

So long as present systems of nomenclature survive, nothing can disturb the application of the title of Cambrian to the rocks of the *Primordial Series*, and that of Silurian to the strata of the *Third Fauna*. In these systems, as thus restricted, the most perversely ingenious partisan could scarcely find room for controversy. Within these limits the labours of their respective founders were comparatively perfect and complete, and the propriety and harmony of their original classifications, though slightly modified in detail by subsequent research, has never been impugned, either by friend or foe. It is vastly different, however, as we have seen, with the intermediate system. From the day it was recognized until now, it has been the object of incessant disputes. Its co-discoverers both committed the gravest of errors regarding either its proper limits, its relationships, or the sequence and fossils of its component formations. It has been the subject of almost as much passionate argument as the Wernerian theory itself; * * *

North Wales itself—at all events the whole of the great Bala district where Sedgwick first worked out the physical succession among the rocks of the intermediate or so-called *Upper Cambrian* or *Lower Silurian* system; and in all probability much of the Shelve and the Caradoc area, whence Murchison first published its distinctive fossils—lay within the territory of the *Ordovices*; a tribe as undaunted in its resistance to the Romans as the Silures. It was indeed the *last* of the old British tribes to yield to their invincible legions; and

[80 In 1913 (Geol. Soc. America Bull., vol. 24, pp. 111–112, 351–376) Savage transferred to his Alexandrian series the "Ohio Clinton" or Brassfield limestone, and placed its top at the base of deposits of the age of the true or typical Clinton of New York. The thickness of the included strata aggregates 140 feet in Illinois.]

it is consequently quite as well worthy of scientific commemoration as the Silures themselves.

Camden thus refers to the Ordovices: * * * "To the *Ordovices* belonged those countries which are now called in English by new names—Montgomeryshire, Merionethshire, Caernarvonshire, Denbighshire, and Flintshire."

Here, then, have we the hint for the appropriate title for the central system of the Lower Palæozoics. It should be called the *Ordovician system*, after the name of this old British tribe.

Whatever arguments may be adduced in support of the term Silurian will apply equally well, or even with greater force, to this new title. Like the term Silurian, it is classic in origin, but at the same time thoroughly British. It is equally euphonious, and far more strictly significant of the geographical area where its strata are typically developed. Indeed, the employment of the one title almost of itself necessitates the adoption of the other; for only in this way is it possible to recognize the systematic equality of the two systems in their very designations—the one receiving its name from the ruling tribe in the *south* of Wales, the other from the dominant tribe in the *north*. If there is anything specially becoming in commemorating the warlike tribe of the Silures in the name of a geologic system, how strikingly appropriate is the title of *Ordovician* in erecting a similar scientific monument to the last and most valiant of the old Cambrian tribes.

On this arrangement the Lower Palæozoic Rocks of Britain stand as follows:—

(c) SILURIAN SYSTEM:—Strata comprehended between the base of the *Old Red Sandstone* [Devonian system] and that of the *Lower Llandovery*.

(b) ORDOVICIAN SYSTEM:—Strata included between the base of the *Lower Llandovery* formation and that of the *Lower Arenig*.

(*a*) CAMBRIAN SYSTEM:—Strata included between the base of the *Lower Arenig* formation and that of the *Harlech Grits*. * * *

For explanation of the foregoing terms see Geikie's classification on accompanying chart.

This original definition of Ordovician includes in the Cambrian the Tremadoc slate, which according to Ulrich's 1914 classification is of Beekmantown age, but which he now (1924) regards as probably representing his Ozarkian system. All American geologists classify the Beekmantown as post-Cambrian, and until 1911 it was universally included in the Ordovician. In 1911 Ulrich[31] proposed the restriction of Ordovician by the separation of the major part of the Beekmantown as an independent system, for which he employed the name "Canadian system." In the same publication he also proposed to restrict the Cambrian as previously used in the United States, by combining the remaining (lower) part of the Beekmantown and beds which he states were erroneously correlated with the upper part of the Cambrian, including the Potsdam sandstone of New York, into another independent system, for which he proposed the name "*Ozarkian*," as explained in the quotation under that name.

[31] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, pp. 647–680, pl. 27.

Some authors prefer the name "Champlainic system" or "Champlainian system" to Ordovician. (See definition on p. 88.)

CINCINNATIAN EPOCH (OR SERIES)

F. B. Meek and A. H. Worthen, 1865 (Acad. Nat. Sci. Philadelphia Proc., vol. 17, p. 155).

As it is now acknowledged that the rocks along the Hudson river valley, to which the name Hudson River Group has been applied, belong, as long maintained by Dr. Emmons, to a different horizon from the so-called Hudson River rocks of western New York, and the states farther westward, it seems to be an awkward misnomer to continue to apply the name Hudson River Group to these western deposits. Hence it is certainly desirable that this group should receive some appropriate and generally applicable name. Its subdivisions, it is true, have already received various lithological names, such as "Utica Slate," "Frankfort Slate," "Lorraine Shale," &c.; but as each of these names will probably be always directly associated, in the minds of geologists, with the particular subdivision to which it was originally applied, while neither of them is applicable to the lithological characters of the whole series, we cannot, without creating confusion, so extend its signification. It has recently been proposed to designate this series as the "Green and Blue Shales and Limestones;" this, however, is not a name, but descriptive phrase, and has the disadvantage of being based upon lithological characters not everywhere characteristic of these beds.

In view of all the facts, we have concluded to propose the name Cincinnati Group—(which will be adopted in the forthcoming reports of the Illinois Geological Survey)—for this series. This name possesses the advantage of being equally applicable to rocks of any color or composition, while it carries the mind to a well-known locality, where the formation referred to is extensively developed, and its fossils so abundant that they have been thence widely distributed, both in this country and Europe. Consequently, geologists will everywhere at once understand to what particular horizon of the Lower Silurian this name refers.

In the early definitions of "Hudson River group" the Utica slate was excluded from it and its top was limited by the base of the Oneida conglomerate or Shawangunk grit. In 1851 Hall transferred the Utica slate to the "Hudson River group." Dana, however, continued to exclude the Utica, as indicated in the editions of his textbook up to and including the edition of 1895.

N. H. Winchell and E. O. Ulrich, 1897 (Minnesota Geol. and Nat. Hist. Survey Final Rept., vol. 3, pt. 2, pp. ci–cv).

Hudson River or Cincinnati period.—Under this term we include all the rocks lying between the top of the Trenton and the base of the Upper Silurian. Space is wanting, nor are we fully prepared to give all our reasons for preferring the term Cincinnati for the period instead of Hudson River group or period, Hudson terrane, or that oldest name of them all, the "Gray Sandstones and Shales of Salmon River" as described and named by Conrad in 1837, in his first report on the geology of the third district of New York. For the present it will be sufficient to say that our preference is dominated by a sense of its utility and fitness. There is no other locality on the continent that deserves so well to be considered the typical locality for the series of strata in question as the region about Cincinnati, Ohio. All the groups into which the period may be divided are well represented there, and when it comes to their faunas and the facilities for collecting fossils, there is no other region in America where the fossils are so plentiful and so easy to obtain. Throughout this volume, however, and in all the Minnesota reports the term Hudson River has been used, and it is only from a sense of consistency that it is placed first in our title. The following subdivisions of the rocks of the "Hudson River or Cincinnati period" were made, enumerated in descending order:

Richmond group.
Lorraine group.
Utica group.

J. M. Clarke and C. Schuchert, 1899 (Science, new ser., vol. 10, pp. 876, 877).

Ontaric or Siluric era or system:
* * *
Oswegan period or group (Paleontaric):
Medina sandstone.
Oneida conglomerate.
Shawangunk grit.
Champlainic era or system (Lower Silurian and Ordovician):
Cincinnatian period or group (Neochamplainic):
Richmond beds (Ohio and Indiana).
Lorraine beds.
Utica shale.
Mohawkian period or group (Mesochamplainic):
Trenton limestone.
Black river limestone.
Lowville limestone.

Cincinnatian.—The formations of the Neochamplainic are not as completely developed in the State of New York as in Ohio and Indiana. In the latter sections the Lorraine fauna is represented, but is followed above by the well-defined fauna of the Richmond beds. Probably in no other region is the succession of these faunas so complete as about Cincinnati, and this fact justifies the recognition of the term Cincinnatian, which already has historic value. For a full description of the series by Winchell and Ulrich, see Geol. and Nat. Hist. Surv. of Minn., vol. 3, pt. 2, pp. ci-cv, 1897.

The United States Geological Survey employs the term *Cincinnatian series* as a provincial name for the Upper Ordovician series, and ascribes to it the same limits as those given by Winchell and Ulrich in 1897 and by Clarke and Schuchert in 1899.

MOHAWKIAN EPOCH (OR SERIES)

James Hall, 1842 (Am. Jour. Sci., 1st ser., vol. 42, p. 52).

Thus according to the report just quoted, and which in fact gives a very accurate account of the rocks of the state [of Ohio], we have in Ohio only two limestone formations, whereas in New York we have three very important ones, with some minor beds. These are, 1st. The limestone along the Mohawk valley, the principal member of which is termed by Mr. Vanuxem, the "Mohawk limestone," a name which with much propriety might be applied to the whole mass, forming the *Mohawk group*. This would include the Mohawk, Birdseye, and Trenton limestones, and the calciferous sandrock [Beekmantown] might also be included as the lower member of the group. 2d. The *Niagara group*.

As above defined the term "Mohawk group" included the Middle Ordovician and the Lower Ordovician of present usage. The name "Mohawk system" had previously been applied by Conrad to all rocks between the base of the Rochester shale and the base of the Potsdam sandstone.

J. M. Clarke and C. Schuchert, 1899 (Science, new ser., vol. 10, pp. 876, 877).

Mohawkian period or group (Mesochamplainic):
Trenton limestone
Black river limestone
Lowville limestone (instead of Birdseye limestone of common use).

Conrad and Vanuxem made use of the term "Mohawk limestone" for certain of the calcareous layers beneath the Trenton, but they differed so widely in their application of the term that in the summation of their results, the geologists decided to abandon it. The name is here revived with a broader meaning. [See chart, last column.] The valley and watersheds of the Mohawk river afforded typical exposures of all members of the group.

The United States Geological Survey employs the term *Mohawkian series* as a provincial name for the Middle Ordovician series, and ascribes to it the same limits as those given above by Clarke and Schuchert—that is, from the base of the Lowville limestone to the top of the Trenton limestone.

"CANADIAN PERIOD (OR SYSTEM)"

J. D. Dana, 1874 (Am. Jour. Sci., 3d ser., vol. 8, p. 214).

Canadian Period.—The fact of the existence of an important Lower Silurian formation in Canada, near Quebec, abounding in fossils, and of about the age of the Calciferous sand-rock and the Chazy limestone, is mentioned, in the first edition of this work, as one of the discoveries of the Canadian Geological Survey, under Sir William Logan. The Reports of the Survey point out the close relations in fossils of the Calciferous sand-rock, Quebec group, and Chazy, and their rather wide separation from the overlying Trenton limestone, showing that they represent, naturally, a distinct period in the Lower Silurian era. This is called the Canadian, because the rocks are well displayed in Canada, and there the most important part of the facts respecting it were first brought to light.

J. D. Dana, 1875 (Manual of geology, 2d ed., pp. 142, 163, 182).

Lower Silurian:
Trenton period:
Cincinnati.
Utica.
Trenton.

Canadian period:

Chazy epoch. (Chazy limestone of New York, Canada, etc. Part of the crystalline limestone of the Green Mountains in Vermont and to the south.)

Quebec epoch. (Levis formation, Canada, near Quebec; Taconic slates of Green Mountains; shales, limestones and sandstones, Newfoundland. Part of the Knox group, Tennessee.)

Calciferous epoch. (Calciferous sandrock in New York. Lower Magnesian limestone of the Mississippi valley; St. Peters sandstone of Wisconsin and Illinois; Knox sandstone, East Tennessee; thick limestones (part of the so called Quebec group) of Newfoundland.)

Primordial or Cambrian period:

Potsdam.

Acadian.

Archæan period.

The rocks of the extensive Quebec group were first distinguished and described in Canada by Canadian geologists, and all the subdivisions are well represented there; and hence the period is named the Canadian.

J. M. Clarke and C. Schuchert, 1899 (Science, new ser., vol. 10, pp. 876, 877).

Champlainic era or system (Lower Siluric and Ordovician):

Cincinnatian period or group.

* * *

Mohawkian period or group:

Trenton limestone.

Black River limestone.

Lowville limestone.

Canadian period or group. This term has the prestige of time and priority.

Chazy limestone.

Beekmantown limestone.

Cambric or Taconic era or system:

Potsdamian.

Acadian.

Georgian.

E. O. Ulrich, 1911 (Geol. Soc. America Bull., vol. 22, pl. 27, pp. 647–679).

Ordovician period or system. * * * [Includes Chazy limestone.]

Canadian period or system:

Beekmantown (Comprising Divisions E, D, C, and part of B).

Tribes Hill limestone. [Shown as in part contemporaneous with lower part of Beekmantown divisions mentioned and in part older.]

Ozarkian period or system.

"CHAMPLAINIC SYSTEM"

E. Emmons, 1842 (Geology of New York, pt. 2, div. 4, Geology of the second district, pp. 100–101, 102–126, 429).

As the rocks which constitute the lower part of the mass of the [New York] Transition system have hitherto received very little attention, it became necessary not only to investigate with great care their characters and relation, but also to provide them with suitable names. After having given them the attention and care they seemed to require, I have, with little hesitation, concluded that they belong to but one group. Although there is a great diversity in the lithological character, still the fossils appear to belong to but few types, and to those which are strictly related to each other. In this single group, the fossils appear to be allied; but when we leave the upper member, and pass to the Medina sandstone, we find a distinct change in the character of the fossils. * * * The name which appeared the most appropriate to this group, is derived from the lake along which they are so well developed, (I refer to Lake Champlain); hence it becomes the *Champlain group.* * * * [Page 100.] The valley of Lake Champlain is excavated out of the Champlain group. [Page 101.]

The "Champlain group" is defined, on the pages cited above, as composing the basal group of the "New York system," as overlying the "Taconic system" and underlying the "Ontario group," and as including Potsdam sandstone, "Calciferous sandrock," Chazy and "Birdseye" limestone, marble of Isle La Motte, Trenton limestone, Utica slate, Lorraine shale, "Grey sandstone," and "Conglomerate." As thus defined it includes the upper part of the Cambrian of present usage, all of the Ordovician, and possibly some rocks that are now classified as Silurian.

J. M. Clarke and C. Schuchert, 1899 (Science, new ser., vol. 10, pp. 875, 876).

Champlainic era or system (Lower Silurian and Ordovician).—This most appropriate designation was introduced by the concurrence of the four geologists [Mather, Emmons, Vanuxem, and Hall] for the formations here [see chart, last column] assigned to it (exclusive of the Potsdam sandstone), and it has clear right of way over the later application of the name to the period of post-glacial alluvium. That the later term has become ingrained in literature renders it all the more conspicuous as an infraction of the law and of the rights of the men who first proposed it. In the face of Champlain, 1842, the term Ordovician has no standing.

Some authors use the term "Champlainian" for the middle part only of the Ordovician—that is, for the Mohawkian epoch plus the Chazy.

PROPOSED OZARKIAN SYSTEM OF E. O. ULRICH

E. O. Ulrich, 1911 (Geol. Soc. America Bull., vol. 22, pp. 548, 627–629, 640, 643, pl. 27).

The Ozarkian system as developed in the southern part of the Appalachian Valley, comprises the various magnesian limestone formations which succeed the last of the upper Cambrian shales and thin limestones, and precede the Canadian limestone, or, where that is absent, the Stones River limestone of the Ordovician system. The whole of this sequence of dolomites and magnesian limestones is commonly referred to a single great formation—the Knox dolomite. However, this composite Knox varies greatly from place to place in its thickness and in the age of the beds contained in it. * * * [Page 548.]

Under the term Ozarkian system I include all the formations in the Appalachian Valley that can be shown to be younger than (1) the top of the upper Cambrian Nolichucky shale in northeastern Tennessee and (2) the top of the Conasauga shale in southeastern Tennessee, northwestern Georgia, and northeastern Alabama and which are older than the base of the Stonehenge limestone of the Canadian system [Beekmantown group, exclusive of division A and part of division B] in southern and central Pennsylvania. Wherever I have seen the contact with the underlying upper Cambrian shale or shaly limestone evidence of interrupted sedimentation was noted. * * * The top of the system also is everywhere in unconformable relations to succeeding deposits.

The most convincing part of the evidence on which it is claimed that an important stratigraphic hiatus separates the upper Cambrian in the southern half of the valley from the overlying Ozarkian lies in the greatly varying age of the beds forming the base of the latter in different localities. Occasionally, as in River Ridge, 3 miles northwest of Morristown, Tennessee, the Copper Ridge chert rests on the Nolichucky. More commonly the Knox begins with an older division 300 to 700 feet thick, while in the vicinity of Montevallo, Alabama, three still older formations, aggregating at a maximum something near 2,500 feet of dolomite, intervene between the base of the typical Knox and the top of the Conasauga. The hiatus between the two systems, therefore, represents locally in east Tennessee over 3,000 feet of known calcareous deposits laid down elsewhere in Tennessee and in central Alabama. Even this great thickness of lower Ozarkian deposits does not fully measure the time break, for a gap is still indicated between the Brierfield dolomite at the base of the new system and the top of the upper Cambrian. [Page 628.]

* * * Though much thinner than the Appalachian record, the Missouri section makes a more satisfactory type because here the rocks are more fossiliferous and the stratigraphic sequence, in an epitomized way, more complete.

Derivation of the name and the type section.—For reasons mentioned the term Ozarkian, a modification and restriction of the name "Ozark series," suggested by Broadhead some years ago (American Geologist, vol. viii, 1891, p. 33) seems highly appropriate. Broadhead was the first to use the geographic name Ozark as a stratigraphic term. * * * [Pages 628–629.]

In Missouri, then, the Ozarkian comprises all beds younger than the Elvins and older than the base of the Canadian system represented in north Arkansas by the Yellville dolomite. [Page 629.]

The Ozarkian in the upper Mississippi Valley.—In the upper part of the Mississippi Valley the Ozarkian includes four long established formations, namely, (1) the Mendota dolomite, (2) the Jordan sandstone (Madison sandstone of Wisconsin), (3) the Oneota dolomite, and (4) the Shakopee dolomite, the last including the New Richmond sandstone, which is thought to indicate an introductory clastic phase of the Shakopee rather than a distinct formation. * * * [Page 640.[32]]

The Ozarkian is represented in New York by the Potsdam sandstone, the Theresa passage beds, the Hoyt limestone, and the Little Falls dolomite. * * * [Page 643.]

As thus originally defined, and shown on Plate 27 of the book cited, the proposed Ozarkian system included, in its typical area, the following formations, named in descending order:

Jefferson City dolomite.
Roubidoux formation.
Gasconade dolomite.
Proctor dolomite.
Eminence dolomite.
Potosi dolomite.

[[32] For Ulrich's present views on this and other sections see pp. 91–92.]

In the upper Mississippi Valley it included, in descending order:

Shakopee dolomite (including New Richmond sandstone).
Oneota dolomite.
Jordan sandstone (then supposed to be equivalent to Madison sandstone).
Mendota dolomite.

In New York it included, in descending order:

Little Falls dolomite.
Hoyt limestone.
Theresa formation.
Potsdam sandstone.

In 1915, after further field studies, Ulrich changed [33] the top of his Ozarkian system in its typical region to the top of the Gasconade, transferring the overlying Roubidoux and Jefferson City formations to his proposed Canadian system; and the top of the Gasconade is where he now (1924) places this boundary in Missouri. Further work in the upper Mississippi Valley has led him (unpublished chart) to place the top of his Ozarkian in that region at the top of the Oneota dolomite, and he now assigns the overlying Shakopee to his Canadian system. He also now includes in the base of the proposed Ozarkian a recently discovered sandstone, to which he has applied [34] the name Devils Lake sandstone, and which he considers younger than the true Jordan sandstone. The Jordan was formerly erroneously considered to be the same as the Madison sandstone, which underlies the Oneota, but is now determined by him to be Upper Cambrian.[34]

The rocks Ulrich now includes in his Ozarkian in the southern Appalachian region remain as described in his original definition, and those now included in it in New York remain unchanged, with the exception that some thin beds above the Little Falls dolomite are now included (unpublished chart).

The following is Ulrich's present (1924) classification (unpublished manuscript) of the formations originally included in his Ozarkian system:

Ozark region, Mo. (type area):
- Jefferson City dolomite } Now known to be middle Canadian.
- Roubidoux formation }
- Gasconade dolomite=upper Ozarkian.
- Proctor dolomite=middle Ozarkian.
- Eminence dolomite } =lower Ozarkian.
- Potosi dolomite }

---

[33] As recorded by R. S. Bassler in U. S. Nat. Mus. Bull. 92, pl. 1, 1915.
[34] Ulrich, E. O., Major causes of oscillations: Washington Acad. Sci. Jour., vol. 10, No. 3, pp. 73–78, 1920.

Upper Mississippi Valley:

Shakopee dolomite=upper Canadian (New Richmond sandstone local development and disregarded).

Oneota dolomite=upper Ozarkian.

(Middle Ozarkian absent.)

Madison sandstone. (The Jordan is not the same as Madison sandstone but last of Upper Cambrian.) Mendota dolomite Devils Lake sandstone	=lower Ozarkian and =Little Falls dolomite, Hoyt limestone, and Potsdam sandstone of New York.

New York:

Little Falls dolomite Hoyt limestone Theresa formation Potsdam sandstone	All lower Ozarkian.

Ulrich has in preparation a monographic description of his proposed Ozarkian system and its fauna.

CAMBRIAN PERIOD (OR SYSTEM)

Rev. A. Sedgwick, 1835 (Edinburgh New Philos. Jour., vol. 19, p. 390, August 14; abstract).

Mr. Murchison and Professor Sedgwick gave a lucid and most interesting account of their views regarding the older rocks of England and Wales, endeavoring to point out their subdivisions, so as to complete the series from the old red sandstone to the oldest slate rocks of Cumberland. Mr. Murchison treated of that part of the subject relating to the deposits which occur between the old red sandstone and the slaty rocks of Wales. This group of rocks has been termed by Mr. Murchison the Silurian System, and has been studied by him during the last five years in Herefordshire, Shropshire, Radnorshire, Brecknockshire, Monmouthshire, and Caermarthenshire. The detailed results of these important investigations will soon be given to the public in the work by Mr. Murchison, which is now in preparation. Professor Sedgwick explained the conclusions he had deduced from his elaborate and extensive examination of the greywacke, or slate series, of the north of England and Wales. Professor Sedgwick divides the old transition series into three groups, viz. the Lower Cumbrian [Cambrian], consisting chiefly of slates, and containing no organic remains; the Middle Cumbrian, composed of slates, conglomerates, and porphyries, and containing fossils; and the Upper Cumbrian, which contains much limestone, is fossiliferous, and approaches the lower beds of Mr. Murchison's Silurian System.

Rev. A. Sedgwick, 1836; read August, 1835 (British Assoc. Adv. Sci. Rept. 5th meeting, pp. 59–61).

On the Silurian *and* Cambrian Systems, *exhibiting the order in which the older Sedimentary Strata succeed each other in England and Wales. By Professor* Sedgwick *and* R. I. Murchison, *V. P. G. S.*

Mr. Murchison described a great group of fossiliferous deposits which rises out from beneath the old red sandstone. To these rocks, which he has termed in descending order the *Ludlow*, *Wenlock*, *Caradoc*, and *Llandeilo* formations, (each distinguished by peculiar organic remains, and frequently by subordinate limestones,) it was found essential to assign a comprehensive term, since they constitute one natural system interpolated between the old red sandstone and the slaty rocks of Wales. He observed that it was well known to all practical geologists, that in consequence of the recent advances of the science, it was absolutely imperative that the term "transition," under which such rocks would formerly have been described, should now be abandoned, since it had been so used, both by Continental and English writers, as to embrace the whole carboniferous series, from which the system under review was not only separated by the vast formation of the old red sandstone, but was specially to be *distinguished* by its fossil contents. Urged, therefore, by many geologists to propound an entirely new name for the class of rocks which had engaged his attention during the last five years, Mr. Murchison recently suggested (see Lond. and Edinb. Phil. Mag., July 1835, p. 48.) that the group should be termed the "*Silurian System*," the name being derived from the ancient British people, the Silures, who under Caractacus made so noble a stand against the Romans, and within whose territory the rocks under consideration are fully displayed. Mr. Murchison then pointed out, that wherever the limestones and typical characters of particular formations were absent or obscure, it was always practicable, over a region of 120 miles in length, extending from the neighborhood of the Wrekin and Caradoc hills, in Shropshire, to the west coast of Pembrokeshire, to separate the groups into two parts, the "Ludlow" and "Wenlock" formations, forming the "*Upper Silurian*," the "Caradoc" and "Llandeilo" the "*Lower Silurian rocks*." He further remarked, that in South Wales he had traced many distinct passages from the lowest member of the "Silurian system" into the underlying slaty rocks, now named by Professor Sedgwick the "Upper Cambrian."

This communication was illustrated by Ordnance Maps extending over large parts of eleven counties, coloured in the field by Mr. Murchison.

Professor Sedgwick commenced by pointing out the imperfection of the sections exhibited in the North of England, and some portions of North Wales, in consequence of the entire want of continuity between the carboniferous series and the inferior schistose groups. Some of the latter are fossiliferous both in Denbighshire and Westmorland; but in the interrupted sections of those counties it is impossible to tell how many terms are wanting to complete the series to the old red sandstone and carboniferous limestone. In the country described by Mr. Murchison these difficulties do not exist, and his sections have filled up a wide chasm in the succession of British deposits. Professor Sedgwick then described in descending order the groups of slate rocks, as they are seen in Wales and Cumberland [Tremadoc slate and Lingula flags]. To the highest he gave the name of *Upper Cambrian group.* It occupies the greatest part of the chain of the Berwyns, where it connected with the Llandeilo flags of the Silurian system, and is thence expanded through a considerable portion of South Wales. In one part of its course it is based on beds of limestone and calcareous slate; but on the whole it contains much less calcareous matter than the Silurian system, and has fewer organic remains. Beds of good roofing-slate occur, and a perfect slaty cleavage is often observed in it transverse to the stratification; but other parts of it are of a coarse mechanical texture. To the next inferior group he gave the name of *Middle Cambrian.* It composes all the higher mountains of Caernarvonshire and Merionethshire, and abounds in fine roofing-slate, alternating with, and apparently passing into, irregularly interstratified masses of porphyry. Some portions of it are coarse and mechanical, and it contains (for example, at the top of Snowdon,) a few organic remains, and a few examples of highly calcareous slates, but no continuous beds of limestone. The same group, with the same mineral structure, and in the same position, but without organic remains, is greatly developed in Cumberland. The *Lower Cambrian* group occupies the S. W. coast of Caernarvonshire, and a considerable portion of Anglesea: it consists chiefly of chlorite schist, passing here and there into mica schist and slaty quartz rock, and contains subordinate masses of serpentine and white granular limestone. It contains no organic remains. Beneath the *Middle Cambrian* system (above described) there occurs in Cumberland (for example, Skiddaw Forest,) a great formation of dark glossy clay slate, without calcareous matter, and without organic remains. It passes in descending order into chiastolite slate, mica slate, hornblende slate, gneiss, etc., which rest immediately on granite. Whether the *Lower Cambrian* was to be placed on the exact parallel of these masses in Skiddaw Forest, the Professor did not determine.

Professor Sedgwick explained the mode of connecting Mr. Murchison's researches with his own, so as to form one general system. He pointed out also the limit, as at present known, of fossils, none having been hitherto discovered in the *Lower Cambrian* schists, and remarked in reviewing the general phaenomena, that geological epochs were not effected by shocks, but, like everything in nature, were under the dominion of the usual laws of causation.

These original definitions of Cambrian included in the Lower Cambrian some Archean rocks, and in the Upper Cambrian much of the Ordovician of present usage. Subsequent studies, however, led to the separation from the Cambrian of the Archean and Ordovician rocks, and to the restriction of the term Cambrian to beds characterized by the trilobite genus *Paradoxides* in what was then supposed to be Lower Cambrian, by the trilobite genus *Olenellus* in what was then supposed to be Middle Cambrian, and by the trilobite genera *Olenus* and *Dicellocephalus* in the Upper Cambrian. As work on the Cambrian rocks progressed, geographic names were sought for the three subdivisions or series into which the Cambrian was divided. Thus the name Potsdam came to be applied [35] to the rocks containing the *Dicellocephalus* fauna, Georgian to the rocks containing the *Olenellus* fauna, and Acadian to the rocks containing the *Paradoxides* fauna.

Owing, however, to the fact that for many years the relations of the rocks containing the *Paradoxides* fauna to those containing the *Olenellus* fauna were misunderstood, not having anywhere been found in the same section, the *Paradoxides* fauna was supposed to occur in rocks older than those containing the *Olenellus* fauna. Thus it happened that the *Olenellus*-bearing rocks at Georgia, Vt. (the type locality of the "Georgian" series), were originally supposed to be of Middle Cambrian age, Upper Cambrian fossils having been found higher in the section in northern Vermont, but no *Paradoxides* having been found.

[35] Walcott, C. D., The Cambrian faunas of North America: U. S. Geol. Survey Bull. 30, 1886.

In 1886, therefore, Walcott,[36] following the classification made by Sir William Logan in 1864, assigned to the Middle Cambrian the *Olenellus* zone, which had been found characteristically developed at Georgia, Vt., and applied to it the geographic name Georgia, a name that Hitchcock had in 1861 applied to the slate formation at Georgia, Vt., which was supposed to be the same as the rocks yielding the *Olenellus* fauna. The discovery in Sweden, however, of *Olenellus kjerulfi* beneath the *Paradoxides* zone led Walcott to restudy the Cambrian rocks of New York and finally to go, in the summer of 1888, to Newfoundland, where a more complete section of the Cambrian was believed to exist. Manuel's Brook, Conception Bay, Newfoundland, furnished the sought-for section, and definitely settled the relations of the *Paradoxides* and *Olenellus* faunas in America. The conformable succession of rocks at that place proved beyond question that the *Olenellus* fauna is older than the *Paradoxides* fauna. Walcott, therefore, in 1888[37] published the following classification of the Cambrian system:

Upper Cambrian (*Dicellocephalus* or *Olenus* fauna), represented in America by the Potsdam and other terranes.
Middle Cambrian (*Paradoxides* fauna), represented by the St. John, Avalon, and Braintree terranes.
Lower Cambrian (*Olenellus* fauna), represented by the Georgia and other terranes.

In 1891 Walcott[38] modified the name Georgia to Georgian.

The name Potsdam (also Potsdamic) continued to be applied to the Upper Cambrian series in America until 1903, when Walcott replaced it by the geographic term "Saratogian," for the reasons stated on a later page, in the quotation under "*Saratogan*" *epoch*. Unfortunately the name Saratoga was found to be preoccupied by a Cretaceous chalk in Arkansas, and in 1912 Walcott withdrew "Saratogan" and replaced it with *St. Croixan series*, the present adopted name for the Upper Cambrian epoch or *Dicellocephalus* and *Olenus* zone. The rocks in the Saratoga region are now regarded by Walcott and Ulrich as younger than the typical Upper Cambrian of the British Isles.

Dawson's name Acadian is still the approved name for the Middle Cambrian epoch or *Paradoxides* zone.

Walcott's name Georgian continued to be applied to the Lower Cambrian epoch or *Olenellus* zone until 1912, when, because of the

---

[36] Op. cit.

[37] Walcott, C. D., The stratigraphical succession of the Cambrian faunas in North America: Nature, vol. 38, p. 551, 1888.

[38] Walcott, C. D., The Cambrian group of rocks in North America: U. S. Geol. Survey Bull. 81, 1891.

varied usage of the name and the conflict with the formation that had been named Georgia slate by Hitchcock in 1861, Walcott withdrew Georgian and replaced it by the present accepted name Waucoban, as explained under *Waucoban epoch.*

Recent detailed studies of the Georgia slate region of Vermont by Arthur Keith have proved that the typical Georgia slate is of Ordovician age (probably either Black River or Trenton), and the rocks of that region that have been called " Georgia shales," " Georgia formation," and " Georgian or Lower Cambrian series " have recently yielded fossils of Upper, Middle, and Lower Cambrian ages, and have been separated by him into several distinct formations, for which new names have recently been introduced.[39]

The type locality of the Cambrian system is, as explained in the early definitions, the ancient area of Cambria, in North Wales, where, according to Walcott, " the Middle and Upper Cambrian faunas occur, and the strata corresponding in position to those containing the Lower Cambrian fauna in America are found beneath the Middle Cambrian Zone."

" SARATOGAN " EPOCH (OR SERIES)

(Discarded name for Upper Cambrian)

C. D. Walcott, 1903 (Jour. Geology, vol. 2, pp. 318–319).

NEW TERM FOR THE UPPER CAMBRIAN SERIES

During a recent revision of the classification of Cambrian formations, in connection with the nomenclature and classification to be used in the geologic atlas of the United States, it became apparent that the term " Potsdam " or " Potsdamic " could no longer be retained as the series name to include the various formations referred to the Upper Cambrian. It was used in this sense by me in 1891,[40] but this usage has led to confusion, owing to the term " Potsdam " being retained for the well-known Upper Cambrian sandstone about the Adirondack mountains. In order to avoid further confusion, the term *Saratogian* is now proposed to include the various formations composing the Upper Cambrian series, leaving the term " Potsdam " restricted to its original application, the Potsdam sandstone. We shall then have the terms " Georgian " (Lower Cambrian), "Acadian" (Middle Cambrian), and " Saratogian " (Upper Cambrian) for the three series of formations of the Cambrian system.

The type locality of the Saratogian is north and west of Saratoga Springs, N. Y. The section has, at the base, about 200 feet of evenly bedded, compact, grayish to yellowish colored sandstone, that rests unconformably against or upon spurs or ridges of pre-Cambrian gneiss. At a locality three miles north of Saratoga Springs the sandstone is about 40 feet in thickness; it is overlain

[39] Keith, Arthur, Cambrian succession of northwestern Vermont: Am. Jour. Sci., 5th ser., vol. 5, pp. 97–139, 1923.

[40] Bull. U. S. Geol. Surv., No. 81, p. 360.

by an oölitic limestone, 30 feet, and a dark gray, evenly bedded limestone 50 feet in thickness. In this latter limestone the following fauna occurs:

Cryptozoa proliferum	*Billingsia saratogensis*
Obolus (Lingulepis) acuminatus	*Matthevia variabilis*
Platyceras minutissimum	*Dikelocephalus hartti*
Platyceras hoyti	*Dikelocephalus speciosus*
Metoptoma cornutiforme	*Ptychoparia calcifera*
Metoptoma simplex	*(A.) saratogensis*

The Calciferous formation of the New York section rests conformably on the Upper Cambrian limestone.

The formations now referred to the Saratogian are as follows:

Type.—Sandstones and limestones of the south side of the Adirondacks, Saratoga county, N. Y., containing the Upper Cambrian fauna.

Correlated.—Upper part of Cambrian limestones of Dutchess county, N. Y., and an unknown portion of the limestones of the "Marble Belt" of western Vermont.

Upper part of shales of Tennessee (Knox), state of Georgia, and Alabama (Connasauga), and the lower part of the Knox dolomite.

Upper part of the sandstones of the Upper Mississippi valley (St. Croix).

Upper Cambrian limestones of South Dakota, Wyoming, Montana, and Colorado.

Upper calcareous beds of the Cambrian of northern Arizona (Tonto) and central Texas (Katemcy).

Upper Cambrian limestones and shales of Nevada (Hamburg), Idaho, and Montana (Gallatin).

Black shales of the upper portion of the New Brunswick and Cape Breton Island Cambrian sections.

Upper Cambrian shales and sandstones of Conception Bay, Newfoundland (Belle Isle).

The name "Saratogian," later changed to "Saratogan," was in 1912 replaced by St. Croixan, as explained in the quotation under *St. Croixan epoch*, which follows. The rocks in the Saratoga region are now considered by Ulrich and Walcott to be younger than the typical Upper Cambrian of the British Isles.

ST. CROIXAN EPOCH (OR SERIES)

(Upper Cambrian)

C. D. Walcott, 1912 (Smithsonian Misc. Coll., vol. 57, No. 10, pp. 306–307).

ST. CROIXAN OR UPPER CAMBRIAN [41]

When I proposed the name "Saratogian" in 1903 [42] for the Upper Cambrian group of formations, an examination of several lists of geological formation names failed to show that the name Saratoga had been used by Dr. J. C. Branner [43] for a Cretaceous chalk marl in Arkansas, in his description of "The Cement Materials of Southwest Arkansas." [44] A description of the forma-

[41] Ulrich, Bull. Geol. Soc. America, Vol. 22, No. 3, 1911, pl. 27, pp. 613 and 614.

[42] Journ. Geol., Chicago, Vol. II, 1903, pp. 318–319.

[43] Dr. John M. Clarke recently (May 27, 1912) called attention to this use of the name Saratoga by Branner, and wrote that he was then discussing the history of the name in a paper in press.

[44] Trans. American Inst. Mining Engineers, Vol. 27, 1898, pp. 52–55.

tion is given, with sections illustrating its stratigraphic position. In 1902[45] Mr. J. A. Taff used the term Saratoga formation in the same sense as Branner and gave illustrations of sections and contained fossils.

In view of the prior use of the name Saratoga by Branner and Taff, I doubt the advisability of continuing the use of Saratogan as a group name for the Upper Cambrian formations. There is also the fact that the two formations of Saratoga County, New York, that are used as the basis for the name, are not typically of Upper Cambrian age. A present tendency is to include them as passage beds between the Cambrian and the superjacent system of strata, or as belonging to the higher systems.[46] With the evidence now known to me from New York and the Appalachian region to the southwest I am inclined tentatively to refer the fauna as found in New York State to the upper limit of the Cambrian. The "Saratogan" would thus be correlated with one of the upper horizons of the "St. Croix sandstone" and included in the Upper Cambrian.[47]

My present view is that the use of the name Saratoga should be restricted to the Cretaceous formation, another name adopted for the group of formations included in the Upper Cambrian, and another name for the Potsdam-Hoyt fauna if that fauna is considered as distinct from the Upper Cambrian fauna.

When looking up a name for the Upper Cambrian formations in 1903, I thought of St. Croixan, but as the name St. Croix had become fixed in geological literature for the Cambrian sandstone of the Upper Mississippi Valley[48] I did not use it. In 1911[49] Dr. E. O. Ulrich proposed to use the name St. Croixan for the sea in which the St. Croix sandstones were deposited, and in his table of correlations of formations (pl. 27) and on page 614 of the same work he uses the term as a collective name for the Upper Cambrian formations. If we drop the term "St. Croix" as a formation name for the sandstones of Wisconsin and Minnesota containing the Upper Cambrian fauna, then the term St. Croixan may be used for the assemblage of formations characterized by the Upper Cambrian fauna.

The Upper Cambrian or St. Croixan epoch is characterized by fossil remains of trilobites belonging to the genera *Olenus* and *Dicellocephalus*. The Upper Cambrian rocks of the St. Croix Valley are now divided into several named formations. (See further explanations under "*Saratogan*" *epoch*, *Cambrian period*, and the proposed new name "*Ozarkian system.*")

ACADIAN EPOCH (OR SERIES)

(Middle Cambrian)

J. W. Dawson, 1868 (Am. Assoc. Adv. Sci. Proc., vol. 16, pp. 117–118).

ON RECENT GEOLOGICAL DISCOVERIES IN THE ACADIAN PROVINCES OF BRITISH AMERICA.

BY J. W. DAWSON, OF MONTREAL, CANADA

(Abstract)

The object of the paper was to notice some recent discoveries which, though of interest, might have escaped the notice of members of the Association.

[45] Twenty-second Ann. Rept. U. S. Geol. Survey, 1902, pp. 714–720.

[46] See Ulrich, Bull. Geol. Soc. America, Vol. 22, No. 3, 1911, pl. 27, and p. 612.

[47] See Smithsonian Misc. Coll., Vol. 57, No. 9, 1912, pp. 255, 256, for a fuller discussion of this question.

[48] See N. H. Winchell, 1873, Ann. Rept. Board of Regents, University of Minnesota. First Ann. Rept. Geol. and Nat. Hist. Surv. for 1872, pp. 68–80.

[49] Ulrich, Bull. Geol. Soc. America, Vol. 22, No. 3, 1911, p. 613.

In New Brunswick, the older rocks in the vicinity of the city of St. John have been reduced to order, and their probable ages ascertained, principally through the labors of Mr. Matthew, Mr. Hartt, and Prof. Bailey. The first step toward the knowledge of their precise date was the discovery of a rich land Flora in some of the upper beds, next below the lower carboniferous rocks which overlie them unconformably. These fossil plants I was enabled to recognize as of the Devonian period, and the zealous researches, more especially of Mr. Hartt, have brought to light no less than forty to fifty species, or half of the whole number known in the Devonian, of Eastern America, as well as six species of insects, four of which have been described by Mr. Scudder.[50] These insects are the first ever found in rocks older than the carboniferous.

These rocks, consisting chiefly of hard shales and sandstones, having been ascertained to be Devonian, there still remained an immense thickness of underlying rocks of uncertain age. In the upper member of these rocks the same active observers already mentioned have discovered a rich primordial fauna, embracing species of *Conocephalites*, *Paradoxides*, *Microdiscus*, and *Agnostus*, as well as an *Orthis* and a new type of Cystidian. These fossils are regarded by Mr. Hartt and Mr. Billings, as of the age of Barrande's "Etage C," and as marking a new and older period of the "Silurian Primordial" than any other as yet recognized in America, with the exception of the slates holding *Paradoxides* in Massachusetts, and the similar slates of the "Older Slate Formation" of Jukes in Newfoundland. Descriptions of these fossils, by Mr. Hartt, will be published in the edition of Acadian geology now in press. It is proposed to call this series, represented in New Brunswick by the St. John slates, the *Acadian Series*.

Below these primordial beds are highly metamorphosed rocks, at least nine thousand feet in thickness, which have not afforded fossils. A portion of these beds, consisting principally of conglomerate and trappose beds, is regarded by Messrs. Matthew and Bailey as of the age of the Huronian. The remainder, containing much gneiss and a bed of crystalline limestone, they regard as Laurentian. If this view is correct, and it certainly seems to be probable, these rocks, thus rising through the oldest members of the lower silurian, and forming a stepping-stone between the Laurentian of Newfoundland and that of New Jersey, show that the foundations of the north-east and south-west line of the east side of North America were already laid in the Laurentian period.

C. D. Walcott, 1891 (U. S. Geol. Survey Bull. 81, p. 248).

The name Acadian was proposed by Sir J. W. Dawson in 1867 for the series of rocks represented in New Brunswick by the St. John slate of Mr. G. F. Matthew.[51] In 1868 these observations were reprinted with the statement that the discovery adds a new formation to the Paleozoic period in America. He says:

"This formation has as yet been known as the 'St. John group,' but I think this name unsuitable, both on account of the number of places known as St. John and on account of the variety of formations occurring near St. John, in New Brunswick, and would propose for the group now under consideration, characterized by *Paradoxides*, *Conocephalites*, etc., and the oldest known member of the Paleozoic of America, the name Acadian group, by which I hope it

[50] Canadian Naturalist and Geologist, 1867.

[51] On recent geological discoveries in the Acadian provinces of British America. Proc. Am. Assoc. Adv. Sci., vol. 16, 1867, pp. 117–119. [Paper read in 1867, published in 1868.]

will be known to geologists in whatever part of America it may be recognized."[52]

In a recent paper on the fauna of the St. John group, Mr. G. F. Matthew limits the term Acadian to his Division 1 of the New Brunswick Cambrian section. This includes the fauna of the Paradoxides zone.[53]

The Middle Cambrian or Acadian epoch is characterized by fossil remains of trilobites belonging to the genus *Paradoxides*. (See further explanation under *Cambrian period*.)

"GEORGIAN" EPOCH (OR SERIES)

(Discarded name for Lower Cambrian)

C. D. Walcott, 1886 (U. S. Geol. Survey Bull. 30).

[See explanation under *Cambrian period*]

The name "Georgian" was in 1912 replaced by Waucoban, as explained in the quotation under *Waucoban epoch*, which follows.

WAUCOBAN EPOCH (OR SERIES)

(Lower Cambrian)

C. D. Walcott, 1912 (Smithsonian Misc. Coll., vol. 57, No. 10, pp. 305–306).

With the development of the mapping of the geological formations of the United States, it has increasingly become evident that the use of more than one term derived from the same geographic name is faulty in principle and confusing in usage. I have long been guilty of doing it in the use of Georgian for the Lower Cambrian series of formations. * * *

WAUCOBAN OR LOWER CAMBRIAN

Under the principle stated in the preceding paragraph, the term Georgian as used by me in 1891[54] is in bad form and should be replaced by a geographic name that has not been used for any geologic formation or group of formations. The history and use of the name Georgia is given in Bulletin 81, cited above, on pp. 98–113, 249–250, and 360.

Since the publication of Bulletin 81 in 1891, it has been found that the greatest development of the Lower Cambrian terrane is in Esmeralda County, Nevada, and the adjoining county of Inyo, California.

The Barrel Spring section of Nevada[55] has several thousand feet of Lower Cambrian strata, with a fine Lower Cambrian fauna. The Waucoba[56] section, 30 miles to the southwest, in California, is also finely exposed, and it has a well-marked Lower Cambrian fauna that extends through 4,000 feet of strata.

In view of the fine section east of Waucoba Springs, on the northeastern side of Saline Valley, and the great development of Lower Cambrian strata to the north and east in Nevada, the term Waucoban is selected to replace Georgian as a group name for the formations included in the Lower Cambrian.

---

[52] Acadian geology. The geological structure, organic remains, and mineral resources of Nova Scotia, New Brunswick, and Prince Edward Islands. 2d ed., London, 1868, p. 638.

[53] Illustrations of the fauna of the St. John Group No. 5. Trans. Roy. Soc. of Canada, vol. 8, 1891, p. 129.

[54] Bull. U. S. Geol. Survey, No. 81, 1891, p. 360.

[55] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, pp. 188–189.

[56] Idem, pp. 185–188.

The Lower Cambrian or Waucoban epoch is characterized by fossil remains of trilobites belonging to the genus *Olenellus*. (See further explanation under *Cambrian period.*)

Schuchert[57] now treats the Waucoban as a provincial rock series, and applies the name "Taconian" to the Lower Cambrian epoch and "Taconian series" to the Lower Cambrian rocks of eastern North America. He says:[57]

The Lower Cambrian is restricted in eastern North America to the Appalachic geosyncline and its rocks will be referred to as the *Taconian series.* The strata of the Cordilleric geosyncline in western North America are embraced under the term *Waucobian series.* * * *

It is only in recent years, through the growth of our science from facts garnered in all parts of the world, that a greater unanimity of opinion has come about, and some of the Taconian formations have been seen actually to have the age relations that Emmons attributed to them. He held that the Taconian rocks are older than the Potsdam sandstone, a formation now referred to the uppermost Cambrian, and that they are at the base of the Paleozoic series, conclusions that are true at least in part. It is on this residuum that the validity of the Taconian rests, and it must be recognized as at least a series term in good standing.

"TACONIC SYSTEM"

E. Emmons, 1842 (Geology of New York, pt. 2, div. 4, Geol. 2d dist., pp. 135–164, 429).

TACONIC SYSTEM

A group or system of rocks which belong evidently to a position between the primary of the Atlantic ranges of mountains, and the New-York system. [Page 136.]

The Taconic system, as its name is intended to indicate, lies along both sides of the Taconic range of mountains, whose direction is nearly north and south, or for a great distance parallel with the boundary line between the States of New York, Connecticut, Massachusetts and Vermont. The counties through which the Taconic rocks pass, are Westchester, Columbia, Rensselaer, and Washington; and after passing out of the State, they are found stretching through the whole length of Vermont, and into Canada as far north as Quebec. It is, however, in Massachusetts, in the county of Berkshire, that we find the most satisfactory exhibition of these rocks. They form a belt whose width is not far from fifteen miles along the whole western border, and which extends clearly to the western base of the Taconic range. The greatest breadth, therefore, as will be seen by an inspection of any map of this section of country, is wider upon the eastern than upon the western side of this range. In Vermont they range along the upper members of the Champlain group, and thus become connected with the Second district. * * * The slates and masses of the Taconic system are not related to, or connected with, those of the Champlain group. By this I mean that they are not the same rocks in another condition; or, in other words, that they are not a part of the former group in a metamorphic state. * * * [Page 138.]

Comparing the several members of the Taconic system with rocks bearing the same name in the Primary, very little doubt remains of their total dissimilarity. * * * Considered geologically, they can be regarded in no other

[57] Schuchert, Charles, Textbook of geology, 2d ed., vol. 2, p. 187, 1924.

light than as inferior to the Potsdam sandstone, or as having been deposited at an era earlier than the lowest member of the New-York Transition system. We have in no instance, however, been able to trace a connection in these masses, and we have never found the Potsdam sandstone resting upon any of the members of the Taconic system. * * * The bare fact that the Potsdam sandstone rests on gneiss or granite, without the interposition of any other rock, we early pointed out. * * * [Page 140.]

The number of rocks which compose the Taconic system is quite limited; this is an important feature, which is not to be lost sight of. It does not, however, follow that it is necessarily thin; on the contrary, it is remarkably thick, and hence becomes of more importance than appears from a simple statement of the number of rocks of which it is composed.

As a whole, we find granular quartz, slate and limestone to form the entire system. But it is to be remarked, that it is necessary to take cognizance of two kinds of slate and two of limestone; for although there are many points of resemblance in each of the two rocks respectively, still their position and lithological differences, though small, require their separation. The full enumeration is as follows:

1. A coarse granular limestone of various colors, which I have denominated *Stockbridge limestone* [ranges in age from Trenton to Lower Cambrian[58]], taking its name from a well-known locality, one which has furnished to different parts of the Union a large proportion of the white and clouded marbles which have been so extensively employed for building and other purposes in construction.

2. *Granular quartz* rock [Cheshire quartzite, of Lower Cambrian age[58]], generally fine-grained, in firm tough crystalline masses of a brown color, but sometimes white, granular and friable.

3. Slate, which for distinction I have denominated *Magnesian slate* [Berkshire schist, of Trenton and Upper Ordovician age[58]] from its containing magnesia, a fact which is distinctly indicated by the soft feel peculiar to rocks when this earth forms a constituent part.

4. *Sparry limestone* [Ordovician and same as top of Stockbridge limestone[58]], generally known as the sparry limerock.

5. A slate, which I have named *Taconic slate* [Ordovician[58]], and which is found at the western base of the Taconic range. It lies adjacent to the Lorrain or Hudson river shales, some varieties of which it resembles. In composition, it contains more alumine and less magnesia than the magnesian slates.

In addition to the above rocks, there is sometimes a slate of a dark color, and quite siliceous, in the granular quartz. This appears less constant, and may be considered as a slaty quartz, or variety of this rock. There are several deposits, important in themselves, which strictly belong to this system: the hematitic iron ores, associated sometimes with carbonate of iron, and the black oxide of manganese. Subordinate to the rocks, we find milky quartz and chlorite, with carbonate and oxide of iron in the magnesian slate.

The following section [text figure], extending from Petersburgh, Rensselaer county, to Adams in Massachusetts, embraces all the rocks in this system. Its direction is nearly east and west, or perpendicular to the strike of the system over which it passes: [Pages 144 to 145.]

The Taconic rocks appear to be equivalent to the Lower Cambrian of Prof. Sedgwick, and are alone entitled to the consideration of belonging to this system, the upper portion being the lower part of the Silurian system. [Page 163.]

[[58] According to the studies of Arthur Keith.]

Schuchert, in the second (1924) edition of his textbook of geology, applies the name " Taconian series " to the Lower Cambrian rocks of eastern North America. (See p. 101, under *Waucoban epoch.*)

ALGONKIAN PERIOD (OR SYSTEM)

The name *Algonkian* was adopted at a meeting of geologists of the United States Geological Survey held in Washington on January 28 to 31, 1889, as explained on pages 62 to 63 of Part I of the Tenth Annual Report of the Director. The name first appeared in print, but without definition, in 1889, having been used by Walcott in tables in a paper read by him before the Philosophical Society of Washington on March 16, 1889, and published in the American Journal of Science for May, 1889. The Tenth Annual Report of the Director was published in 1890. (See citations below.)

C. D. Walcott, 1889 (Am. Jour. Sci., 3d ser., vol. 37, pp. 383, 384, May, 1889; name used but not defined).

J. W. Powell, 1890 (U. S. Geol. Survey Tenth Ann. Rept., pt. 1, pp. 19–20, 59–61, 66; letter of transmittal dated July 25, 1889).

The tenth period shall be the time of deposition of clastic rocks older than the Cambrian. Its lower delimitation can not be definitely fixed, but its upper is definitely determinate as just below the beginning of the Cambrian. The period is represented by some rocks which have been referred to the Cambrian, many which have been referred to the Huronian, and some formations which have not hitherto been classified. Exception being taken to the term Eparchean, and also to the term Huronian (proposed on the ground that it had been previously applied to a part of the rocks, but opposed on the ground that the definitions of this period are entirely unlike those accepted for the Huronian), the term Algonkian was offered and agreed to as the designation of the period.
The oldest time division shall cover the time of formation of the ancient crystalline rocks, and its designation shall be Archean. [Page 66.]

As thus originally defined the Algonkian included all pre-Cambrian *clastic* rocks. Later work, however, revealed the presence of metamorphosed sedimentary rocks in the basement complex to which the name Archean had been restricted. The definition of Algonkian now recognized by the United States Geological Survey is as follows:

In various parts of the world, below the Cambrian, and usually separated from that system by an unconformity, is a great system of rocks to which can be applied the ordinary methods of stratigraphy. This system consists dominantly of rocks deposited under substantially the same physical conditions as those which obtained during the Cambrian and later periods. That is, these rocks are chiefly shales, sandstones, and limestones, and their metamorphosed equivalents. Associated with this system of rocks, both as intrusives and extrusives, are igneous rocks, precisely as is the case with the later systems. In some regions this older system is represented by two or more series, separated by unconformities. While scanty fossils have been found in a few areas, as yet they have not been discovered so distributed and in such abundance as to serve the purposes of correlation of the series from province to province.

The characters by which the Algonkian and Archean are discriminated are lithologic and structural.[59]

Within the Algonkian system a number of provincial series are discriminated. In the Algonkian of the Great Lakes region two great unconformable series are recognized, the Keweenawan series above and the Huronian series below, and unconformities of greater or less magnitude are recognized within the Huronian series. The Algonkian rocks exposed in Montana and northern Idaho have been given the provincial series name *Belt series*, from the Big Belt and Little Belt Mountains of central Montana, where they are well exposed. The Algonkian rocks of northern Arizona have been named the *Grand Canyon series*, from their admirable exposures in the Grand Canyon of the Colorado. The pre-Cambrian rocks of central Texas, which are at least chiefly of Algonkian age, but which may include some Archean rocks, are known as the *Llano series*, from Llano County, Tex. The pre-Cambrian rocks of the Adirondack Mountains of New York and neighboring parts of Canada have long been known as the *Grenville series*, from their exposures at Grenville, Canada. The series of metamorphosed pre-Cambrian sediments in southeastern Pennsylvania, Maryland, and northern Virginia have recently been named *Glenarm series*, as described on page 112.

The name *Algonkian* is derived from the Algonkian Indians, who once inhabited and still occupy in part the Lake Superior-Ontario-Hudson Bay country, where rocks of this age probably have their greatest development. The rich iron and copper deposits that have made the Great Lakes region famous in the commercial world are contained in these rocks, the iron ores occurring in the Huronian series and the copper ores in the Keweenawan series.

KEWEENAWAN EPOCH (OR SERIES)

T. B. Brooks, 1876 (Am. Jour. Sci., 3d ser., vol. 11, pp. 206–211).

We are therefore justified, I think, in regarding the Copper-bearing rocks of Lake Superior as a distinct and independent series, marking a definite geological period which separates the Silurian from the Huronian ages. Should future observations confirm this view, it would be advisable to have some more convenient and geologically acceptable name for the series than that now in use. Since Keweenaw Peninsula forms one of the most striking geographical features in Lake Superior and is the locality where the Copper series are best exposed and were first studied, I suggest the name Keweenawian for this period.

The foregoing is regarded as the original definition of the Keweenawan series, although in 1873 T. Sterry Hunt,[60] in a paper

[59] U. S. Geol. Survey Twenty-fourth Ann. Rept., p. 26, 1903.
[60] Am. Inst. Min. Eng. Trans., vol. 1, pp. 331–346, 1873.

entitled "The geognostical history of the metals," referred to the copper-bearing rocks in the following way:

We may here remark that the late researches of Messrs. Brooks and Pumpelly seem to establish that the great copper-bearing series of Keweenaw occupies a place between the Huronian schists and the nearly horizontal red and white sandstone of the region, which is itself below the Trenton limestone. In all this they have confirmed the previous conclusions of Houghton, Whitney, Hall, and Logan. The silver deposits of Thunder Bay and its vicinity, including Silver Islet, are in veins traversing a series of dark-colored argillites and sandstones, which are as yet known only in this region, and are overlaid in slight discordance by red and white sandstone, apparently the same with those of the Keweenaw district and the St. Marys River. This older series of Thunder Bay and its vicinity, which may be named the Animikie group, from the Indian name of the bay, is the lower division of the upper copper-bearing series of Logan.

The great Keweenaw group, with its cupriferous amygdaloids, is here absent, though met with a few miles to the eastward, and the almost horizontal dark-colored sediments of the Animikie group rest directly upon the edges of the crystalline Huronian schists, and are cut by great dykes of diorite. * * * [Page 339.]

To a like process we may perhaps ascribe the rich deposits of native copper in the Keweenaw amygdaloids and conglomerates which rest upon the ancient Huronian schists. * * * [Page 341.]

I may here suggest in a few words as a probable solution, that the horizontal sandstones of Thunder Bay, whether identical with those of the south shore or not, and whether paleozoic or mesozoic, are really newer than the adjacent cupriferous amygdaloids, and are not to be confounded with the sandstone strata which, on both sides of the lake, are found interstratified with these as integral parts of the more ancient Keweenaw or copper-bearing series. [Page 342.]

F. D. Adams, Robert Bell, A. C. Lane, C. K. Leith, W. G. Miller, and C. R. Van Hise, 1905 (Report of the special committee for the Lake Superior region: Jour. Geology, vol. 13, p. 102).

There is an important structural break at the base of the Keweenawan. The term "Keweenawan" should include substantially all of the areas which have been thus mapped, or mapped as Nipigon, by the Canadian and United States Surveys, and the State Surveys of Michigan, Minnesota, and Wisconsin.

The Keweenawan series, or copper-bearing rocks of the Great Lakes region, consists of interbedded eruptive rocks and sediments, with basic intrusive rocks, and it unconformably overlies the Animikie group and uncomformably underlies the Cambrian sandstone of that area. The rocks were originally believed to be of Cambrian age.

HURONIAN EPOCH (OR SERIES)

W. E. Logan and T. S. Hunt, 1855 (Esquisse géologique du Canada, pp. 29–31).

CAMBRIAN OR HURONIAN SYSTEM

The shores of Lakes Huron and Superior offer us a series of schists, sandstones, limestones and conglomerates, intercalated with great thicknesses of diorite and resting unconformably upon the Laurentian system. As these rocks are beneath the Silurian terrane, and as, moreover, they have not up to the present yielded any fossils, they may well be referred to the Cambrian system (the Lower Cambrian of M. Sedgwick). The schists of this system on Lake Superior are of a bluish color, and contain beds of horny flint with limestone bands, the fractures of which are often filled with anthracite [graphite?].

These rocks are covered by a considerable thickness of trap, on which are superimposed thick strata of white and red sandstone, which sometimes pass into conglomerate containing pebbles of quartz and jasper. Beds of reddish argillaceous limestone are found interposed in these sandstones, which are intruded and overlain by a second formation of diorite of great thickness and having a columnar structure. This formation, which according to the observations of M. Logan, has a total thickness of nearly 4,000 meters, is cut by a large number of trap dikes.

In the corresponding formation on the northern shore of Lake Huron there are sandstones having a more vitreous aspect and more abundant conglomerates than on Lake Superior, associated, however, with some schists and schistose conglomerates like those just described, the whole forming a great mass intercalated with diorite. A bed of limestone having a thickness of 16 meters forms a part of this series, to which M. Logan ascribed a thickness of more than 3,000 meters. M. Logan has shown that the intrusion of these interstratified diorites was followed by that of two systems of diorite dikes and a third of granite of an epoch intermediate between the last two. The metalliferous veins belong to a still more recent epoch. The principal kinds of veins are native copper, quartz, calcspar, dolomite, fluorite and barite, with several zeolites, of which the most abundant is laumontite. One also encounters heulandite, stilbite, thomsonite, apophyllite, and analcite, as well as prehnite and datolite. These veins are not metalliferous except where they penetrate the trap.

F. D. Adams, Robert Bell, A. C. Lane, C. K. Leith, W. G. Miller, and C. R. Van Hise, 1905 (Report of the special committee for the Lake Superior region: Jour. Geology, vol. 13, pp. 103–104).

Below the Keweenawan is the Huronian system, which in our opinion should include the following series: In the Marquette district, the Huronian should include the Upper and Lower Marquette series, as defined in the monographs of the United States Geological Survey, or the Upper, Middle, and Lower Marquette series, as given in the previous paragraphs. In the Penokee-Gogebic district, the Huronian should include the series which have been called the Penokee-Gogebic series proper, and the limestone and quartzite which have local development, and which we visited east of the Presque Isle River. In the Mesabi district, the Huronian should include the Mesabi series proper, and the slate-graywacke-conglomerate series, unconformably below the Mesabi series. In the Vermilion district, the Huronian should include the Knife slates and the Ogishke conglomerates. In the Rainy Lake district, the Huronian should include that part of the Couchiching of the south part of Rainy Lake which is limited below by basal conglomerate as shown at Shoal Lake. In the Thunder Bay district, the Huronian should include the Animikie and the graywacke series in the Loon Lake area. In the original Huronian area, the Huronian should include the area mapped by Logan and Murray as Huronian, except that the Thessalon greenstones should probably be excluded. * * *

The following succession and nomenclature are recognized and adopted:

Cambrian—Upper sandstones, etc., of Lake Superior.
Unconformity.
Pre-Cambrian:
- Keweenawan (Nipigon).[a]
- Unconformity.
- Huronian:
  - Upper (Animikie).
  - Unconformity.
  - Middle.
  - Unconformity.
  - Lower.
- Unconformity.
- Keewatin.
- Eruptive contact.
- Laurentian.

As originally defined the Huronian included at the top the great series of copper-bearing rocks that were later named Keweenawan, as well as the underlying slate, iron-bearing rocks, and quartzite later called upper Huronian and named Animikie group. In 1876 the copper-bearing rocks were separated from the Huronian as a distinct series and named Keweenawan by T. B. Brooks. The pre-Cambrian rocks, in which, owing to their highly metamorphosed condition, few fossils occur, are characterized by very complex structure. Thus, in attempting to unravel their history, complications were found and disagreements arose among the geologists working in different parts of the Great Lakes region, where the pre-Cambrian rocks of America have their greatest development. In order to harmonize these differences of opinion and determine the classification that would best apply to these rocks, a joint field and office conference of American and Canadian geologists was held in 1904 and 1905. The definition of the Huronian series adopted by that committee (consisting of F. D. Adams, Robert Bell, W. G. Miller, A. C. Lane, C. K. Leith, and C. R. Van Hise) applied the name to the rocks unconformably beneath the Keweenawan series and unconformably above the Keewatin series. As thus defined the Animikie group is included in the Huronian. Several unconformities were recognized within the Huronian series. The one at the base of the Animikie group is now regarded by some workers as of greater magnitude than the others, and they would exclude the Animikie rocks from the Huronian series and make a separate series of them. This is still a debated question. (Note the diverse classifications

[a] Dr. Lane dissents as to the position of the Keweenawan as follows:
"The use of pre-Cambrian above does not imply unanimity in the committee with regard to the pre-Cambrian correlation of the Keweenawan—a topic the committee as such did not investigate."

given in the chart and on pages 15–43 under the heading *Pre-Cambrian era terms.*) In more recent reports some authors have dropped the name Huronian altogether and have elevated the middle and lower Huronian to series rank, under the names "Timiskamian," "Bruce," "Seine," etc., the definitions of which will appear in the stratigraphic lexicon now in preparation.

The Huronian series consists of metamorphosed and unmetamorphosed rocks, and includes slates, quartzites, graywackes, fine-grained green schists, mica schists, hornblende schists, fine-grained gneisses, iron-bearing schists, and interbedded basic and acidic eruptive rocks of various kinds.

As the term Cambrian was generally understood at the time the name Huronian was introduced it included some rocks that are now classified as pre-Cambrian. This explains the original reference of the Huronian rocks to the Cambrian system of Sedgwick, a reference that was corrected many years ago.

The United States Geological Survey recognizes within the Huronian series many local subdivisions (the definitions of which are given in the stratigraphic lexicon now in preparation) and the fact that it is penetrated by granitic intrusions of different ages.

OTHER PROVINCIAL SERIES TERMS

BELT SERIES

A. C. Peale, 1893 (U. S. Geol. Survey Bull. 110, pp. 15–20).

Cambrian:
- Gallatin formation.
- Flathead formation [including Flathead quartzite at base].

Algonkian?:
- Belt formation.

The Paleozoic section of the Three Forks region, including the beds provisionally assigned to the Algonkian, consists of a series of sedimentary deposits of nearly 10,000 feet thickness, resting upon Archean gneiss. Over 8,000 feet are shown in the Gallatin section, which does not, however, reach down to the Archean. A few miles south of the region shown on the map this thickness is reduced to a little over 3,600 feet by the absence of the Belt formation, as the Flathead formation [Cambrian] whenever seen there rests unconformably upon the Archean gneisses without the interposition of the Belt formation. The section of the region to the north, as given by Mr. W. M. Davis, is from 15,000 to 20,000 feet, the increased thickness being due mainly to the greater development of the Belt formation (called by him Lower Cambrian barren slates).

The gneisses of our region can not at present be correlated, even provisionally, with the Archean rocks of the east. They are certainly pre-Cambrian, if the Flathead formation is of Lower Cambrian age, for included in the lower strata of the latter at several localities are fragments of gray and red gneiss evidently derived from the underlying Archean, and that they are pre-Algonkian is proved by similar occurrences in the Belt formation in the northern portion of our sheet.

The evidence for the reference of the Belt formation to the Algonkian is of a somewhat negative character, and will be noted more particularly when the included beds are described on a subsequent page. The entire section so far as observed is conformable from the base to the top. There is difficulty in attempting to define exactly the lines between the formations, even so far as the greater divisions are concerned, and the correlation necessarily has not been carried any farther, local names being applied to the minor divisions. It is a question whether the divisions of the geological scale as made in the eastern United States can ever be recognized in the strata of the Rocky mountain region.

ALGONKIAN

Belt formation

The section in the vicinity of the Three Forks begins with a series of beds of littoral formation which was in 1884 provisionally called the East Gallatin group, so named from the well exposed outcrops occurring along the north side of the East Gallatin river near its junction with the West Gallatin, where a detailed section of 2,300 feet has been carefully measured. It consists of an alternation of coarse micaceous sandstones and conglomerates, with beds of hard argillaceous slates, and bands of thin bedded dark-blue siliceous limestones. The latter are very hard and some are slightly magnesian. * * * [Analyses.]

The limestones are developed mainly toward the base of the measured section and occur in bands from 5 to 20 feet in thickness but sometimes reaching nearly 50 feet. Many of the beds are very finely laminated, of a dark blue almost black color in fresh fractures, and showing light yellowish brown on weathered surfaces. About half way up in the section the limestones change in their appearance. They are more compact, not so dark in color, but are still highly siliceous and layers with peculiar flat round concretions are seen. These concretions have been mistaken for fossil turtles by the people living in this part of the Gallatin valley. Some of the concretions are very large, often measuring several feet in diameter and from 6 to 12 inches in thickness, but they average about 6 inches to a foot in diameter with a thickness of only 3 to 4 inches. Sections of them show no peculiarities.

The indurated clay slates are also most abundant towards the middle and base of the measured section, and present a variety of colors—yellowish brown, olive-green, and bluish black predominating. The beds are very fissile, frequently breaking down into fine splintery débris, generally of a light color, and with frequent local bands of a bright red tint, as though the beds had been subjected to heat. These appear to be scattered over the country irregularly, and their weathering gives a very bright red débris. The slates are particularly well exposed in the bluffs along the west side of Dry Creek below its first canyon.

The sandstones are prominent in the upper and lower parts of the section, and occur in heavy beds of 5 to 10 and sometimes 20 or 30 feet in thickness. They frequently break into cubical blocks with sharp edges, which increases their resemblance to eruptive rocks, for which they have sometimes been mistaken. As seen in hand specimens, their arkose character is evident, and often water-rolled pebbles of considerable size are seen, especially in the coarser beds near the base of the section.

The name "bastard granite" has locally been applied to them. Some of the layers are slightly calcareous, especially near the base, where they are intercalated with numerous thin bands of limestone, and some of the lowest sandstones are cut by seams of pure dolomite. The beds are generally very coarse and in places strongly conglomeratic. That Archean land masses, when they were deposited, existed not far to the south is very evident from the general character of the beds, and is also proved conclusively when they are compared microscopically with the Archean rocks of the adjacent region.

In the Bridger range, where the section is carried lower than on the East Gallatin, they contain many pebbles of Archean rocks, and in the lowest outcrops there are included angular masses of gneiss, showing the immediate proximity of the ancient shore line. There is considerable difference between the various beds so far as structure is concerned, but all are more or less micaceous and occur in massive layers. They are very similar in color, dark greenish gray, steel-gray, and rusty brown tints prevailing. Seen from a distance, these sandstones resemble outcrops of eruptive rocks, owing partly to their somber appearance and partly to their mode of weathering; in fact, when first seen in 1860, they were so mistaken. * * *

In the Big Belt range, north of the limits of the Three Forks sheet, Mr. W. M. Davis, in two sections, found a series of from 10,000 to 12,000 feet of beds, which from his description undoubtedly belong to this group. He refers to them as "a vast series of Lower Cambrian barren slates." * * *

Nowhere in the Gallatin valley have we as yet seen this group in immediate superposition upon the Archean, although we have reason to think that the line of junction is nearly reached at the base of the section, as seen in the Bridger range. * * *

As to the age of this formation we have no paleontological evidence to offer, as careful search in the beds for fossils during several seasons has been unsuccessful. Hayden, in 1860, in 1871, and 1872, was inclined to regard them as representing a portion of the Potsdam sandstone.

In 1885 they were doubtfully referred to the Middle Cambrian; in 1872 the writer suggested the possibility of their Huronian age, and as already noted, Davis and Newberry both refer to them as Lower Cambrian.

All that can be said with certainty is that they are post-Archean and probably pre-Cambrian, as they are made up largely of Archean débris and lie below beds containing Cambrian fossils. So far as observed, no well-defined unconformity between them and the overlying Flathead quartzite has been seen; but there is certainly an unconformity by subsidence, which is not always well shown and might easily be overlooked. There is no doubt that after the Belt formation was deposited there was an orographic movement by which the Archean area of nearly the entire region represented on our map south of the Gallatin and Three Forks was submerged just prior to the beginning of the Cambrian before the Flathead quartzite was deposited. Whether this movement occurred immediately after the laying down of the Belt beds or after an interval is of course the question to be decided, and the decision can not be positively reached with the meager data now at hand. I am inclined to think that the subsidence of the Archean continent (or possibly islands) began with the first accumulation of the sediments that formed the lower portion of these beds and was coincident with their deposition throughout the entire period. It may have been succeeded by an emergence of the land area for a brief period, but the probability is that the interruption to the downward movement, if it occurred, was slight. Next the widespread pre-Cambrian subsidence preceding the formation of the Flathead quartzite took place, and the Cambrian sea covered large areas that had thitherto been above the sea level. There is a marked difference in the character of the beds of the two groups. Little, if any, induration is seen in the Flathead formation, while the Belt beds are so altered in most cases as to resemble closely the metamorphic crystalline rocks which underlie them, and from the breaking down of which they were derived. Notwithstanding the metamorphism there is no mistaking their sedimentary character.

We have, therefore, a nonfossiliferous group of clastic beds, sometimes slightly metamorphosed, which lie between the Archean gneisses and a belt of quartzite, above which are beds with Middle Cambrian fossils. From its stratigraphical position this group could be only of Lower Cambrian or of Algonkian age.

The possibility that Lower Cambrian fossils may yet be found in the quartzite at the base of the Flathead formation; the absence of organic remains in the Belt formation; the metamorphosed condition of the latter, and the existence of the unconformity between the quartzite and the beds below lead us to refer the latter, for the present at least, to the Algonkian.

C. D. Walcott, 1899 (Geol. Soc. America Bull., vol. 10, pp. 199–215, 235).

The results of my investigations were the discovery of a great stratigraphic unconformity between the Cambrian and the Belt formations; that the Belt terrane was divisible into several formations, and that the fossils occurred in the Greyson shales nearly 7,000 feet beneath the highest beds of the Belt terrane.

The rocks of the Belt terrane are widely distributed in central Montana, the best sections being exposed in the Big Belt and Little Belt mountains, in Meagher and Broadwater counties. They extend to the north in Cascade, to the west in Lewis and Clarke and Jefferson counties, and to the south in Gallatin, Park, and Sweetwater counties, in all covering a known area of more than 6,000 square miles. Throughout this area the Cambrian rocks rest unconformably on different members composing the Belt terrane. * * *

I think that an unconformity to the extent indicated is sufficient to explain the absence of lower Cambrian rocks and fossils and to warrant our placing the Belt terrane in the pre-Cambrian Algonkian system of formations.

C. R. Van Hise, 1909 (U. S. Geol. Survey Bull. 360, pp. 32–33, 39, 41, 46, 350).

The largest area of Algonkian known is that of the Belt series of northern Montana, Idaho, and southern British Columbia. The Belt series is subdivided lithologically into a number of formations, but represents practically continuous deposition. To the south in Montana the Cherry Creek sedimentary rocks are assigned to the Algonkian. While their relations to the Belt series are not shown by direct contact, the relatively greater metamorphism and deformation of the Cherry Creek group indicate its earlier age and probable separation by unconformity. The quartzites of the Uinta and Wasatch mountains, correlated with the Belt series, are essentially structural units. The same is true of the quartzites and slates of Needle Mountains, Colorado. In the Grand Canyon of the Colorado there are two groups classed in the Algonkian, separated from each other by a minor unconformity. [Pages 32–33.]

The Belt series of Montana also is unconformable upon the Archean with marked discordance. [Page 39.]

The Belt series in its now known extent constitutes the greatest area of Algonkian on the continent, and it may be that this area should be extended to include Utah, Colorado, and Arizona quartzites. [Page 41.]

If the Animikie group is ever found to be the equivalent of the Belt series of British Columbia, as is thought possible, this would make more probable the Cambrian age of the Keweenawan lying above the Animikie, in view of the fact that in British Columbia the Belt series apparently grades up into the Cambrian.

Against this evidence of possible conformity and favoring the view here held that the Cambrian lies unconformably above the upper Keweenawan are the following facts: * * * [Page 350.]

The United States Geological Survey classifies the Belt as a provincial series belonging to the Algonkian system. The name is derived from the extensive development of the rocks in the Big Belt and Little Belt mountains of central Montana.

GLENARM SERIES

E. B. Knopf and A. I. Jonas, 1922 (Geol. Soc. America Bull., vol. 33, p. 110).

The crystalline schists of Baltimore County, Maryland, are Precambrian. The base of the section is the Baltimore gneiss, a highly crystallo-blastic paragneiss injected in some places by granitic magma. Overlying the Baltimore gneiss is the Glenarm series of recrystallized sediments, whose thickness is provisionally estimated at 8,000 to 10,000 feet. These rocks show a metamorphism whose intensity decreases progressively from highly crystalline schists at the base to mildly anomorphosed sediments at the top. The lower formations of the Glenarm series are cut by plutonic intrusions, and the upper formations contain amphibolite schists that are probably metamorphosed volcanics and may be the equivalent of the Precambrian Catoctin lavas.

E. B. Knopf and A. I. Jonas, 1923 (Am. Jour. Sci., 5th ser., vol. 5, pp. 45-49, 61-62).

Overlying the Baltimore gneiss [of early pre-Cambrian age, according to page 61] is a series of pre-Cambrian sediments here named the Glenarm series, from its typical development near Glenarm, 13 miles northeast of Baltimore. The Glenarm series comprises [ascending order] the Setters formation, the Cockeysville marble, the Wissahickon formation, the Peters Creek schist, the Cardiff conglomerate, and the Peach Bottom slate. The total thickness of the series probably amounts to between 8,000 and 10,000 feet, although no accurate estimates can be made, for the middle formations have been repeated by close folding. So far as now known, deposition of this series was not interrupted by erosion or by orogenic deformation, although the earlier formations are overlapping shore deposits.

The basal formation is the Setters, which overlies the Baltimore gneiss unconformably but with no basal conglomerate. * * * In the absence of positive evidence of erosion, it seems likely that the irregular thickness of the Setters formation and of the Cockeysville marble is due to transgression rather than to erosion. * * *

Therefore the presence of Catoctin greenstones in this facies [of the Wissahickon formation] would establish the pre-Cambrian age of the Glenarm series. Corroborative evidence is the presence within the lower part of the Glenarm series of strongly deformed plutonic intrusions. The known Paleozoic rocks of Pennsylvania and Maryland are conspicuously free from all igneous material except pegmatites, and these are doubtless genetically associated with the Woodstock granite, which is considered on account of its undeformed condition to be younger than the pre-Cambrian intrusives. * * *

The Glenarm series underlies a succession of lower Paleozoic rocks whose outcrop is confined to the northern part of the region.

The United States Geological Survey has adopted the name *Glenarm series* as a provincial series term for the rocks of later pre-

Cambrian age in southeastern Pennsylvania, Maryland, and northern Virginia.

GRAND CANYON SERIES

J. W. Powell, 1876 (Geology of the eastern portion of the Uinta Mountains, pp. 43, 61–62, 70, U. S. Geol. and Geog. Survey Terr., 2d div.).

Grand Cañon group.—Sandstones, shales and a few limestones. Thickness 10,000 feet. On further study this group will probably be subdivided. [Page 43.]

This group is exposed in the great southern bends of the Grand Cañon, where the Colorado River passes the end of the Kaibab Plateau. The best exposure can be seen about ten miles below the mouth of the Little Colorado. Many of the lateral streams coming in from the west and north cut through this group and afford fine exposures. The best one probably is in Kwá-gunt Valley. Some of the members are again exposed at the bottom of the Grand Cañon, where it passes the Shi-wits Plateau. [Pages 61–62.]

The Grand Cañon Group rests unconformably upon the crystalline schists. The evidence of this is complete, for the lower sandstones and conglomerates first filled the valleys and then buried the hills of schistic rocks, and these conglomerates at the base of the group are composed of materials derived from the metamorphic hills about; and hence metamorphism was antecedent to the deposition of the conglomerates.

The plane of demarkation separating this group from the [overlying] Tonto Group is very great. At least 10,000 feet of beds were flexed and eroded in such a manner as to leave but fragments in the synclinals. Then followed a period of erosion during which beds of extravasated material were poured over the fragments, and these igneous beds also were eroded into valleys prior to the deposition of the Tonto Group. [Page 70.]

C. D. Walcott, 1894 (U. S. Geol. Survey Fourteenth Ann. Rept., pt. 2, pp. 518–519).

The period of erosion, represented by the unconformity between the Tonto sandstone and the Grand Canyon series, is considered to more than equal lower Cambrian time, and to constitute a well-defined boundary between the Paleozoic and pre-Paleozoic formations. In my earlier work, in 1883, I referred the Grand Canyon and Chuar strata to the Cambrian, but upon further study of the Cambrian rocks and their contained faunas, and in view of the extent of the time break indicated by the nonconformity by erosion, this was changed in 1886, and all pre-Tonto strata were referred to a pre-Cambrian series.

In the scheme of nomenclature adopted by the Geological Survey in 1888 the clastic rocks beneath the Cambrian and superjacent to the Archean were grouped under the term Algonkian—of equivalent rank to Cambrian, Silurian, etc. In this classification the system name—equivalent to Paleozoic, etc.—was not decided upon; but I am strongly in favor of adopting the name "Proterozoic," proposed by Dr. Irving and accepted by Prof. C. R. Van Hise. Under this nomenclature the Grand Canyon series will be referred to the Algonkian system of the Proterozoic group. * * *

The Grand Canyon series, the Llano series of Texas, and the Algonkian series of the Lake Superior region afford an opportunity of comparing the stratigraphic succession of somewhat similar lithologic series of strata, but a definite correlation can not be made until a more reliable factor is obtained than lithologic resemblance of the various formations. It is quite probable that the Grand Canyon series and the Keweenawan series of Lake Superior represent the same time interval; also that the strata beneath Packsaddle Mountain in central Texas are the equivalent of the Chuar terrane of the Grand

Canyon; but until paleontologic evidence is secured it may be said that these correlations are little more than possibilities. The Grand Canyon, Llano, and Keweenawan series may be referred to the Algonkian, as that system of rocks includes the strata of sedimentary origin between the Archean complex and the base of the Cambrian; beyond that any correlation on trustworthy data is impossible.

The United States Geological Survey classifies the Grand Canyon as a provincial series of late Algonkian age.

GRENVILLE SERIES

W. E. Logan, 1863 (Canada Geol. Survey Fifteenth Rept. Prog., pp. 43–45).

In this investigation a single band of limestone, which has been termed the Grenville band, varying apparently in thickness from 60 to 1000 feet, and averaging perhaps 750 feet, emerging from beneath the Silurian rocks, has been traced from Grenville to the Iroquois Chute, fifty miles up the valley of the Rouge. It presents the general form of a trough, but its distribution is so complicated by subordinate undulations that in a triangular area, of which the base extends about twenty-five miles between the Petite Nation seigniory and Lachute, and of which the apex is at the Iroquois Chute, the line of calcareous outcrop measures upwards of 200 miles. * * *

From what has been said, it will be observed, that in the present state of the investigation, without counting the Proctor's Lake bed, which is too small for separate consideration, there appear to be four important bands of crystalline limestone in the Laurentian area of which the structure has been partially examined. The wrinkled condition of the strata is such that there are in some parts four and five anticlinals in the breadth of a mile, the effect of each of which is perceptible in the geographical distribution of the strata, and this renders it very difficult to determine with precision the volume of rock in which the four calcareous bands are inclosed; but according to the best estimate arrived at, it appears probable that the following would be an approximation to the thickness of the various constituent parts of the mass arranged in ascending order:

	Feet
1. Orthoclase gneiss composing Trembling Mountain; though the mass has not been especially examined nor any geographical position shewing its inferior limit ascertained, yet the general aspect of the mountain induces the supposition that it must be of great thickness, and it is presumed that it will exceed the volume here given	5, 000
2. Crystalline limestone of Trembling Lake	1, 500
3. Orthoclase gneiss between the limestone of Trembling Mountain and that of Great Beaver Lake	4, 000
4. Crystalline limestone of Great Beaver Lake and Green Lake, including two bands of interstratified garnetiferous rock and hornblendic orthoclase gneiss, which may equal half the amount	2, 500
5. Orthoclase gneiss intermediate between the limestone of Great Beaver Lake and Long Lake, and the Grenville limestone on the Rouge at the Iroquois Chute, the lower part having several bands of garnetiferous gneiss and quartzite, and the upper part much coarse grained porphyroid orthoclase gneiss	3, 500

	Feet
6. Crystalline limestone of Grenville, in some parts interstratified with a band of gneiss. The thickness appears to vary from about 1500 feet to 60 feet, and may be estimated at about	750
7. Orthoclase gneiss between the limestone of Grenville and Proctor's Lake limestone	1,580
8. Proctor's Lake limestone	20
9. Orthoclase gneiss passing gradually into anorthosite between Proctor's Lake limestone and the Morin band. This would probably include the quartzite of the Quartz Mountain, the orthoclase gneiss above it, and the gneiss of passage	3,400
The nearest geographical approach of the Grenville and Morin limestones that has been ascertained is about two miles; the present estimate of their stratigraphical separation is 5000 feet, which is not perhaps extravagant.	
10. Anorthosite above the Morin band of limestone; the thickness is wholly conjectural	10,000
	32,750

W. E. Logan, 1865 (Canada Geol. Survey Sixteenth Rept. Prog., p. 20 and map).

A detailed map, showing the distribution of the Laurentian rocks in parts of the counties of Ottawa, Terrebonne, Argenteuil [typical Grenville area], and Two-Mountains; together with portions of the adjacent Lower Silurian formations.

Lower Silurian:
* * *
Potsdam.
Huronian (wanting).
Upper Laurentian:
Anorthosite gneiss, etc.
Lower Laurentian:
Fourth orthoclase gneiss.
Grenville limestone.
Third orthoclase gneiss
Green Lake limestone.
Second orthoclase gneiss.
Trembling Lake limestone.
First orthoclase gneiss.

A. R. C. Selwyn, 1879 (Canada Geol. Survey Rept. 1877–78, pp. 9A–15A).

Laurentian.[62]—I shall now make some observations on the results of the recent work of the Survey in unraveling the complications of the stratigraphy of the older "*crystallines*" on the north side of the St. Lawrence Valley. Since 1866, Mr. H. G. Vennor, of the Geological Corps, has been occupied in a careful examination of the stratigraphical relations of the Laurentian rocks. His observations, commencing in Hastings county, north of Lake Ontario, have now extended across the Ottawa River, eastward, to Petite Nation and Grenville, embracing a band of country 200 miles in length, with an average breadth

[62 As here used applies to all pre-Huronian rocks.]

of fifty-five to sixty miles. Throughout this tract of country Mr. Vennor has followed and mapped, in all their windings and convolutions, the great series of Laurentian limestone bands first investigated and described by Sir W. E. Logan in the years from 1853 to 1856, more particularly in the Grenville region, and in 1865, by Mr. Macfarlane, in the Hastings region. The results and conclusions of all these earlier examinations are given in detail in the Geological Survey Reports. And these shew that the classification then adopted by Sir W. E. Logan was regarded by him as provisional. (See Note, p. 93, Geological Survey Report, 1866.)

Thus, at the commencement of Mr. Vennor's investigation in 1866, it was supposed that the limestones and calcareous schists of Tudor and Hastings holding *eozoon*, together with certain associated dioritic, felsitic, micaceous, slaty conglomerate rocks, were a newer series than those already examined and described by Sir W. E. Logan, and they were accordingly designated, in the report published in 1870, the *Hastings series*, and it was further supposed, from its apparent stratigraphical position and from certain lithological resemblances, that it might be of Huronian age. The gradual progress of the work, however, from west to east has now, I think, conclusively demonstrated that the Hastings group, together with the somewhat more crystalline limestone and gneiss groups above referred to, form one great conformable series, and that this series rests quite unconformably on a massive granitoid, or syenitic, red gneiss. * * *

We can, however, confidently state that these crystalline limestones and their associated strata occupy an unconformable position between a massive gneiss formation below and unaltered Potsdam, or Lower Silurian, rocks above; and this may likewise be stated respecting the stratigraphical position of the typical "Huronian series" of the Georgian Bay, which, together with its close proximity to the western-most known exposures of the crystalline limestone series which we now know, extends from Parry Sound to Lake Nippising, and includes some labradorite gneiss, renders it very probable that a connection will eventually be traced out, between even these supposed greatly different formations, similar to that now, as already stated, proved to exist between the Hastings and Grenville series. * * *

In the reconstruction of the geological map of eastern Canada,—and in this I include the country from Lake Winnipeg to Cape Breton and Labrador—rendered necessary by the present state of our knowledge, I should propose to adopt the following divisions of systems to include the groups enumerated [ascending order]:

I. Laurentian: To be confined to all those clearly lower unconformable granitoid or syenitic gneisses in which we never find interstratified bands of calcareous, argillaceous, arenaceous and conglomeratic rocks.

II. Huronian: To include—1. The typical or original Huronian of Lake Superior and the conformably—or unconformably, as the case may be—overlying upper copper-bearing rocks.

2. The Hastings, Templeton, Buckingham, Grenville and Rawdon crystalline limestone series.
3. The supposed Upper Laurentian or Norian.
4. The altered Quebec group, as shewn on the map now exhibited, and certain areas not yet defined between Lake Matapedia and Cape Maquereau in Gaspé.
5. The Cape Breton, Nova Scotia and New Brunswick pre-Primordial sub-crystalline and gneissoid groups.

III. Cambrian: In many of the areas, especially the western ones, the base of this is well-defined by unconformity, but in the Eastern Townships and in some parts of Nova Scotia it has yet to be determined. The limit between it and Lower Silurian is debatable ground, upon which we need not enter.

F. D. Adams, 1893 (Jour. Geology, vol. 1, pp. 328–330).

The Grenville Series.—In certain parts of the Laurentian area, and notably in the Grenville district before mentioned, the Laurentian [63] has a decidedly different petrographical development. Orthoclase gneiss is still the predominating rock, but it presents a much greater variety in mineralogical composition, and is much more frequently well foliated, often occurring in well defined bands or layers like the strata of later formations.

Amphibolites are abundant, also hornblende schists, heavy beds of quartzite and numerous thick bands of crystalline limestone or marble, all these rocks being interbanded or interstratified with one another. In the vicinity of the limestones the variety in petrographical character is especially noticeable; garnets often occur abundantly in the gneiss, the quartzite and the hornblende schist, as well as in the limestone itself, beds of pure garnet rock being found in places. Pyroxene, wollastonite and other minerals are also abundant, while the presence of graphite disseminated through the limestones and their associated rocks, often in such abundance as to give rise to deposits of economic value, is of especial significance. This mineral which is not found in the Fundamental Gneiss, occurs usually in little disseminated scales but occasionally in veins. The limestones are thoroughly crystalline, generally somewhat coarse in grain and often nearly pure. They usually, however, contain grains of serpentine, pyroxene, mica, graphite or other minerals, of which over fifty species have been noted. They are often interstratified in thin bands with the gneiss, in places are very impure, and may be traced for great distances along the strike, being apparently as continuous as any other element of the series. This development of the Laurentian is known as the Grenville Series, and has been considered by all observers to be above and to rest upon the Fundamental Gneiss. In it are found all the mineral deposits of economic value—apatite, iron ore, asbestos, etc., which occur in the Laurentian. The rocks of this series, though generally highly inclined, over some large areas lie nearly horizontal or are inclined at very low angles, but even in such cases they show evidence of having been subjected to great pressure, resulting in some cases in the horizontal disruption of certain of the beds.

The areas occupied by the Grenville series although of very considerable extent, being known to aggregate many thousand square miles, are probably small as compared with those underlain by the Fundamental Gneiss. The relative distribution of the two series has not been ascertained except in a general way in the more easily-accessible parts of the great Archean Protaxis. The Grenville series is known to occupy a large part of its southern margin between the city of Quebec and the Georgian Bay, while the discovery of crystalline limestone in the gneiss elsewhere at several widely separated points, as for instance on the Hamilton River in Labrador, in the southern part of Baffin Land and on the Melville Peninsula, makes it probable that other considerable areas will, with the progress of geological exploration, be found in the far north. Over the greater part of the Protaxis, however, the more monotonous development of the Fundamental Gneiss seems to prevail.

[63 As here used the term includes all pre-Huronian rocks.]

The question of the origin and mutual relations of the Fundamental Gneiss and the Grenville series is one about which, though much has been written but little is known. * * *

How much of the Fundamental Gneiss really consists of eruptive material is not known. * * * The evidence accumulated goes to show that the Fundamental Gneiss consists of a complicated series of rocks of unknown origin, but comprising a considerable amount of material of intrusive character.

F. D. Adams, A. E. Barlow, A. P. Coleman, H. P. Cushing, J. F. Kemp, and C. R. Van Hise, 1907 (Report of a special committee on the correlation of the pre-Cambrian rocks of the Adirondack Mountains, the "Original Laurentian area" of Canada, and eastern Ontario: Jour. Geology, vol. 15, pp. 215–217).

The committee considers that over the whole area covered by their investigations—namely, the Adirondack Mountains, that portion of eastern Ontario which they examined, the "original Laurentian area" in the province of Quebec and its continuation to the east as far as the river St. Maurice—the pre-Cambrian sedimentary development is represented by one great series. This series is essentially identical in petrographical character throughout the whole region.

The only locality where the possible (Coleman would say probable) existence of a second unconformable sedimentary series was suggested by the facts observed, was that on the Queensboro road, east of Madoc, Ontario. It is, however, still a matter of uncertainty as to whether the conglomerate here developed marks the base of an overlying, infolded, unconformable series or not.

In Logan's original classification of the Laurentian this term—apart from the Upper Laurentian which was proved to be composed essentially of anorthosite intrusions—included two series differing in character, namely, the Lower Orthoclase (Fundamental) Gneiss and the Grenville series. Now that investigations have shown that these two series differ in origin, one being essentially a great development of very ancient sediments, and the other consisting of great bodies of igneous rock intruded through them, it becomes necessary to separate these two developments in drawing up a scheme of classification.

As the great intrusions of gneissic granite, forming what has been termed the "fundamental gneiss," have an enormously greater areal development than the overlying sedimentary series, constituting, as they do, a very large part of the whole northern protaxis, the committee recommend that the term "Laurentian" be restricted to this great development of igneous gneisses. The nomenclature suggested for the pre-Cambrian rocks of this eastern region will thus conform, so far as the use of this term is involved, with that suggested by the Special Committee for the Lake Superior region.

For the overlying sedimentary series the committee recommend the adoption of the name "Grenville series," as it is the name originally given by Logan to the series as typically developed about the township of Grenville in the "Original Laurentian area" on the north shore of the Ottawa River, in the Province of Quebec, between the cities of Montreal and Ottawa. The term "Hastings series" in the opinion of the committee should be abandoned as a serial name, seeing that the development to which this name was applied by Logan is merely the Grenville series in a less altered form, as Logan in giving the name had conjectured was probably the case. The committee, however, think that it may in some cases be advantageously employed as a qualifying term to designate the less highly altered phase of the Grenville series, which may thus be referred to as the "Hastings phase" of the Grenville series.

In Canada this Grenville series everywhere on going north is invaded by and frays away into the great Laurentian bathyliths, while in the Adirondacks it is cut to pieces by the great intrusions of that area which, when worked out in detail, may prove also to have a more or less similar bathylithic form.

The following succession in this region is therefore recognized and adopted by the committee:

Cambrian—Potsdam sandstones, etc.
(Unconformity)
Pre-Cambrian:
Grenville series.
(Intrusive contact).
Laurentian.

The committee consider that it is inadvisable in the present state of our knowledge to attempt any correlation of the Grenville series with the Huronian or Keewatin, so extensively developed in the region of the Great Lakes. The Grenville series has not as yet been found in contact with either of these, and until this has been done and the relations of the several series have been carefully studied, their relative stratigraphical position must remain a mere matter of conjecture.

C. R. Van Hise and C. K. Leith, 1909 (U. S. Geol. Survey Bull. 360, p. 32).

Part of the Hastings and Grenville rocks of eastern Ontario and western Quebec are probably Algonkian, but their stratigraphy and correlation are not yet solved.

W. G. Miller, 1919 (Geol. Mag., London, dec. 6, vol. 6, pp. 525–526).

The age relations of another historic series, the Grenville, have also been determined only during recent years. Most authors had suggested that the Grenville belonged to the so-called Huronian group of sediments, but it has proved to be the oldest sedimentary series. The Keewatin rocks, essentially schists and greenstones, represent, for the most part, submarine lava-flows. On the surface of these flows were deposited the Grenville sediments. While the major part of the Grenville is later than the major part of the Keewatin, a minor part of one group is contemporaneous with a minor part of the other.

C. Schuchert, 1924 (Textbook of geology, 2d ed., vol. 2, pp. 102, 145).

[On page 102 the Grenville series is placed in the "Archeozoic or Archean," and opposite the "Keewatin-Coutchiching series," but with the statement: "May not be Archeozoic." On page 145 is the statement that the Grenville series "may prove to be Proterozoic (Huronian)."]

The foregoing quotations will serve to show, briefly, the origin and history of the name Grenville. The name was originally used for one of the limestones forming a part of the Grenville series of present usage. The United States Geological Survey treats the Grenville as a provincial series of pre-Cambrian metamorphosed sedimentary rocks, which it classifies as of Algonkian (?) age. According to Miller (1919, quoted above) the Grenville is chiefly of post-Keewatin age, but its basal part corresponds to some rocks which the United States Geological Survey classifies as Archean.

The name is derived from the development of the rocks in Grenville Township, Argenteuil County, Ontario.

LLANO SERIES

C. D. Walcott, 1884 (Am. Jour. Sci., 3d ser., vol. 28, pp. 431–432).

The writer had the opportunity the past season to make a hurried reconnoissance of a portion of the Paleozoic area of Central Texas: the chief object in view being the study of the Cambrian section and the collecting of fossils from the Texas Potsdam horizon.

At all localities where the base of the Potsdam was observed, it rests, *unconformably*, on a great formation that is stratigraphically the equivalent of Powell's Grand Cañon series (Grand Cañon [64] and Chuar groups). In the Grand Cañon of the Colorado the latter are overlaid by the Tonto group, a series of rocks, in both lithologic and paleontologic characters, singularly like the Texas Potsdam group.

For this series of Pre-Potsdam strata the local name of Llano group is proposed from the best exposures of the group occurring in the county of Llano. Outcrops also occur in Burnet, Mason, San Saba, Blanco and Gillespie counties.

The finest exposure seen by the writer, in direct contact with the base of the Texas Potsdam group, is along the western base of Packsaddle mountain, in Llano county. Here the massive reddish colored sandstones of the Potsdam strike north and south with a slight dip to the eastward, and rest on alternating beds of shale, sandy shales, sandstone, limestone and schists that strike east and west, dipping south 15° to 40°. The strata exhibit but little evidence of metamorphism, being indurated but little more than the beds of the overlying Potsdam and Carboniferous. The section shows the Llano and Potsdam groups unaffected by changes subsequent to the consolidation of the Potsdam sediments.

Across the valley of Honey Creek, four miles west of Packsaddle mountain, the strata of the Llano group have been more metamorphosed, plicated, and broken by intrusive dykes of granite. This is along the eastern base of a ridge of Potsdam, Silurian and Carboniferous rocks that strike eastward with a dip that increases from 10° at the north end of the ridge to 40° at the south end. The movement producing this position, as compared with the Potsdam beds of Packsaddle mountain, appears to have been at the close of the Paleozoic, and to have caused, in part, the metamorphism of the strata of the Llano group, but was not accompanied by the intrusive rocks, as they are Pre-Potsdam—in part contemporary with the deposition of the sediments of the Llano group, but more largely the result of extrusions of granite at or near the close of the erosion of the Llano group and before the deposition of the Potsdam. It is to this age that the great masses of granite observed in western Burnet and all through Llano county belong. At the crossing of the Llano river, on the road from Burnet to Honey Creek Cove, fragments of the shales and sandstones of the Llano group may be seen imbedded in the granite, and on Morgan's creek, Burnet Co., the Potsdam rests directly on the granite.

The thickness of the Llano group was not determined owing to lack of time to study it in detail. In Honey Creek valley, from two to three thousand feet of shales, sandstone and limestones were observed, and northwest of the town of Llano a great mass of reddish sandstone occurs.

On Roessler's map of Llano county, all of the Llano group is referred to as "granitic, metamorphic and igneous," and has been considered as Archean. The writer did not observe any rocks of undoubted Archean age. No fossils were found in the Llano group, but, from its lithologic character and position

[64 Later renamed Unkar group, to avoid the double use of Grand Canyon, for the series and for one of the groups of the series.]

in relation to the overlying Potsdam, I refer the group to the Paleozoic, and correlate it with the Grand Cañon groups, which are of Paleozoic age and referred to the Lower Cambrian.

In 1890 Comstock[65] assigned the Llano rocks to the "Eparchean group of the United States geologists," and stated that he considered them equivalent to a portion of the Algonkian system. In 1899 Walcott[66] changed his name *Llano group* to *Llano series*, and assigned it to the pre-Cambrian. In 1912 Paige mapped the rocks of the typical Llano area, and classified them as Algonkian(?), which is the age designation of the United States Geological Survey. Paige stated:[67]

> The Llano series has proved to be a completely metamorphosed series of schists, marbles, and gneisses and can be classified as Algonkian in contradistinction to Archean only on the very broadest evidence, such as the preponderance of metamorphic sediments over igneous material. Roessler's description of these rocks as granitic, metamorphic, and igneous was therefore concise and, possibly except for his reference of the series to the Archean, correct.
>
> Llano series is the name applied to the metamorphosed series of schists, marbles, and gneisses which represent the pre-Cambrian sedimentary rocks of this region. The series, which is tentatively regarded as of Algonkian age, is divided into two formations, the Valley Spring gneiss and the Packsaddle schist.

The name is derived from the exposures of the rocks in Llano County, Tex.

"KILLARNEY REVOLUTION"

W. G. Miller and C. W. Knight, 1914 (Ontario Bur. Mines Rept., vol. 22, pt. 2, p. 125 and chart).

The report cited gives the following classification (descending order) of the pre-Cambrian rocks of Ontario:

Keweenawan.
Animikean.
Intrusives (Algoman):

Algoman of Lawson, 1913. Laurentian, in part, of some authors and Huronian granite of others. Lorrain granite of Cobalt. Moira granite of Hastings county. Killarney granite of north shore of Lake Huron.	Names that have been employed for rocks of various localities.

Temiskamian. Includes part of the Huronian of Logan and Murray and of many other authors. Part of the Lower Huronian of Van Hise and Leith (U.S.G.S. Bull. 360). Temiskaming series of Miller. Sudbury series of Coleman (The Nickel Industry, Mines Branch, Ottawa, 1913).
Intrusives (Laurentian).

---

[65] Comstock, T. B., Preliminary report on the geology of the central mineral region of Texas: Texas Geol. Survey First Ann. Rept., pp. 252, 276–282, 1890.

[66] Walcott, C. D., Pre-Cambrian fossiliferous formations: Geol. Soc. America Bull., vol. 10, p. 218, 1899.

[67] Paige, Sidney, U. S. Geol. Survey Geol. Atlas, Llano-Burnet folio (No. 183), pp. 2, 3, 1912.

Loganian:

Grenville (sedimentary). Includes most of the Hastings and Grenville of older authors, and the Couchiching of Lawson.

Keewatin complex (igneous).

This name [Algoman], introduced by A. C. Lawson (Int. Geol. Congress, 1913), appears to the authors to be a good one. Their investigations in southeastern Ontario, as well as at Cobalt and surrounding region, have proved that granite and gneiss of post-Temiskaming and pre-Animikie age are of wide extent. Ten years ago the authors gave to granite of this age in the Cobalt area the name Lorrain granite, and later they gave to a granite of similar age in southeastern Ontario the name Moira. On the north shore of Lake Huron granite of similar age has been called Killarney. Algoman now being preferred, although not having priority, Lorrain, Moira, and Killarney may be discarded or used locally. In the descriptions of many areas Algoman granite and gneiss have in the past been classed as Laurentian, age relations not being definitely known.

W. H. Collins, 1922 (Jour. Geology, vol. 30, pp. 204–210).

The sediments forming these [Lacloche] mountains are Precambrian (Huronian), and the intrusive granitic batholiths are late Precambrian (Killarney). [Page 204.]

If intense regional disturbance and batholithic invasion indicate mountain-building, it must be concluded that following Timiskaming time the whole region, shown in Figure 3, was mountain-built. The southern portion was long afterward involved in the Killarnean mountain-building and, in that part, any evidence of this earlier orogeny was pretty completely demolished; but there is little doubt that the older mountains extended over the whole region. [Pages 207–208.]

Following or during the Keweenawan another (third) process of mountain-building (Killarnean) took place which affected only the southern portion of the region. These Killarnean Mountains were reduced to a state of fairly low relief before the Ordovician marine sediments were deposited upon them. [Page 210.]

The map on page 205 of the journal cited is entitled "Map of northeastern Ontario to show the known distribution of the batholithic intrusives, which are of three distinct ages and are related to three corresponding processes of mountain-building," and the map units are as follows:

Sediments and volcanics.
Killarney granite.
Pre-Huronian granite.
Pre-Dorean granite.

C. Schuchert, 1924 (Textbook of geology, 2d ed., vol. 2, pp. 102, 160, 171).

Eras	General terms for major divisions	Lake Superior, after Leith	Lake Huron-Michipicoten, after Leith
	Killarney Revolution.	Keweenawan granite.	Killarnean granite.
Proterozoic.	Keweenawan series.	Keweenawan formations.	Keweenawan (norites).
	* * *	* * *	* * *

[Page 102.]

At the close of this [Proterozoic] era the Killarney mountains arose out of the Ontaric geosyncline, dividing the vast interior of North America into a northern (Canadian Shield) and a southern (United States and Mexico) plain. [Page 160.]

Killarney Revolution.—Collins (1922) has shown that the whole area of the Ontaric geosyncline from at least Sudbury, Ontario, into southern Wisconsin, was folded and injected by granite bathyliths, making the Killarney mountains. These have long been known as the "Lost Mountains of Wisconsin," and Lawrence Martin thinks they may originally have been as high as the present Alps. In a northeast direction the Killarney mountains are known to have extended at least 1,000 miles, from southwestern Minnesota (Sioux Falls) to beyond Lake Huron (see map, p. 193). [Page 171.]

"ALGOMAN REVOLUTION"

A. C. Lawson, 1914 (Cong. géol. internat., 12th sess., Toronto, Compt.-rend., p. 361).

From the foregoing summary of observations, it is obvious that we have to deal with the products of two widely separated periods of plutonic activity in the earth's crust, one post-Ontarian [post-Keewatin] and pre-Huronian, and the other post-Huronian and pre-Animikie. The rocks of both periods were at first confused and regarded as all belonging to the Laurentian. In later years, notwithstanding the gradual recognition of the distinctness and time interval between the two irruptive periods, the rocks of both continue to be called Laurentian. As long as this practice continues we shall never be able to clear up the problems of the Archæan; and the time has come when the second great period of batholithic development in the Lake Superior region must receive recognition not only in observational records but also in our nomenclature. In a report on the Rainy Lake region for the year 1911, submitted to the Director of the Geological Survey of Canada, I have proposed that this period be called the *Algoman*, from the old western Ontario district of Algoma, in which these plutonics are well displayed and widely distributed.

A. C. Lawson, 1916 (California Univ. Dept. Geology Bull., vol. 10, No. 1, chart opp. p. 18).

Adams (Problems of American Geology, p. 63) takes exception to placing the Laurentian and Algoman granites in the sequence of formations on the ground that they are intrusive masses and not members of the stratigraphic succession. It may be urged, however, that the sequence is chronological as well as stratigraphic and in the standard scale we need a term for these two periods of batholithic development. Perhaps the terms Laurentian Revolution and Algoman Revolution used in the tabulation will meet the objection.

W. G. Miller, 1919 (Geol. Mag., London, dec. 6, vol. 6, p. 525).

The following classification is now employed by the Ontario Bureau of Mines:

Keweenawan.
Unconformity.
Animikean.
Great unconformity.
Algoman granite and gneiss.
Timiskamian.
Great unconformity.
Laurentian granite and gneiss.
Loganian:
    Grenville (sedimentary). Deposited on the Keewatin lavas.
    Keewatin (igneous).

H. C. Cooke, 1920 (Jour. Geology, vol. 28, pp. 328–329).

A brief discussion of the nomenclature of the granite of Timiskaming district may be added here, as closely related to the main purpose of this paper. The term Algoman has recently been applied by Miller, Burrows, and others, when referring to granites intrusive into the Timiskaming series but underlying the Cobalt series.[68] The term Algoman was first used in the Rainy Lake district by A. C. Lawson, and was defined by him as applying to granites intrusive into the Middle Huronian but underlying the Upper Huronian or Animikie.[69] The transfer of this term to Timiskaming district 500 miles to the east was made upon a correlation of the Cobalt series with the Animikie, since both series are flat lying and overlie a great unconformity, and a secondary decision that the Timiskaming, as a folded sedimentary series lying beneath the Animikean, was probably Lower Huronian. But with the determination of the Timiskaming series as pre-Huronian in age, while the intrusive granites are found in the Lake Huron area to underlie the Bruce or Lower Huronian, it is clear that the use of the term Algoman is entirely unjustified.

In its place the writer would apply the term Laurentian to these granites.

"TIMISKAMIAN SERIES"

W. G. Miller, 1911 (Eng. and Min. Jour., vol. 92, pp. 647–648).

The article cited gives the following classification (descending order) of the pre-Cambrian rocks in the Cobalt and surrounding areas of Ontario:

> *Nipissing Diabase.*—Quartz diabase of Cobalt sill, etc.
> (Intrusive contact.)
> *Cobalt Series.*—Lower Huronian conglomerate, etc., of the cobalt—silver deposits. Lies in an almost horizontal position.
> (Unconformity, erosion.)
> *Lorrain Granite.*
> (Intrusive contact.)
> *Temiskaming Series.*—Conglomerate, etc., of Kirk, Cross and Temiskaming lakes, etc. Dips at high angles. In previous reports included in Keewatin.
> (Unconformity, erosion.)
> *Keewatin.*

For the fragmental series, in which the cobalt-silver veins characteristically occur, we propose to employ the name Cobalt Series, which we have heretofore used in a general way. For the older, more disturbed conglomerate series, which outcrops at Kirk and Cross lakes and in greater volume on Lake Temiskaming, outcrops also being known a considerable distance south of Cobalt and 90 miles to the northwest at Porcupine, the name Temiskaming will be used. The granite intrusive into the Temiskaming series but not into the Cobalt series will be called the Lorrain Granite, a name under which it is already known. The quartz diabase of the sill at Cobalt, which is of such great economic importance and is so widespread, not only in that vicinity but throughout a large territory in the district of Nipissing, will be called the Nipissing Diabase. This will serve to distinguish it from diabases of other ages that occur in the region.

---

[68] Ont. Bur. Mines, Rept. No. 22, Part 2, pp. 123–127, 1913.
[69] Geol. Surv. Can. Mem. No. 40, p. 82, 1913.

W. G. Miller and C. W. Knight, 1914 (Canada Bur. Mines Rept., vol. 22, pt. 2).

The report cited contains the following classification of the pre-Cambrian rocks of Ontario, western Quebec, and southeastern Manitoba:

Keweenawan.
Unconformity.
Animikean. (Upper Copper-bearing rocks of Lake Superior; Lower group, Geol. Can., 1863. Includes Middle and part of Lower Huronian of Lake Huron of various authors (U. S. G. S. Bull. 360). Animikie or Upper Huronian of Lake Superior, and of the Sudbury basin, Whitewater and Ramsey Lake series. Cobalt series of Cobalt and surrounding region.)
Great unconformity.
Algoman (intrusives). (Algoman of Lawson, Int. Geol. Con., 1913. Laurentian, in part, of some authors and Huronian granite of others. Lorrain granite of Cobalt. Moira granite of Hastings county. Killarney granite of north shore of Lake Huron). [In subsequent reports the latter granite has been assigned to the Keweenawan epoch.]
Temiskamian. (Includes part of the Huronian of Logan and Murray and of many other authors. Part of the Lower Huronian of Van Hise and Leith (U. S. G. S. Bull. 360). Temiskaming series of Miller, Eng. and Min. Jour., Sept. 30, 1911, and Ont. Bur. of Mines, vol. XIX, part 2. Sudbury series of Coleman, The Nickel Industry, Mines Branch, Ottawa, 1913).
Great unconformity.
Laurentian (intrusives). Granite and gneiss.
Loganian:
  Grenville (sedimentary). Includes most of the Hastings and Grenville of older authors, and the Couchiching of Lawson.
  Keewatin (igneous).

A. P. Coleman, 1915 (Problems of American geology: Yale Univ. Pub., pp. 89–90).

[See quotation under "*Sudburian*," below]

"SUDBURIAN"

A. P. Coleman, 1913 (The nickel industry: Canada Dept. Mines, Mines Branch, pp. 6–7).

This report was made "with special reference to the Sudbury region, Ontario." The rocks described are all assigned to the pre-Cambrian, and are described as consisting, in descending order, of

Later dykes.
Norite-micropegmatite sheet.
Upper Huronian or Animikie, 8,750 to 9,450 feet.
Middle Huronian absent.
Lower Huronian. "In previous reports described as middle Huronian."
Laurentian.
Acid eruptives of the Sudbury series.
Basic eruptives of the Sudbury series.
Sudbury series.
Grenville series.
Keewatin.

The "Sudbury series" is defined as follows:

SUDBURY SERIES

Later in age than the Grenville and Keewatin, but earlier than the Laurentian, is a great series of sediments, chiefly quartzite, but including also arkose, greywacke, slate, and some thin sheets of conglomerate. These are steeply tilted and sometimes folded, and have been penetrated and partly metamorphosed by acid and basic eruptives. They have hitherto been called lower Huronian, but they differ so much in attitude and relationship from the typical lower Huronian not far to the west that they probably belong to an earlier period, equivalent perhaps to the Timiskaming series, described by Dr. Miller and other geologists in the Cobalt region as lower than the Huronian. It is proposed to call them the Sudbury series.

The Timiskaming series and the rocks here referred to are not to be looked upon as a "Lowest Huronian," beneath the usually recognized bottom of that series, but as a new division of the Archæan equal in rank to the Huronian and Keewatin.

If these rocks are put in the position suggested it will imply also that the conglomerate near Ramsey lake, hitherto called middle Huronian, must be lowered one stage and be named lower Huronian. The Ramsey Lake conglomerate is more like the Cobalt and Echo Lake conglomerates of the lower Huronian regions hitherto carefully studied than are the sedimentary rocks underlying, giving support to the suggested change. * * *

These quartzites have a width of from 3½ to 6 miles, and if they have not been duplicated by faulting, of which there is no evidence, have a maximum thickness of 15,000 or 20,000 feet, making them one of the greatest well defined sedimentary formations in Ontario.

Apparently beneath the quartzites there is a thinner, but still important band of greywacke and slate, also well stratified and showing its original structures when not too much affected by adjoining eruptives. It has a width of two miles or more and a thickness of several thousand feet, and in various places it comes in contact with offset ore deposits but scarcely touches the main nickel range.

A third, and probably lower division of the sediments is more enigmatic, since it has undergone much greater changes, largely obliterating its original structure. This consists of quartzite or arkose, pink in color and greatly recrystallized, running northeast and southwest as a band of hills not more than half a mile wide from near Frood mine to a point southeast of Creighton. This rock touches Copper Cliff mine and was described earlier as felsite.

The three sedimentary formations may have a total thickness of 30,000 feet.

A. P. Coleman, 1915 (Problems of American geology: Yale Univ. Pub., pp. 89–90).

A Temiscaming Series of sediments very similar to those of Sudbury has been set apart by Miller and Knight and Burrows below the Cobalt (Lower Huronian) Series eighty miles to the north; and the Pontiac Series of Quebec not far to the east, as described by Morley E. Wilson, occupies probably the same position.

Since the Sudbury rocks have been longest known, have an estimated thickness of 20,000 feet, and cover a much larger area than the Temiscaming or Pontiac Series, the term Sudbury Series or Sudburian may be expanded to cover the whole and will have equal standing with the Keewatin below or the Huronian above. * * *

As thus worked out, the pre-Cambrian groups may be arranged as follows: [See table on p. 40 of this bulletin.]

ARCHEAN PERIOD (OR SYSTEM)

J. D. Dana, 1872 (Am. Jour. Sci., 3d ser., vol. 3, p. 253).

3. *Archæan rocks.*—Besides the limestones and Taconic schists and gneiss, there is, near Poughquag, in still more intimate connection with the quartzite, rocks of the Azoic age, a continuation of the Highland range of New Jersey—a range recognized as Azoic first by H. D. Rogers, and shown to continue into Dutchess county by Logan and Hall (this Journal, II, XXXIX, 96). They are probably Laurentian, as stated by Logan and Hall, that is, they are equivalents of the oldest known Azoic rocks of Canada. But as this point is not definitely settled, and since the term Azoic has been ruled out by facts proving that the era was not throughout destitute of life, I propose to use for the Azoic era and its rocks the general term *Archæan* (or Archean), from the Greek ἀρχαῖος, *pertaining to the beginning.*[70]

As thus originally defined the name Archean applied to all pre-Cambrian rocks. In 1887 the rocks now designated the Algonkian system were separated from the Archean by R. D. Irving, under the name "Agnotozoic." In 1888 Irving again suggested for them the name "Agnotozoic," also "Eparchean." Both of these names were in 1889 discarded by the United States Geological Survey in favor of the name Algonkian. The definition of Archean now recognized by the United States Geological Survey is as follows:

Below the Algonkian, and separated from it by a profound unconformity in the majority of regions, is another system of rocks of radically different character. This system consists dominantly of schists and gneisses, the chemical composition of which, so far as tested, corresponds with igneous rocks rather than with sedimentary rocks. The lithologic variations of these schists and gneisses are exceedingly complex. Usually accompanying this lithologic complexity is exceeding intricacy of structure. In this matter of unparalleled intricacy of structure the system is unique. Many masses of igneous rocks belonging to later systems are intrusive in the ancient schists and gneisses. In various parts of the world minor masses of metamorphosed sediments are intimately associated with the remainder of the system.[71]

No indisputable fossils have been found in the sediments of the Archean, but there is indirect evidence indicating the existence of some form of life, probably both plants and animals, during their deposition.

LAURENTIAN EPOCH (OR SERIES)

W. E. Logan, 1854 (Canada Geol. Survey Rept. Progress 1852–53, pp. 7, 8).

The country which lies between the upper end of the island of Montreal and Cape Tourmente on the left side of the St. Lawrence, and occupies the space intervening between the river and the flank of the metamorphic hills, to which

[70] Whatever part of the Archæan beds are proved to belong to an era in which there was life, will be appropriately styled *Archeozoic.* This term avoids the objection which Eozoic derives from the doubtful nature of the Eozoum.

[71] U. S. Geol. Survey Twenty-fourth Ann. Rept., p. 26, 1903.

Mr. Garneau in his History of Canada has given the name of Laurentides, has a length of about 200 miles, and it gradually widens from a point at Cape Tourmente, to about thirty miles at Montreal, having thus an area of about 3,000 square miles. * * *

The name which has been given in previous Reports to the rocks underlying the fossiliferous formations in this part of Canada is the Metamorphic series, but inasmuch as this is applicable to any series of rocks in an altered condition, and might occasion confusion, it has been considered expedient to apply to them for the future, the more distinctive appellation of the Laurentian series, a name founded on that given by Mr. Garneau to the chain of hills which they compose.

The geological formations which underlie the district in ascending order would thus be as follows:

1. Laurentian series.
2. Potsdam sandstone.
3. Calciferous sandrock.
4. Chazy limestone.
5. Birdseye, Black-River and Trenton limestones.
6. Utica slate.
7. Hudson-River group.
8. Oneida conglomerate.

In 1855 Logan and Hunt[72] divided the ancient rocks of Canada into Laurentian system and Cambrian or Huronian system, thus applying the name Laurentian to all pre-Huronian rocks. This usage continued for many years.

The definition of Laurentian adopted by the joint committee of American and Canadian geologists in 1905, and still followed by the United States Geological Survey, is as follows:

For the granites and gneissoid granites which antedate or protrude through the Keewatin, and which are pre-Huronian, the term "Laurentian" is adopted.

KEEWATIN EPOCH (OR SERIES)

A. C. Lawson, 1885 (Report on the geology of the Lake of the Woods region, with special reference to the Keewatin (Huronian?) belt of the Archæan rocks: Canada Geol. and Nat. Hist. Survey, 1885, the same being part CC of Canada Geol. and Nat. Hist. Survey Ann. Rept., new ser., vol. 1, 1886, pp. 10CC–13CC, 14CC–15CC).

REASONS FOR PROPOSING THE NAME "KEEWATIN"

The belt of schistose rocks which runs through the granitoid gneiss, across the northern parts of the Lake of the Woods has, as above stated, been regarded as of Huronian age. In this report, upon the first detailed investigation of the belt as a whole, I feel it incumbent upon me, at the outset, to say a few words on the nomenclature of the series of rocks comprised within it, and particularly to question the advisability, in the light of recent investigations, of relegating these rocks to a position stratigraphically and geognostically equivalent to the typical Huronian of Sir William Logan, as described in the Geology of Canada, (1863). It must always be an extremely difficult matter to demonstrate the equivalency or non-equivalency of any two widely separated

[72] Logan, W. E., and Hunt, T. S., Esquisse géologique du Canada, à l'Exposition Universelle de Paris, Paris, 1855.

sets or series of Archæan rocks, devoid of fossils. Lithological similarity has by no means been established as a criterion of geological equivalency, except in a very general way of little or no value in specific comparisons of given series of rocks. On the other hand, it seems reasonable to suppose (and indeed the rocks themselves establish the fact), that volcanic activity played a much more important part in the development of the formations of Archæan times than in that of later geological ages; and farther, since these volcanic rocks were mixed with ordinary aqueous sediments, and the volcanic action was intermittent and irregular, we would expect to find series of the same geological age, of all gradations of lithological character, from an almost wholly volcanic to an almost wholly sedimentary composition. Thus the extreme dissimilarity of series so composed would be no proof of geological disparity. Lithological character is only one of several considerations that must be taken into account in a question of the correlation of two geological series geographically separated.

The schistose belt of the Lake of the Woods appears to me to differ from the typical Huronian of Sir W. Logan, both lithologically and in other respects. The typical Huronian of Logan is, from his description of it, essentially a quartzitic series, in which the quartzites are true indurated sandstones. The schistose belt of the Lake of the Woods is not so characterized. Quartzites form an extremely small proportion of the rocks of the Lake of the Woods, and then they are only local developments in formations of mica-schist and felsite-schist. Bedded limestones are characteristic of Logan's typical series. On the Lake of the Woods there are, so far as I have been able to determine, no bedded limestones, the nearest approach to them being small segregated bands of dolomite, of the character of vein-stones. These two differences alone are sufficient to throw doubt on the equivalence of the two series, if lithological character is to be regarded as an aid to geological reclassification. There are, however, other differences. The basal conglomerate of Logan's Huronian, on Lake Temiscamang, is described as "holding pebbles and boulders, sometimes a foot in diameter, of the subjacent gneiss, from which they appear to be derived. The boulders display red orthoclase feldspar, translucent, colourless quartz, green hornblende and brownish-black mica, arranged in parallel layers, which have a direction according with the attitude in which the boulders were accidentally enclosed." The rocks on the Lake of the Woods, which are in the following pages referred to as "agglomerate-schists," are not basal conglomerates. They are not at the base of the series included in the schistose belt, nor are they apparently composed of water-worn fragments, derived from the rocks upon which they rest.

No fragments that can be referred to the underlying granitoid gneisses are found included in the agglomerate-schists of the Lake of the Woods. All the facts connected with them point to a volcanic origin for these agglomerates, and the fragments are very frequently sharply angular, often with re-entering angles although, for the most part they are elongated and lenticular in shape as a result of pressure, and the paste in which they are imbedded does not differ from them materially in composition as a rule. In rare instances they pass into pebble- or boulder-conglomerate, in which the pebbles are usually of a reddish felsitic material and indicate the co-existence of aqueous, with volcanic deposition.

The "green slate rock" conglomerates at the mouth of the Doré River, Lake Superior, described by Sir W. Logan, supposed by him to be equivalent to the rocks of his main Huronian area, appear to resemble the agglomerate-schists of the Lake of the Woods. This Doré River area of "green slate rocks" is, however, geographically distinct, and appears to differ from the series in the typical Huronian region. The rocks are described as standing in a nearly vertical attitude, while those of the latter are comparatively flat. Neither are they associated with beds of quartzites or limestones to a material extent. Those differences, with the geographical separation, may, I believe, warrant us in considering the possibility of Logan having embraced under one designation two distinct series and in regarding as Huronian, for the present, at least, only his main Huronian area, which is mapped in detail.

As a general rule the basal member of the schistose series of the Lake of the Woods is a group of black hornblende-schists with associated trap-rocks, principally altered diabases and diorites. In Logan's Huronian, this formation appears to be wanting in this stratigraphical position, or finds its analogue in "a mass of rather coarse-grained greenstone or diorite, usually interposed between the Laurentian gneiss and the recognized Huronian rocks, on the Sturgeon, Wahnapitae, and White-fish Rivers; but whether this is an overflow constituting the base of the upper formation, or an eruptive mass in the form of a dyke intruded at a later period, has not been ascertained.

Mica-schists, hydromica-schists and clay-slates appear to be but sparingly, or not at all represented in Logan's typical Huronian series. In the Lake of the Woods belt they are extensively developed and form an important constituent of the series.

There is, however, one point of resemblance. In Logan's series there is 2,000 ft. of "chloritic and epidotic slate, interstratified with trap-like beds." In the Lake of the Woods belt, there is abundance of chlorite. The hornblende-schists, diabases and diorites are generally very much decomposed, and the rocks are as a result largely chloritic. In addition to this, there are formations—particularly interbedded with the hydromica-schists—of soft, finely fissile, green schists, which appear to be altogether chloritic.

In the face of so many important points of difference, I hesitate to believe in the equivalency of the two series, although quite prepared to admit the possibility of two series of geologically the same age having widely different lithological characters in geographically separate regions.

There are, moreover, other considerations. There are two conditions which appear to be generally characteristic of the Laurentian gneisses of North America:—1. They are sharply folded. 2. They are cut by intrusive granites. Now the Lake of the Woods belt of schists is folded with the granitoid gneisses and is cut by several very large masses of granite and many smaller dykes. That is to say, the present schistose rocks of the Lake of the Woods were laid down upon the granitoid Laurentian gneisses, whatever may have been the original form of these, before the main era of folding was inaugurated and before the granites (probably as a concomitant of the folding) were forced up from below. It is extremely doubtful that this is true of Logan's Huronian series, from his description of it. The series is flat-lying or gently undulating, and its basal member contains "boulders of the subjacent gneiss, from which they appear to be principally derived."

Further, Logan's mapped area of Huronian is not characterized by the presence of large masses of granite, although in the immediate vicinity of one part of this area "the intrusive granite occupies a considerable area on the coast of Lake Huron, south of Lake Pakowagaming. It there breaks through and disturbs the gneiss of the Laurentian series, and forms a nucleus from which emanates a complexity of dykes, proceeding to considerable distances. As dykes of a similar character are met with intersecting the rocks of the Huronian series, the nucleus in question is supposed to be of the Huronian age, as well as the greenstone dykes which are intersected by it." Similarly, just beyond the northern border of Logan's Huronian area, "cliffs of syenite and granite" are recorded as observed on the Mississague River, although none are stated to cut the Huronian strata in the neighborhood. Logan does not state in so many words that the underlying gneisses are folded, but both on his map, by the plotted dips, and in his sections 1 and 1 A, he shows that such he conceived to be their condition.

It thus appears that while the Lake of the Woods schists are older than the time of folding and older than the granites which are intruded through them, Logan's typical Huronian has come into existence later than the time of folding of the gneiss and possibly also later than the main period of granitic irruption. If then we suppose as there is every reason for doing, that the time of folding of gneiss and irruption of the granite was in a general way the same over this portion of the continent, we have the Huronian series and the Lake of the Woods series at once relegated to two very distinct geological ages.

F. D. Adams, Robert Bell, A. C. Lane, C. K. Leith, W. G. Miller, and C. R. Van Hise, 1905 (Report of the special committee for the Lake Superior region: Jour. Geology, vol. 13, pp. 103–104).

Unconformably below the Huronian is the Keewatin. The Keewatin includes the rocks so defined for the Lake of the Woods area and their equivalents. We believe the Kitchi and Mona schists of the Marquette district, the green schist (Mareniscan) of the Penokee-Gogebic district, the greenstone series of the Mesabi district, the Ely greenstones and Soudan formation of the Vermilion district, the part of the area mapped as Keewatin by Lawson in the Rainy Lake district not belonging structurally with the Couchiching, and probably the Thessalon greenstone series on the north shore of Lake Huron, to be equivalent to the Keewatin of the Lake of the Woods, and, so far as this is true, they should be called Keewatin.

In the Rainy Lake district, the Huronian should include that part of the Couchiching of the south part of Rainy Lake which is limited below by basal conglomerate as shown at Shoal Lake.

C. R. Van Hise and C. K. Leith, 1909 (U. S. Geol. Survey Bull. 360, pp. 377–378).

Keewatin.—This name, first applied by Lawson to the greenstones, green schists, and iron formation of the Lake of the Woods area, has been by other writers applied to green rocks of different ages. In northern Minnesota the term "Keewatin," as used by N. H. Winchell, includes rocks of the basement complex and of the Huronian. Van Hise, believing that the term Keewatin was not originally applied to a structural unit, and believing also that its usefulness had been impaired by its promiscuous application to green rocks of different ages elsewhere, proposed the term "Mareniscan" to cover the greenstone, green schist, and iron formation portion of the basement complex. When Lawson's original Keewatin area of the Lake of the Woods was examined by the joint committee of Canadian and United States geologists [[73]] it was ascertained that the Keewatin of this area is a structural unit, and the term Keewatin was recommended to cover all of the greenstone, green schist, and iron formation portion of the basement complex in place of "Mareniscan." This is the sense in which Keewatin is now generally used.

[[73] Consisting of F. D. Adams, Robert Bell, W. G. Miller, C. K. Leith, A. C. Lane, and C. R. Van Hise.]

The name is derived from the great development of the rocks in the Keewatin district, Canada.

"COUTCHICHING SERIES"

A. C. Lawson, 1887 (Am. Jour. Sci., 3d ser., vol. 33, pp. 473–480).

In the Rainy Lake Region there can be distinguished five groups of rock formations which are geologically distinct from one another. * * * [Page 473.]

The group of rocks comprised in the table [petrographic] given above is designated geologically as the Laurentian System in accordance with the practice in vogue among geologists of so naming the lowest well-defined system of crystalline rocks which is clearly separable from overlying strata. It is not intended by the use of this term to imply that the rocks are necessarily of the same age as those described as the typical Laurentian by Logan, or as those named Laurentian in any other part of the world. For it is manifestly at variance with scientific methods to definitely correlate, with reference to age, rocks in which there are no criteria for comparison other than their petrographical characters. * * * [Pages 475–476.]

Superimposed upon the rocks thus referred to the Laurentian system, the splendid exposures of the shores of Rainy Lake reveal, as the next geological group a thick series of very distinctly stratiform mica schists and fine grained, gray, evenly bedded, often garnetiferous, very quartzose granulitic-gneisses. * * * [Page 476.]

This thick series of mica schists and granulitic gneisses attains its greatest development so far as has yet been observed in the southern part of Rainy Lake, where its thickness in continuous exposure, with the strata at low angles which preclude the idea of reversed dips, can be measured for a thickness of over two miles in a low anticlinal. The series is for convenience designated the Coutchiching series, from the Coutchiching Rapids at the head of Rainy River where the rocks are first met with on entering Rainy Lake from the west. They are very sharply and distinctly marked off from the lower granites and gneisses of the Laurentian. The geological contact between the Coutchiching series and the Laurentian system is one of neither conformity nor unconformity. The break is of an entirely different order, and the contact is eminently that of an igneous injection or intrusion of the lower through the upper rocks. This series appears to thin out rapidly toward the north, and on the north shores of the southern part of Rainy Lake, in the neighborhood of Seine, Swell, Red-gut and Rocky Islet Bays, and in the islands of the lake, it is seen to form a trough in which lies folded another higher series of entirely different character. The rocks comprising it are for the most part of volcanic origin. They are chiefly black-green, compact, hornblende schists; softer, less compact, and more fissile green schists in which hornblende is the prevailing constituent, but with chlorite, calcite, epidote and other decomposition minerals well represented in them; and, in intimate association with these schists and interbedded with them, great sheets of "trap" comprising uralitic diabases and gabbros (often called diorites) and other massive altered basic volcanic rocks of less determinate characters. These altered traps are sometimes quite massive and sometimes schistose to a varying extent, in which case the crushed or stretched condition of the rock is so clearly displayed in microscopic sections as to leave no doubt that the schistosity is due to pressure and to stretching or pulling forces upon the rocks after the assumption of a firm crystalline condition. When the crushing has been excessive the original character is often almost or completely obliterated, particularly, as the comminution of the rock under such forces is accompanied by the development of secondary minerals like quartz, calcite, epidote, zoisite, chlorite and albite. Included also in this series are dark green, very fissile glossy schists holding water-worn pebbles; green volcanic breccias; finer textured clastic rocks or "graywackes;" sericitic schistose quartz-porphyries and regular porphyroids; and soft, fissile, nearly always much decomposed hydromicaceous schists with which are associated yellowish dolomitic segregations.

The breccias, graywackes, and hydromica schists are more commonly met with in the northern part of the Rainy Lake Region than on Rainy Lake itself. This group of rocks is the same as a large portion of the series described in my report on the Lake of the Woods Region as the Keewatin series, and in the northern part of the Rainy Lake Region can be traced in direct continuity with that series. They will therefore be referred to as the Keewatin series of rocks. Concerning the geological relations of the Coutchiching and Keewatin series it is not possible to make any sweeping statement as to their conformity or unconformity. The Coutchiching rocks do not appear to have been at all disturbed prior to the deposition of the Keewatin, and the parallelism of the strike and dip of the strata or beds of the two series is often seen to be perfect. But as Geikie points out the geological conformity or unconformity of two sets of strata implies a broader question than the mere relations in space of their contiguous portions. Strata which are in close contact and show at certain places perfect parallelism may sometimes be separated by ages. The appearance of parallelism is often simulated by pressure and folding so that it is not always a criterion of continuity of geological history. The very diverse character of the two series, the Coutchiching and the Keewatin, is proof of a profound alteration in the conditions of rock formation, which implies a geological break, though it does not indicate its duration. The Coutchiching series is seen occasionally to be cut by intrusions of a certain character which have not been detected traversing the Keewatin rocks. These may possibly be instances of vents from which the traps of the Keewatin series were extravasated. In the northern part of the Rainy Lake Region the Keewatin series comes into direct contact with the Laurentian without the intervention of the Coutchiching series, and the conditions of contact are those which have been described as obtaining in the Lake of the Woods Region. The contact of the hornblende schists and altered traps with the Laurentian rocks is of the same igneous or brecciated character as that observed on the Rainy Lake between the Coutchiching and the Laurentian, the direct inference being, of course, that the Laurentian rocks are of more recent age as such than either the Coutchiching or Keewatin, although stratigraphically they are inferior to both. * * * [Pages 477–478.]

The rocks of the region or their equivalents appear in their eastward geographical distribution in the neighborhood of Lake Superior to pass in a folded state under the flat lying beds of the Animikie series, the contact being one of marked unconformity. The Animikie is, according to the prolonged and valuable researches of Prof. R. D. Irving, of the United States Geological Survey, the geological equivalent of the typical Huronian of Logan.

The Animikie or Huronian is, according to the same eminent authority, distinct from and underlies the Keweenawan (Nipigon). Hence the classification of the various geological systems or series of rocks in the country west of

Lake Superior, so far as our present knowledge goes, is with reference to their place in the ideal geological column, as follows:

Keweenawan (Nipigon).
Huronian (Animikie).
Keewatin.
Coutchiching.
Laurentian.

With reference to their age, as follows:

Keweenawan (Nipigon).
Huronian (Animikie):
Diabase dykes and gabbro.
Granite, post-Laurentian.
Laurentian.
Keewatin.
Coutchiching.

F. D. Adams, Robert Bell, A. C. Lane, C. K. Leith, W. G. Miller, and C. R. Van Hise, 1905 (Jour. Geology, vol. 13, pp. 95, 103).

In the Rainy Lake district the party observed the relations of the several formations along one line of section at the east end of Shoal Lake and at a number of other localities. The party is satisfied that along the line of section most closely studied the relations are clear and distinct. The Couchiching schists form the highest formation. These are a series of micaceous schists graduating downward into green hornblendic and chloritic schists, here mapped by Lawson as Keewatin, which pass into a conglomerate known as the Shoal Lake conglomerate. This conglomerate lies upon an area of green schists and granites known as the Bad Vermilion granites. It holds numerous large well-rolled fragments of the underlying rocks, and forms the base of a sedimentary series. It is certain that in this line of section the Couchiching is stratigraphically higher than the chloritic schists and conglomerates mapped as Keewatin. * * * [Page 95.]

In the Rainy Lake district, the Huronian should include that part of the Couchiching of the south part of Rainy Lake which is limited below by basal conglomerate as shown at Shoal Lake. [Page 103.]

C. K. Leith, 1914 (Cong. géol. internat., 12th sess., Toronto, Compt.-rend., pp. 410–411).

A large part of the series which Lawson originally classed as Coutchiching, in fact one of the largest areas he described as typical Coutchiching, he now admits is later than and unconformably upon the Keewatin. He calls it the Seine series. This part of the Coutchiching he says is unconformably above another part of the original Coutchiching series. From a detailed consideration of his field work we are doubtful whether he has succeeded in proving this unconformity. * * *

Other parts of the original Coutchiching have been found to be merely schistose phases of Keewatin basalts and not sedimentary. These parts are now eliminated from the Coutchiching. More such parts are likely to be eliminated.

After taking from the Coutchiching the rocks above mentioned, it is doubtful how much, if any, of the series is left to meet Lawson's definition of Coutchiching.

If it should prove that there is a residuum of Coutchiching sediments actually beneath the Keewatin of Rainy lake, it remains to be proved that they are below the lowest Keewatin, and that they are not interbedded sediments in the Keewatin on a somewhat larger scale perhaps than known sediments in the Keewatin in the Vermilion and other districts. * * * In the event that some of the Coutchiching sediments being proved to be beneath the Keewatin of this particular locality, the most that can be said is that here are sediments conformably beneath at least a part of the Keewatin, with no evidence that they are anywhere near the bottom of the Keewatin, or that they constitute anything more than interlayered sediments.

"LOGANIAN"

W. G. Miller and C. W. Knight, 1914 (Ontario Bur. Mines Rept., vol. 22, pt. 2, p. 127).

The Loganian.[74]—Since the relation between the Grenville and Keewatin is such that, for the most part, they are not separated by an unconformity or an eruptive contact, it seems best to group them under one general heading, Loganian, giving to the sediments the old name Grenville and to the igneous material the name Keewatin. Moreover, since similar sediments to those to which Lawson gave the name Couchiching are found as one of the members of the Grenville, it does not seem to be necessary to retain the name Couchiching, except for use locally in northwestern Ontario. It is held by Lawson that the Couchiching in certain northwestern Ontario localities is older than the Keewatin represented there, but the authors are of the opinion that on the whole the pre-Laurentian sediments, Grenville and Couchiching, are younger than the Keewatin, although a minor part of the Keewatin may be intrusive into the sediments. In this connection it should be noted that, especially in localities where Temiskamian sediments are absent, certain post-Temiskamian igneous rocks may readily be mistaken for Keewatin rocks.

[74] The name Ontarian was proposed by A. C. Lawson (Bull. G. S. A., Vol. I, pp. 176–177) for the pre-Laurentian rocks of northwestern Ontario. But the name Ontaric, introduced in 1843, is employed by the geological survey of an adjoining State, New York, as synonymous with Siluric. In order to avoid confusion, it does not seem advisable to retain Lawson's name. Since the Grenville, especially, is characteristic of the district in southeastern Ontario and the adjoining part of Quebec first described by Logan, we propose the name Loganian for the pre-Laurentian rocks.

INDEX